INSTRUCTIONS FOR AUTHORS
https://medicine.uiowa.edu/orthopedics/education/iowa-orthopedic-journal

We will consider any original article relevant to orthopedic surgery, orthopedic science or the teaching of either for publication in The Iowa Orthopedic Journal. The manuscript submitted will be considered for print or an e-publication. The printed Iowa Orthopedic Journal is released in June and the e-publication is released in December. The deadline to submit to The Iowa Orthopedic Journal is January 31 of that year to be considered for either issue. Submissions are not limited to University of Iowa affiliates – all authors are welcome to submit.

Published articles and illustrations become the property of The Iowa Orthopedic Journal. The journal is peer reviewed and referenced in PubMed, Index Medicus and MEDLINE, where it receives 57,000 “hits” per month. Articles previously published will not be accepted unless their content has been significantly changed.

When submitting an article, send the following:

1. TITLE PAGE: The title page should list the authors’ names and credentials in the order in which they should appear. The corresponding author must be clearly identified with mailing and e-mail address. Statements including sources of funding and conflicts of interest must also be included. Lastly, include a running head title

2. ABSTRACT: Word count is limited to 350 words. The abstract should consist of five paragraphs, with the headings Background (which states the primary research question), Methods, Results, Conclusions; and Level of Evidence (for clinical articles) or Clinical Relevance (for basic-science articles).

3. REFERENCES: References must list references in order of appearance (not alphabetically), and be double-spaced. References must be presented in the text by superscript numbers. All references must be cited in the text. Journal names should be abbreviated and capitalized according to the National Library of Medicine. https://www.ncbi.nlm.nih.gov/nlmcatalog?term=currentlyindexed

4. ILLUSTRATIONS/IMAGES/LEGENDS: Each figure and table should be submitted on its own, separate page. Tables are preferred to be submitted as separate word or excel files. Figures are preferred to be submitted as high resolution (300 ppi) jpeg, pdf or tif files. Legends for all illustrations should be listed in order of appearance and single spaced. Color illustrations may not be used unless it is the opinion of the journal that they convey information not available in grayscale. Web page images are to be avoided. Set digital cameras to their highest quality (ppi) setting for photographs. When submitting an illustration that has appeared elsewhere, give full information about previous publication and credit to be given, and state whether or not permission to reproduce it has been obtained.

5. PREPARATION OF MANUSCRIPT: Manuscripts must be typewritten and double spaced using wide margins. Write out numbers under 10 except percentages, degrees or numbers expressed as decimals. Direct quotations should include the exact page number on which they appeared in the book or article. All measurements should be given in SI metric units. The body of the manuscript should contain an Introduction, Methods, Results, Discussion, Acknowledgements (if any), References, and Figure Legend.

6. SUBMISSION OF MANUSCRIPT: Authors may submit the manuscript in a word file with continuous numbering and as many additional files (figures, illustrations, legends, etc.) as needed. Please visit https://ioj.scholasticahq.com to submit your manuscript.

7. Additional information may be obtained by visiting https://medicine.uiowa.edu/orthopedics/education/iowa-orthopedic-journal or by e-mailing the Iowa Orthopedic Journal at ioj@uiowa.edu.
THE IOWA ORTHOPEDIC JOURNAL

2022 • Volume 42 • Issue 1

EDITORS
Trevor R. Gulbrandsen, MD  
Malynda S. Wynn, MD

BUSINESS MANAGER
Joshua M. Eisenberg, MD

STAFF ADVISORS
J. Lawrence Marsh, MD  
Jose A. Morcuende, MD, PhD

E-Publication — December 2022 ................................................................. i
Editors Emeriti ......................................................................................... iii
2022 Editors’ Note .................................................................................... iv
Dedication — Honoring Dr. Jose A. Morcuende .......................................... v-vii
Department of Orthopedics and Rehabilitation Faculty ................................ viii-ix
Department of Orthopedics and Rehabilitation Residents .............................. x
2022 Graduating Orthopedic Residents ...................................................... xi-xiii
2022 Graduating Fellows .......................................................................... xiv
2022 New Orthopedic Faculty ................................................................. xv-xvi
Bonfiglio Award and Iowa Orthopaedic Society Award ................................ xvii

DIVERSITY
Opportunities and Vision: My Experiences With OTA Leadership
Heather A. Vallier, MD .................................................................................. 1
Glass Ceiling in Hand Surgery: Publication Trends by Gender
Joshua T. Bram, BS, Lacey C. Magee, BA, Andrew Parambath, BA, Andrea S. Bauer, MD, Ericka A. Lawler, MD, Patricia E. Miller, MS, Apurva S. Shah, MD, MBA ................................................................. 3
Pregnancy During Orthopaedic Surgery Residency: The Good, Bad, and the Ugly
Malynda Wynn, MD, Ericka Lawler, MD ........................................................ 11

EDUCATION AND SPECIAL INTEREST
What Do We Do About US News?
Benjamin J. Miller, MD, MS ........................................................................... 15
Current State of Research Gap-Years in Orthopedic Surgery Residency Applicants: Program Directors’ Perspectives
Eric J. Cotter, MD, Evan M. Folse, BS, Kathryn L. Williams, MD, Andrea M. Spiker, MD, Brian F. Grogan, MD, Gerald J. Lang, MD ................................................................. 19
The Impact of Orthopaedic Surgical Training on Body Composition
Michael C. Marinier, BS, Trevor R. Gulbrandsen, MD, Jacob M. Elkins, MD, PhD ................................................................. 31

PEDIATRICS
Do Pediatric Hospitals Improve Operative Efficiency?
Michael Russell, MD, MBA, MPH, Joshua Holt, MD, Lori Dolan, PhD, Trevor Gulbrandsen, MD, Stuart Weinstein, MD ................................................................. 35
The Effect of Obesity on Pediatric Tibia Fractures
Patrick Cole McGregor, MD, Madeline M. Lyons, MD, Amy Wozniak, MS, Kristina Linko, BA, Felicity Fishman, MD, Teresa Cappello, MD ................................................................. 41

SPINE
Achieving Shoulder Balance Using Medial and Lateral Radiological Measures in Adolescent Idiopathic Scoliosis
Pawin Gajaseni, MD, Luca Labianca, MD, Piyush Kalakoti, MD, Stuart L. Weinstein, MD ................................................................. 47
Intrathecal Morphine Use in Adolescent Idiopathic Scoliosis Surgery is Associated with Decreased Opioid Use and Decreased Length of Stay
Kevin P. Feltz, MD, Nicklaus Hanson, BA, Nathan J. Jacobson, MD, Paul A. Thompson, PhD, Geoffrey F. Haft, MD ................................................................. 53
The Impact of Isolated Baseline Cannabis Use on Outcomes Following Thoracolumbar Spinal Fusion: A Propensity Score-Matched Analysis
Neil V. Shah, MD, MS, Joshua D. Lavian, BS, Cameron R. Moattari, BS, Hassan Eldib, BS, George A. Beyer, MD, MS, David H. Mai, MD, MPH, Vincent Chailier, MD, Peter G. Passias, MD, Renaud Lafage, MSc, Virginie Lafage, PhD, Frank J. Schwab, MD, Carl B. Paulino, MD, Bassel G. Diebo, MD ................................................................. 57

The Iowa Orthopedic Journal
TRAUMA
Is Psychiatric Illness Associated With Worse Outcomes After Pilon Fracture?
Kevin Rezzadeh, MD, MBA, Bo Zhang, MD, Diana Zhu, MD, Mark Cubberly, MD, Hayk Stepanyan, MD, Babar Shafiq, MD, Phillip Lim, MD, Ranjan Gupta, MD, Jacques Haquebord, MD, Kenneth Egol, MD

Malnutrition is Common and Increases the Risk of Adverse Medical Events in Older Adults With Femoral Fractures
Brady R. Wilkinson, MD, Qiang An, PhD, Natalie Glass, PhD, Aspen Miller, MD, Jay Davison, MPH, Michael C. Willey, MD

Reliability of Multifrequency Bioelectrical Impedance Analysis to Quantify Body Composition in Patients After Musculoskeletal Trauma
Brandon Koch, BS, Aspen Miller, BS, Natalie A. Glass, PhD, Erin Owen, PhD, MPH, Tessa Kirkpatrick, BS, Ruth Grossman, PhD, Steven M. Leary, MD, John Davison, MD, Michael C. Willey, MD

Does Aspirin Provide Adequate Chemoprophylaxis for Venous Thromboembolic Events in Operative Pelvic and Acetabular Fractures?
Kathryn B. Metcalf, MD, Jerry Y. Du, MD, George Ochenjele, MD

Comparison of Early versus Late Below Knee Amputation After Trauma With Standardized Prosthetic Care
Gabrielle Bui, MD, Joseph Buckwalter V, MD, PhD, Jason Wilken, PhD, John Davison, MPH, Jeffery Palmer, CPO, Don Shurr, CPO, PT, Nathan Davidson, MD, Ignacio Garcia-Fleury, MD, Michael Willey, MD

The Rurality of Lower Extremity Firearm Injuries
Matthew D. McIlrath, BS, Kirk Welsh, BS, Ignacio Garcia-Fleury, MD, Qiang An, MS, Joseph A. Buckwalter V, MD, PhD

FOOT AND ANKLE
Utilization of Arthroscopy During Ankle Fracture Fixation Among Early Career Surgeons: An Evaluation of the American Board of Orthopaedic Surgery Part II Oral Examination Database
Alan G. Shamrock, MD, Zain M. Khazi, MD, Christopher N. Carender, MD, Annunziato Amendola, MD, Natalie Glass, PhD, Kyle R. Duchman, MD

Quality of Life Improvement Following Reconstruction of Midtarsal Charcot Foot Deformity: A Five Year Follow-Up
Patrick Cole McGregor, MD, Madeline M. Lyons, MD, Michael S. Pinzur, MD

Evaluating the Association Between Anesthesia Type and Postoperative Complications for Patients Receiving Total Ankle Arthroplasty
Frank R. Chen, MD, Theodore Quan, BS, Joseph E. Manzi, BS, Alex Gu, MD, Chapman Weib, BS, Sean Tabaei, MD, Marc Chodos, MD, Cary B. Chapman, MD, Kane O. Pryor, MD, Jiabin Liug, MD, PhD

Acute Tarsal Tunnel Syndrome After Total Ankle Arthroplasty With Varus Deformity
Obianuju A. Obioha, MD, Daniel D. Bohl, MD, MPH, Simon Lee, MD, Kamran S. Hamid, MD, MPH

JOINT ARTHROPLASTY
Total Hip Arthroplasty: Direct Anterior Approach Versus Posterior Approach in the First Year of Practice
Trevor R. Gulbrandsen, MD, Scott A. Muffly, MD, Alan Shamrock, MD, Olivia O’Reilly, MD, Nicholas A. Bedard, MD, Jesse E. Otero, MD, PhD, Timothy S. Brown, MD

Similar Outcomes Achieved Between Anterior and Posterior Approach Total Hip Arthroplasty Using Dual Mobility Implants
Vivek Singh, MD, MPH, Jeremiah Thomas, BS, Jerry Arraut, BS, Christian Oakley, BS, Joshua C. Rozell, MD, Roy I. Davidowitz, MD, Ran Schwarzkopf MD, MSc

Surgical Management of Tibial Bone Loss in Revision Total Knee Arthroplasty: Clinical Outcomes and Radiographic Analysis of Tantalum Cones, Titanium Cones and Titanium Sleeves
Emmanuel Gibon, MD, PhD, Terrie Vasilopoulos, PhD, Edvinas Sipavicius, BS, Justin T. Deen, MD, Hernan A. Prieto, MD, Chancellor F. Gray, MD, Hari K. Parvataneni, MD, Luis Pulido, MD

Operative Time and Risk of Surgical Site Infection and Periprosthetic Joint Infection: A Systematic Review and Meta-Analysis
Noah M. Scigliano, BS, Christopher N. Carender, MD, Natalie A. Glass, PhD, Jennifer Deberg, MLS, Nicholas A. Bedard, MD

Does Isolated Unilateral Hip or Knee Osteoarthritis Lead to Adverse Changes in Extremity Composition
David E. DeMik, MD, PharmD, Michael C. Marinier, BS, Trevor R. Gulbrandsen, MD, Natalie A. Glass, PhD, Jacob M. Elkins, MD, PhD

Perioperative Opioid Counseling Reduces Opioid Use Following Primary Total Joint Arthroplasty
Christopher N. Carender, MD, Christopher A. Anthony, MD, Edward O. Rojas, MD, Nicolas O. Noisieux, MD, Nicholas A. Bedard, MD, Timothy S. Brown, MD

Volume 42 Issue 1
SPORTS MEDICINE
Outcomes Following Primary Anterior Cruciate Ligament Reconstruction Using a Partial Transphyseal (Over-the-Top) Technique in Skeletally Immature Patients
Alan G. Shamrock, MD, Kyle R. Duchman, MD, William T. Cates, DO, Robert A. Cates, DO, Zain M. Khazi, MD, Robert W. Westermann, MD, Matthew J. Bollier, MD, Brian R. Wolf, MD, MS .................................................................179

Do Current Stability Scores After MPFL Reconstruction Correlate With Patient Satisfaction Postoperatively?
Matthew T. Gulbrandsen, MD, David Hartigan, MD, R. Casey Rice, MD, David E. Ruckle, MD, Karan Patel, MD, Anikar Chhabra, MD, MS .................................................................187

Patient and Disease Related Risk Factors Associated With Return to Sport Rates After Avascular Necrosis (AVN) Treatment
Patrick England, BA, Julien T Aoyama, BA, Divya Talwar, PhD, MPH, Lawrence Wells, MD .................................................................193

HAND
Accelerated Return to Play in Professional Basketball Players With Surgically-Treated Metacarpal Shaft Fractures
Harin B. Parikh, MD, Mojca C. Herman, MA, OTR/L, CHT, Steven S. Shin, MD ........................................................................................201

Comparing Accuracy of Wrist Intra-articular Needle Placement Via Ulnocarpal Approach by Training Level: A Cadaveric Study
Sierra Phillips, MD, Megan Lameka, MD, Christopher Beaumont, MD, Nileshkumar Chaudhari, MD, Jared Halstrom, BSc, James Rush Jones, BSc, Nicholas A. Andrews, BSc, Ashish Shah, MD ........................................................................................207

SHOULDER
The Operative Treatment of Scapula Fractures: An Analysis of 10,097 Patients
Wyatt Vander Voort, MD, Brandon Wilkinson, MD, Nicholas Bedard, MD, Nathan Hendrickson, MD, Michael Willey, MD .................................................................213

Risk Factors for Blood Transfusions in Primary Anatomic and Reverse Total Shoulder Arthroplasty for Osteoarthritis
Danny Lee, MD, Ryan Lee, MBA, Safa C. Fassihi, MD, Monica Stadecker, MD, MBA, Jessica H. Heyer, MD, Seth Stake, MD, Kyla Rakoczy, BS, Thomas Rodenhous, MD, Rajeev Pandarinath, MD ........................................................................................217

Return of Scapulohumeral Rhythm in Patients After Reverse Shoulder Arthroplasty: A Midterm EOS Imaging Analysis
Shannon E. Linderman, MS, MA, James R. L. Hall, MD, Joshua E. Johnson, PhD, Andrea P. Caceres, MS, Carolyn M. Hettrich, MD, MPH, Donald D. Anderson, PhD ........................................................................................227

ORTHOPEDIC ONCOLOGY
Local Recurrence of Soft Tissue Sarcoma Revisited: Is There a Role for “Selective” Radiation?
Nathan A. Saxby, Qiang An, MBBS, MSPH, Benjamin J. Miller, MD, MS ........................................................................................239

The Relationship Between Lesion Size and Load To Failure After Stabilization of Simulated Metastatic Lesions of the Proximal Femur
Arham Pasha, MD, Jessica Goetz, PhD, Marc Brouillette, PhD, Palani Permeswaran, MS, Trevor R. Gulbrandsen, MD, Benjamin J. Miller, MD, MS ........................................................................................249

Detection of Ferritin Expression in Soft Tissue Sarcomas With MRI: Potential Implications for Iron Metabolic Therapy
Michael S. Petronek, MS, Ann M. Tomanek-Chalkley, BS, Varun Monga, MBBS, Mohammed M. Milhem, MBBS, Benjamin J. Miller, MD, MS, Vincent A. Magnotta, PhD, Bryan G Allen, MD, PhD ........................................................................................255

Surgical Hip Dislocation for a Diagnostic Dilemma: Differentiating Synovial Chondromatosis and Pigmented Villonodular Synovitis
Aliya G. Feroe, MPH, Mahad M. Hassan, MD, Mitchell S. Fourman, MD, MPhil, Megan E. Anderson, MD, Young-Jo Kim, MD ........................................................................................263

SYSTEMS AND PRACTICE
The Effects of Face Masks on the Doctor-Patient Relationship in Orthopaedics
Shivani Pandya, BS, Anil B. Sedani, MD, Alina Syros, MPH, Ramakanth R. Yakkanti, MD, Seth D. Dodds, MD, Amiethab A. Alyer, MD ........................................................................................267

Physician-Patient Communication in the Orthopedic Clinic: Surgeon-Identified Challenges
Olivia C. O’Reilly, MD, Alan G. Shamrock, MD, Marcy Rosenbaum, PhD, Charles R. Clark, MD, Brendan M. Patterson, MD, MPH ........................................................................................275

A Large Number of Reviews on Physician Rating Websites May Reflect Reputation Management
Shyam Ramachandran, BSA, David Ring, MD, PhD, David Langerhuizen, MD, Gregg Vagner, MD ........................................................................................283
E-PUBLICATION – DECEMBER
2022 • Volume 42 • Issue 2

EDUCATION AND SPECIAL INTEREST
The Importance of Mentorship and Interest Group Involvement for the Orthopedic Surgery Applicant
Jacob E. Milner, BS, Caroline Granger, BS, Lisa K. Cannada, MD, Amiethab Aiyer, MD
Educational Factors and Financial Implications of Medical Students Choosing and Matching Into Orthopedic Surgery
Alex M. Meyer, BS, BA, Matthew D. Karam, MD, Jerrod N. Keith, MD

TRAUMA
Does Irrigating While Drilling Decrease Bone Damage?
Justin C. Woods, MD, James L. Cook, DVM, PhD, Chantelle C. Bozynski, DVM, MS, Jason D. Tegethoff, BA,
Keiichi Kuroki, DVM, PhD, Brett D. Crist, MD
Does Anterior Impaction Affect Radiographic Outcomes of Pilon Fractures?
Trevor R. Gulbrandsen, MD, Malynda Wynn, MD, Andrew James Garrone, MD, Robert M. Hulick, MD, Clay A. Spitler, MD,
Brett D. Crist, MD

FOOT & ANKLE
Deformity Correction in Ankle Osteoarthritis Using a Lateral Tran-Fibular Total Ankle Replacement: A Weight-Bearing CT Assessment
Christian VandeLune, BS, Nacime Salomao Barcachan Mansur, MD, PhD, Tutku Tazegul, BBME,
Samuel J. Ahrenholz, BS, Kepler Alencar Mendes de Carvalho, MD, Cesar de Cesar Netto, MD, PhD

JOINT ARTHROPLASTY
Patient Reported Outcomes After Conversion vs. Primary Total Hip Arthroplasty: A Propensity Matched Analysis
Jason S. Lipof, MD, Brittany F. Haws, MD, David A. Quinzi, MD, Benjamin F. Ricciardi, MD, Kyle T. Judd, MD, MS
Length of Stay Is Associated With More Complications After Total Knee Arthroplasty
David E. DeMik, MD, PharmD, Christopher N. Carender, MD, Qiang An, MBBS, MPH, John J. Callaghan, MD,
Timothy S. Brown, MD, Nicholas A. Bedard, MD
Differences in Infection Rates by Surgical Approach in Total Hip Arthroplasty and Patient Sex: A Systematic Review
Dylan T. Wolff, BS, Neil V. Shah, MD, MS, Ahmed M. Eldib, MD, Auditt T. Shah, MD, Avi J. Panchal, BS,
Benjamin Krasnyanskiky, BS, BA, Vivek Singh, MD, Akhilesh Sastry, MD, Qais Naziri, MD, MBA
Medicaid Payer Status Is Associated With Increased 90-Day Resource Utilization, Reoperation, and Infection Following Aseptic Revision Total Hip Arthroplasty
Aman Sharma, MD, Kevin X. Farley, BA, Jacob M. Wilson, MD, Andrew M. Schwartz, MD, Thomas L. Bradbury, MD,
George Guild, MD
Resident Participation During Revision Total Knee Arthroplasty Is Not Associated With Increased Risk of 30-day Postoperative Complication
Trevor R. Gulbrandsen, MD, Zain M. Khazi, MD, Matthew T. Gulbrandsen, MD, Alan G. Shamrock, MD, Timothy S. Brown, MD,
Jacob Elkins, MD, PhD
Clean or Dirty? A Systematic Review of Splash Basin Use and Its Infectious Potential in Orthopaedic Surgery
Kevin Rezzadeh, MD, MBA, Harin Parikh, MD, Isabella Guanche, BS, Eytan Debbi, MD, PhD, Sean Rajaee, MD, MS,
Ran Schwarzkopf, MD, MSc, Guy Paiement, MD, MBA
Does the Patient-Reported Outcomes Measurement Information System Correlate to Legacy Scores in Measuring Mental Health in Young Total Hip Arthroplasty Patients?
Wahid Abu-Amer, MD, Charles M. Lawrie, MD, Susan Thapa, PhD, MPH, Jeffrey J. Nepple, MD, and John C. Clohisy, MD

TOTAL KNEE ARTHROPLASTY
A Quantitative Assessment of Online Patient Education Resources
Trevor R. Gulbrandsen, MD, Mary Kate Skalitzy, MD, Sarah E. Ryan, MD, Burke Gao, MD, Alan G. Shamrock, MD,
Timothy S. Brown, MD, Jacob M. Elkins, MD, PhD
Is There a Time-Dependent Contamination Risk to Open Surgical Trays During Total Hip and Knee Arthroplasty?
Michael Russell, MD, MPH, MBA, Michael Orness, MD, Cameron Barton, MD, Alyssa Conrad, MS, Nicholas A. Bedard, MD,
Timothy S. Brown, MD
Patient Resilience Influences Opioid Consumption in Primary Total Joint Arthroplasty Patients
Jonathan Q. Trinh, BS, Christopher N. Carender, MD, Qiang An, MS, Nicolas O. Noisieux, MD, Jesse E. Otero, MD, PhD,
Timothy S. Brown, MD
HAND
Efficiency Benefits of Live Fluoroscopy in Hand Clinics
Kyle Kesler, MD, Joseph A. Buckwalter V, MD, PhD

ORTHOPEDIC ONCOLOGY
Delayed Onset Post-Operative Neurologic Deficit in a Patient With Mucopolysaccharidosis Type VI: A Case Report
Christopher Lindsay, MD, Joshua Holt, MD, Stuart Weinstein, MD
IOWA ORTHOPEDIC JOURNAL
EDITORS EMERITI

1981  Frederick R. Dietz
      Randall F. Dryer

1982  John J. Callaghan
      Randy N. Rosier

1983  Don A. Coleman
      Thomas J. Fox

1984  Fred G. McQueary
      Nina M. Njus

1985  Patrick M. Sullivan
      Mark D. Visk

1986  John J. Hugus
      Randall R. Wroble

1987  Thomas C. Merchant
      Mark C. Mysnyk

1988  Richard A. Berger
      David M. Oster

1989  James L. Guyton
      Peter M. Murray

1990  Craig G. Mohler
      Joseph E. Mumford

1991  Devon D. Goetz
      Thomas K. Wuest

1992  Robert L. Bass
      Brian D. Mulliken

1993  Kenneth J. Noonan
      Lacy E. Thornburg

1994  George J. Emodi
      James C. Krieg

1995  Steven M. Madey
      Kristy L. Weber

1996  Jay C. Jansen
      Laura J. Prokuski

1997  James S. Martin
      Todd M. Williams

1998  R. Dow Hoffman
      Darron M. Jones

1999  Matthew B. Dobbs
      Dennis P. Weigel

2000  Gregory N. Lervick
      Jose Morcuende
      Peter D. Pardubsky

2001  Daniel Fitzpatrick
      Erin Forest
      Rola Rashid

2002  Karen Evensen
      Stephen Knecht

2003  Mark Hagy
      Christopher Sliva

2004  Timothy Fowler
      Michael Sander

2005  Kirk D. Clifford
      Anthony V. Mollano

2006  Mohana Amirtharajah
      Christina M. Ward

2007  Michael S. Chang
      Matthew R. Lavery

2008  Jaren M. Riley
      Christopher J. Van Hofwegen

2009  Jonathan Donigan
      Ryan Ilgenfritz

2010  Christopher E. Henderson
      Bryan A. Warme

2011  William D. Lack
      Matthew J. Teusink

2012  Julian Carlo
      Jaron Sullivan

2013  Cameron W. Schick
      Michael C. Willey

2014  Mai Nguyen
      Andrew Pugely

2015  Christopher Martin
      Robert Westermann

2016  Joshua Holt
      Kyle Duchman

2017  Jacob Elkins
      J. Joseph Gholson

2018  S. Blake Dowdle
      Sean Sitton

2019  Jocelyn Compton
      Nathan Hendrickson

2020  Cameron Barton
      Christina Hajewski

2021  Christopher Carender
      David DeMik
      Alan Shamrock

2022  Trevor R. Gulbranssen
      Malynda S. Wynn
We are pleased to present the 42nd edition of the Iowa Orthopedic Journal (IOJ). While healthcare has certainly seen a shift in practice during the ongoing COVID-19 pandemic, orthopedic surgeons have continued to make contributions to the field through research. We received a record number of submissions, over 100, from institutions across the United States and world this academic year. Due to the continued success of the IOJ, we are fortunate to continue the tradition of publishing a Fall electronic issue for a fourth consecutive year.

We would like to recognize our graduating class of senior residents: Drs. David DeMik, Christopher Carender, Christopher Cychosz, Kyle Kesler, Christopher Lindsay, and Alan Shamrock. They have provided us with incredible leadership and teaching as well as camaraderie along the way. We wish them all the best as they complete their training, move onto fellowship, and start their careers.

We would also like to thank several key individuals without whom the publication of the IOJ would not be possible. We would like to thank Angie Poulsen, who was instrumental in the organization and preparation of this year’s IOJ. We thank Dr. Josh Eisenberg for his efforts to coordinate corporate sponsors. We also extend thanks to our sponsors for their generous support of the IOJ, as publication would not be possible without their contributions. We thank Dr. Jose Morcuende and Dr. John Lawrence Marsh for their continued guidance as faculty advisors to the journal. Finally, we would like to recognize David DeMik as Resident Reviewer of the Year for the exceptional quality and quantity of his reviews this year.

We feel honored to serve as this year's editors. The University of Iowa Orthopedics Department provides remarkable training, and we feel privileged to be a part of its legacy. We are excited for the future of the department and hope that the readership enjoys this year’s publication of our journal.

Trevor Gulbrandsen, MD
Malynda Wynn, MD
Co-Editors
Iowa Orthopedic Journal
University of Iowa Hospitals and Clinics
Department of Orthopedics and Rehabilitation
For more than 100 years the University of Iowa Department Orthopedics has been a national and international leader in patient care, teaching, and research. Significant factors in establishing and sustaining the department’s excellence are the contributions of many talented people, including Arthur Steindler, Ignacio Ponseti, and Adrian Flatt, who moved from their native countries to live and work in Iowa City; and, to dedicate themselves to strengthening and advancing the missions of the University of Iowa Orthopedics Department. Jose Morcuende has continued this legacy. He received his MD and PhD from the Universidad Autónoma, in Madrid. He completed an Orthopaedic Residency and a Pediatric Orthopaedic fellowship in Spain before moving to Iowa City in 1991 to be a visiting Associate; he then moved to the Shriner’s Hospital in Tampa, Florida for a two-year research fellowship. It is the University of Iowa’s good fortune that Dr. Morcuende returned to Iowa City to pursue a second Orthopaedic Residency which he completed in 2001, a very significant accomplishment 10 years after his first residency.

Since joining the faculty in 2001, Dr. Morcuende has been an enthusiastic and vital part of the University of Iowa Department of Orthopedics and Rehabilitation and the Carver College of Medicine. He is recognized as a caring, thoughtful, and empathetic physician and surgeon. He is an excellent teacher and role model for students and residents. Residents enjoy his infectious positivity and optimistic attitude; and greatly admire his attention to detail with casting and close relationship with the families he sees. He is often one of the first faculty encountered as an intern and instills a sense of pride and loyalty to the rich history of orthopedics within the Iowa Orthopedic Department, while fostering enjoyment for taking care of pediatric patients. In addition to his clinical practice, he has authored more than 200 scholarly publications and gained National and International recognition for his many original contributions to Orthopedic research and clinical Pediatric Orthopedics. His outstanding accomplishments were recognized when he was named the Marvin and Rosalie Pomerantz Chair in Orthopedic Surgery in 2015.

Dr. Morcuende’s most important and lasting achievement has been his teaching and promotion of the Ignacio Ponseti treatment for children afflicted with clubfoot. In the waning years of Dr. Ponseti’s career, Dr. Morcuende worked closely with him and gradually assumed the major clinical responsibility for the treatment of clubfoot patients. (Picture 1) At the University of Iowa, he has championed the Ponseti technique, and has built a nationally recognized referral service for children with clubfoot. He runs three clubfoot specialty clinics every week for children from around the country. Unlike many clubfoot clinics, Dr. Morcuende’s care is personal and hands on. Just like Dr. Ponseti before him, he does all
his own clubfoot casting with gentle correction of the deformity and then meticulous molding of the cast. In addition, Dr. Morcuende has personally taught the Ponseti technique to 175 surgeons visiting the University of Iowa from throughout the world. (Picture 2)

Dr. Morcuende has also devoted time, expertise, and personal passion to improve clubfoot care in underdeveloped countries around the world. His international contributions are at a level that very few clinicians ever achieve. He has traveled to more than 70 countries to guide their development of clubfoot treatment programs. Numerous international trips per year were common for Dr. Morcuende over many years. Past residents who have had the opportunity to travel with him comment on the ease with which he is able to relate to healthcare providers of all backgrounds, steady dedication in the face of healthcare environment challenges, and joy he brings to those around him. (Picture 3) Through his personal appearances in local clinics, he has directly changed the lives of countless children around the world. More importantly, he has introduced local education and treatment programs that will assure that the Ponseti technique will be permanently adopted and lead to long lasting improvement in clubfoot care.

In addition to his own travel, Dr. Morcuende has been a leader in organizing philanthropic efforts to improve worldwide clubfoot care. In 2014, he spearheaded the idea of designating June 3rd as World Clubfoot Day. The date was chosen to commemorate the birthdate of Dr. Ignacio Ponseti, (1914-2009). The goal of World Clubfoot Day is to raise awareness about clubfoot disability and its prevention using the Ponseti Method. Dozens of countries around the world celebrate the day with walks, runs and family celebrations at their local clubfoot clinic. (Picture 4) He is also the Director and Founder of the Ponseti International Association (PIA), a significant philanthropic effort that has helped spread the Ponseti Clubfoot technique to underdeveloped countries. Over the last 20 years the PIA has facilitated the Ponseti treatment of 250,000 children with clubfeet. PIA and the Center for Bioinformatics and Computational Biology at the University of Iowa created the International Clubfoot Registry. Thus far, 1,261 physicians at 809 hospitals have entered information on 108,609 patients treated for clubfoot deformity. Dr. Morcuende is also a founding member of the Rotary Action Group for Clubfoot (RAG4Clubfoot), officially recognized by the Rotary International Board of Directors in 2015. RAG4Clubfoot and PIA have a formal partnership to link Rotarians and PIA together to organize and plan Ponseti Method training grants and national programs. To date, The Rotary Foundation and multiple Rotary districts/clubs have funded Ponseti Method training global grants in Brazil, Mexico, Bolivia, Colombia, and Argentina. Dr. Morcuende and many of the orthopedic surgeons in international countries he has trained over the years, host clinical workshops to train other orthopedic surgeons on Ponseti Method protocols.

Jose and his wife Ulpi have been fixtures of the orthopedic department and the Iowa City community for decades. Their children Irene (pediatrics) and Miguel (anesthesia) have both followed their father by pursuing careers in medicine. Ulpi has privately tutored children in Spanish and is an accomplished artist. (Picture 5)

We are pleased and proud to dedicate this year’s Iowa Orthopaedic Journal to Jose Morcuende as a well-deserved recognition of his many significant contributions to the Department and to the University of Iowa. This dedication recognizes his incredible passion for and personal effort to improving the care of children with clubfoot throughout the world by sustaining the Iowa legacy of the Ponseti method.
Dr. Morcuende is dedicated to continuing the mission of his friend and mentor, Dr. Ponseti. Through philanthropic support, The Ponseti Legacy Fund for Clubfoot has been established both to honor Dr. Ponseti and to ensure the Ponseti technique is available to all in need. This endowment will help to strengthen programming and solidify the long-term commitment of Ponseti International Association. It will ensure enough doctors in the United States and around the world are properly trained in the Ponseti technique so that families do not have to travel out of their home state to seek treatment for their children. To learn more about The Ponseti Legacy Fund for Clubfoot and how you can support the work of Dr. Morcuende and PIA, please contact Kari Nickol at The University of Iowa Center for Advancement at 319-467-3675 or Kari.Nickol@foriowa.org.

Dr. Morcuende placing a long leg cast on a patient with clubfoot utilizing the Ponseti method.

Dr. Morcuende with patient during World Clubfoot Day.
Christopher N. Carender, MD

Chris was born in Pittsburgh, PA to Neil and Wendy Carender. He grew up in the small town of Dexter, MI, on the outskirts of Ann Arbor. Along with his older brother, Jonathan, Chris was an avid ice hockey player. Chris graduated from Dexter High School in 2009, where he played ice hockey and lacrosse, serving as team captain of the ice hockey team in his senior year. From there, he attended the University of Michigan, majoring in Microbiology. Chris’ interests in microbiology and immunology pushed him to consider medicine as a career choice. After graduation, Chris moved to Cleveland, OH, to attend medical school at Case Western Reserve University.

During his time at Case Western, Chris discovered his interest in orthopedic surgery as well as clinical research while working as a research assistant under Dr. Raymond Liu. In his fourth year of medical school, Chris performed a Sub-Internship at Washington University in St. Louis, where Dr. Joseph Buckwalter V was performing fellowship training. Over a few margaritas, Dr. Buckwalter told Chris that he should consider the University of Iowa for his residency training in orthopedic surgery. A few months later, Chris was fortunate to match at the University of Iowa. He graduated with Honors for Distinction in Research from Case Western in 2017. During his time at Case Western, Chris met his wife, Kayla, who was pursuing her Master’s degree in Social Work. Chris convinced Kayla to leave her hometown of Cleveland, OH and move with him to Iowa. Chris and Kayla were married in a small ceremony (thanks, COVID) in October 2020. Together, they have a rescue dog, Indy, a four-year-old great pyrenees-pointer mix.

While at Iowa, Chris’ passion for clinical research grew, pursuing projects aimed at evaluating clinical outcomes following total hip and total knee arthroplasty, the influence of antibiotics on periprosthetic joint infection following primary and revision hip and knee arthroplasty, and how opioid pain medications are prescribed to and consumed by patients. After graduation, Chris plans to continue performing clinical research while attending fellowship in Adult Reconstructive Surgery at the Mayo Clinic in Rochester, MN.

Chris would like to thank his wife, Kayla, for her unwavering support, love, and endless patience throughout medical school and residency. He would also like to thank his parents, Neil and Wendy, and his brother and sister-in-law, Jon and Laura, for serving as role models of dedication and work ethic and providing much-needed advice and encouragement from the very beginning. Chris would also like to thank his co-residents, and all the faculty and staff at the University for the countless hours of teaching and mentorship they have generously provided over the past four years.

Christopher Cychosz, MD

Chris was born in Iowa and has lived in Iowa for his entire life, so far. He grew up on a farm outside of Ames, Iowa and lived there until high school when his father accepted a job as the Ames Police Chief and they had to move to the city. Growing up, his mother worked as a nurse for an orthopaedic surgery practice which helped him to gain early exposure to the field of orthopaedics. He attended Iowa State University where he graduated at the top of his class in Biochemistry while also working for ISU recreation services as a lifeguard and diving instructor. During his free time he enjoys scuba diving and exploring shipwrecks in the Great Lakes as well as the caves of Missouri and Mexico.

After college he was fortunate to be accepted to Carver College of Medicine for medical school where he immediately became involved in foot and ankle research and was inspired by his mentors to ultimately pursue this as a subspecialty. Following medical school he was honored to match at University of Iowa for Orthopaedic Surgery residency. During residency he has been thankful for the guidance of his research mentors Dr. Femino, Dr. Buckwalter V, Dr. Cesar de Netto and Dr. Phisitkul who have been instrumental in completing his various research projects on topics ranging from foot and ankle surgery to virtual reality simulation and even basic science research identifying novel roles of cilia genes in hippocampal neurogenesis and long-term context fear condition in mice.

Following graduation, Chris will be moving to New York City to complete a Foot and Ankle Fellowship at the Hospital for Special Surgery.

Chris would like to thank his parents, Jean and Charles Cychosz, as well as his brother Dan, for their unconditional support over the years. He would also like to thank his co-residents and all the staff in the Department for all of the time and resources that they have invested in his training.
Dave attended college at the University of Iowa, where he completed a Doctor of Pharmacy degree in 2012 and was recognized with the Distinguished Student Award. He elected to forgo an opportunity to complete a research fellowship, instead deciding to pursue a newfound passion to attend medical school. Dave spent a year working two pharmacist jobs before enrolling at University of Iowa Carver College of Medicine in 2013. While in medical school, Dave co-founded the Healthcare Delivery Science and Management Distinction Tract, was inducted into Alpha Omega Alpha during his junior year and participated in many intramural sports with his “School of Doc” classmates. Dave was sold on a career in orthopedic surgery after a sub-internship with the trauma team and experiencing the gratification that comes with restoring function and quality of life. Most importantly, he met his future wife, Colette, during the first year of medical school. Dave and Colette were very fortunate to match at the University of Iowa for residency. They were married in the Fall of 2018 and Colette has since become the unofficial resident obstetrician of the orthopedic department.

Under the guidance of Drs. Callaghan and Bedard, Dave developed a strong interest in large database research and competed many projects related to postoperative outcomes, obesity, opioid usage, quality of care, and epidemiology. He also worked closely with Dr. Elkins in exploring novel methods of preoperative risk stratification through assessment of body composition. In addition to his research pursuits, Dave served as co-editor of Iowa Orthopaedic Journal and on the editorial board for Journal of Arthroplasty.

Dav will be completing a fellowship in Adult Reconstruction at the Rothman Orthopaedic Institute in Philadelphia, while Colette completes her fellowship in Minimally Invasive Gynecologic Surgery at Indiana University. He credits experiences with all the arthroplasty division faculty for inspiring his career choice. Dave and Colette are actively exploring options for their future practices.

Dave has several people to thank, as his achievements would not have been possible without the support of his family and friends. In particular, he would like to thank his parents Dave and Debby, sister Jillian, brother-in-law Travis, and in-laws Dave and Julie for their encouragement and understanding of the demands of residency training. He is also thankful for the teaching and mentorship from all the faculty, especially Drs. Callaghan, Bedard, Brown, Elkins, Noiseux, and Weinstein. He is also extremely grateful for the friendship of his exceptional group of co-residents – Chris, Chris, Chris, Alan, and Kyle. His wife, Colette, is deserving of the most thanks for her unconditional love, sacrifice, and support.

Kyle Kesler, MD
Kyle has a reputation for being organized and a perfectionist, but nothing compares to his passion for BLT’s and by logical extension, tomatoes. He has perfected the BLT taste and is currently the president of UIHC’s “Tomato Time” club. He is proud to report he has expanded the groups’ participation each year of residency. Kyle is from Utah attending undergrad at Utah State University, and during this time spent two years serving abroad in Korea before ultimately deciding to attend medical school at Vanderbilt University. He is the oldest child of three and has always enjoyed working with his hands with prior jobs and interests including founding a concrete bench company, farm work, building classic cars, and instructing bread making courses. His odd jobs over the years showed him he has always had a gift for connecting and relating to people. Combined with the opportunity to see instant improvement in patient’s quality of life through hands-on surgery made orthopedic surgery a natural choice.

Kyle’s main research interest involves how best to maximize efficiency within the orthopedic surgery specialty. He has served as an Epic Superuser for the past three years during which time he has implemented several efficiency driven initiatives within the UIHC electronic health record. His research has reflected this as he took a deeper dive into where most time is spent by orthopedic providers within the electronic health record during a given day. This data led to the identification of quality improvement areas within a provider’s day that can be individualized to a particular provider.

Kyle is planning to pursue a fellowship in spine surgery after graduation. He recently has matched into Spine Fellowship at the Norton Leatherman Spine Institute in Louisville, KY. He is excited to train with highly respected leaders in the field of spine surgery after graduation. He is most interested novel approaches and techniques for future spine practice. He will plan to practice wherever his tomatoes can grow the best.

Kyle would like to acknowledge the support of his mentors, Dr. Weinstein and Dr. Pugely, his family, and co-residents who collaborated on projects with him throughout residency, and supported his decision to pursue a career in spine surgery. A special mention should be made to Dr. Pugely’s graceful acceptance of the biweekly practical jokes (photoshopped pictures, hidden cameras, concealed chickens, tainted food…etc) provided by yours truly.
Christopher P. Lindsay, MD

Chris Lindsay grew up in Asheville, NC in the shadows of the Appalachian Mountains. He spent his youth hiking, biking, and spending as much time as possible outdoors, earning the rank of Eagle Scout in high school. In college, he became interested in a career in medicine while completing his Health Scholars Diploma in the Honors College at Virginia Tech in Blacksburg, VA. His education continued at the University of North Carolina School of Medicine in Chapel Hill, NC. There, he completed a year of focused research as part of the prestigious Howard Holderness Research Scholars Program, investigating surface modifications in titanium implants and the effects on dermal integration for transcutaneous applications, among other projects. He also gained an appreciation for the impact that orthopedic surgeons can have on their patients and the breadth and diversity of the field of orthopedics itself.

After matching at the University of Iowa for orthopedic residency, his research interests have been varied, and include cadaveric biomechanical work, opioid use and risk factors, spine outcomes research, and patient education, most recently being awarded Third Best Resident/Fellow Paper at the Cervical Spine Research Society Annual Meeting in December for his abstract entitled: “Publicly Available Online Resources for ACDF are not Easily Read or Understood by the Average Patient.” He plans to continue pursuing patient-centered outcomes and education research within spine surgery.

Chris will be completing an Adult Spine Surgery Fellowship at the University of Wisconsin in Madison to train under the supervision of Dr. Thomas Zdeblick. He looks forward to his post-residency training and to a rewarding career in spine surgery.

He would like to thank everyone who has supported him along the way; first and foremost, his wife Taylor, and children Boyd (3), Nora (2) and Wren (6 mos.). He would also like to thank his mother Paula, in-laws Barbie and Bill, and countless other family and friends. Lastly, he would like to thank his fellow chief residents for their camaraderie and support, as well as all his mentors at Iowa, but especially Dr. Weinstein, Dr. Pugely, Dr. Igram, and Dr. Fowler for their guidance and wisdom along the way.

Alan G. Shamrock, MD

Alan was born and raised in Eustis, Florida, a small town about an hour north of Disney. He attended high school in neighboring Mount Dora and participated in varsity basketball, soccer, cross country and golf, eventually graduating as valedictorian of his class. He credits his parents, Greg and Donna, who are both veterinarians, for instilling a desire for him to help others at an early age (regardless of the number of legs they walked on). Ever since he can remember, he has been on the water. It was the combination of his love of the water and that of science instilled in him by his parents that led him to the University of Miami on academic scholarship to double major in Marine Biology and Chemistry. He obtained dual degrees with a 4.0 GPA, fulfilling a lifelong dream of becoming a marine biologist.

Following his decision to go to medical school, he was accepted by the University of Miami Miller School of Medicine as an undergraduate sophomore into the prestigious Medical Scholars Program, allowing him to obtain both a B.S. and M.D. degree in 7-years’ time. While in medical school, Alan spent time with numerous faculty mentors including Drs. Frank Eismont, Tabs Aiyer, and Seth Dodds, inspiring him to pursue a career in orthopedic surgery.

Alan considers himself unbelievably fortunate to have matched at the University of Iowa, the best orthopedic residency program in the country. Here, he has had the distinct pleasure to learn from some of the most influential thought leaders in the field. He will forever be grateful for the training he has received during his residency, for the guidance and support of his mentors, and for the lifelong friendships that were made in Iowa City. During his time in Iowa, Alan pursued a litany of research interests, including infection prevention following ACL reconstruction, the dangers of postoperative narcotic pain medication, and the role of antioxidants in the reduction of articular cartilage injury during arthroscopy. He has authored 38 peer-reviewed publications, given more than 100 research presentations, and was awarded more than $20,000 in grant funding.

Following completion of his residency, Alan will pursue a Sports Medicine fellowship at the Hospital for Special Surgery in New York City, with the ultimate goal of an academic Sports Medicine practice focusing on athletic injuries of the knee, shoulder, and ankle.

Alan would like to thank his parents for their love and support during his training (and the many years leading up to residency too), his younger brother, Keith, for always providing an example of excellence, his grandparents, Keith and Pat Shamrock and Ed and Rayna Smith, for teaching him the importance of hard work and instilling a drive for perfection, and his co-residents, Chris, Chris, Chris, Dave, and Kyle, for all the fun that has caused 5 years to go by in a flash. And Molly. The positive impact you have had on my residency experience, career aspirations, and life is not easily put into words. I cannot wait to see what happens next.
2022 GRADUATING FELLOWS

David Knowles, MD

David Knowles is the hand surgery fellow here at Iowa this academic year. Originally from Ohio, he received his undergraduate degree in biochemistry and German from Miami University (OH) and his medical degree from the University of Cincinnati College of Medicine. He then went on to complete his orthopedic surgery residency in Kalamazoo, MI at Western Michigan University Homer Stryker School of Medicine before starting here at Iowa. After fellowship he will be moving to Omaha, NE and joining CHI Health and Creighton University School of Medicine.

David would like to thank Drs. Lawler, Fowler, Buckwalter, and Caldwell for all their mentorship, support, patience, and instruction throughout this past year. He has truly enjoyed working with and getting to know each of them. The multifaceted nature of the fellowship program here with all of the faculty's different niches and areas of expertise and passion have made it a wonderful training experience. He is also thankful for all the residents he worked with and spent time with throughout the year (and for surviving his lectures). He would also like to thank the hand APPs and all the clinic and OR staff who make the day-to-day operations run smoothly and keep the ship afloat. Everyone was always incredibly friendly and helpful from day one; he will always look back fondly at his time at Iowa with the friendships he has made and everything he has learned.

Jeff Rossow, MD

Jeff Rossow is the current Orthopedic Sports Medicine fellow at the University of Iowa. Minnesota born, he went to Gustavus Adolphus College for his undergraduate degree followed by the University of Minnesota Medical School. He then underwent residency at SUNY Upstate Medical University in Syracuse, New York. He moved to Iowa for further training with his fiancé, Breahna, who he then married during his year of fellowship. His plans post fellowship is to work for the Marshfield Clinic in Weston, Wisconsin.

Jeff would like to thank Drs. Wolf, Bollier, Westermann and Duchman for everything they have contributed throughout the year. Each of them demonstrated an obvious commitment to mentorship and teaching as they shared seemingly limitless amounts of time, support, and knowledge. Additionally, Jeff thoroughly enjoyed his time while working with Hawkeye athletics and they gained another lifelong fan. The training received at the University of Iowa will always be appreciated as it has been a fantastic experience. Go Hawkeyes!

Jennifer Walt, MD

Jennifer Walt is the current Foot and Ankle Fellow at the University of Iowa. She grew up in Texas and completed undergraduate training at Texas A&M University with a degree in Biomedical Sciences. She obtained her medical degree from McGovern Medical School in Houston, Texas. Her Residency in Orthopedic Surgery was completed at Louisiana State University in Shreveport. Then she came to Iowa for her foot and ankle fellowship with Dr. Femino and Dr. Cesar de Netto. She is thankful for the entire Foot and Ankle team for being welcoming and creating an amazing learning experience. Her plans are to return to Texas and practice in McAllen at University of Texas Rio Grande Valley.
NEW ORTHOPEDIC FACULTY

Rahul Bijlani, MD
Dr. Rahul Bijlani grew up in Chicago, Illinois. He completed his undergraduate training at the University of Illinois at Urbana-Champaign, where he majored in Microbiology and Psychology. He then moved back home and completed his medical school education at Loyola University Chicago. He then went on to complete his residency in Physical Medicine and Rehabilitation at Washington University in St. Louis.

Following residency, Dr. Bijlani moved to Ann Arbor, MI to compete an Anesthesiology fellowship in Interventional Pain. Upon completing fellowship, Dr. Bijlani returned to Chicago where he worked in private practice for 1 year and then joined the University of Iowa Orthopedic and Rehabilitation department in November of 2021. He lives in Coralville, IA. Dr. Bijlani enjoys caring for patients with joint and back pain and those requiring rehabilitation. His research interest includes pre-surgical rehabilitation and interventions to minimize pain and chronic opiate usage.

Kara Gange, PhD, LAT, ATC
Dr. Kara Gange is a Clinical Associate Professor in the Master of Science in Athletic Training program. She is originally from Champlain, MN and has 24 years of teaching experience. Kara earned her BS from Minnesota State University Mankato, her MAEd from the University of Nebraska-Kearney, and her PhD from North Dakota State University. Her most recent position was at NDSU as the Program Director for their post-professional Advanced AT program. She has also spent time at Minnesota State University-Moorhead, the University of Southern Maine, and Two Rivers Physical Therapy Clinic. Kara and her husband, Derek, live in Solon with their sons, Owen and Milo, and dog Ollie.

Hongshuai Li, MD, PhD
Dr. Hongshuai Li is an Assistant Professor in the Department of Orthopedics and Rehabilitation at the University of Iowa. Prior to joining UI, Dr. Li served as an Assistant Professor in Department of Orthopaedics Surgery in University of Pittsburgh and the Director of the Musculoskeletal Growth & Regeneration Laboratory. Dr. Li obtained his M.D & Ph. D degrees in China and did his Postdoc training in University of Pittsburgh. Dr. Li has a long-standing research interest in musculoskeletal diseases and regenerative medicine and made significant scientific contributions to the understanding of pathophysiology of various musculoskeletal disorders including osteonecrosis, muscle injuries, bone, and cartilage defects, as well as osteoarthritis. The long-term goals of Dr. Li's research are to understand how skeletal muscle, the largest organ in the body, communicates with other organs as a harbor of progenitor cells and signaling molecules; and to develop cellular and molecular therapies to treat various musculoskeletal injuries and degenerative conditions.

Ashlee LaFontaine Enzinger, MD, CAQSM, FAAP
Dr. Enzinger is a Clinical Assistant Professor in the Department of Orthopedics and Rehabilitation at the University of Iowa. She joined the faculty in 2021 and is a nonoperative sports medicine specialist working at UI Sports Medicine in Cedar Rapids. She completed her Pediatric & Adolescent Medicine Residency at the Mayo Clinic and a two-year Sports Medicine fellowship at Vanderbilt University. She has covered sporting events at all levels from middle school to professional and with athletes of all abilities, including those with adaptive and special needs. Before coming to Iowa, she spent 3 years working at Vanderbilt in primary care sports medicine and was a team physician for the Vanderbilt baseball team when they won the NCAA College World Series in 2019. She is currently a team physician for Cedar Rapids Washington and Kennedy High Schools. Dr. Enzinger is a native of Augusta, Georgia and lives in Marion, Iowa with her husband (Justin). She enjoys spending time with her family, traveling, and outdoor activities, especially sports. She has a special interest in baseball and softball injuries.
Catherine Olinger, MD, MS

Dr. Cat Olinger grew up in Estes Park, CO. She completed her undergraduate, graduate, and medical training at Creighton University in Omaha, NE where she majored in Biology, Spanish, and Clinical Anatomy. She then moved to Memphis, TN where she completed her orthopedic residency training at the University of Tennessee Health Science Center - Campbell Clinic. Following residency, Dr. Olinger moved to Seattle, WA to complete her fellowship training in Spinal Surgery at the University of Washington Harborview Medical Center. Upon completing fellowship, Dr. Olinger joined the orthopedic faculty at the University of Iowa in the fall of 2021. She lives in Iowa City, IA with her husband Chad of ten years, and their son Edward (8 years). Dr. Olinger enjoys caring for patients with complex spinal disorders. Her research interests include biomaterials, growth factors, and hardware development at the Bone Healing Research Lab and Iowa Spine Research lab.

Than Pham, DO, PharmD

A native of Des Moines, IA, Dr. Pham completed his Pharm.D. at Drake University and D.O. at Des Moines University. He later completed his residency training in Physical Medicine and Rehabilitation at University Hospitals in Cleveland, Ohio followed by a fellowship in Interventional Spine at The Spine and Sports Center in Houston, TX. Dr. Pham joined the Department of Orthopedics and Rehabilitation at the University of Iowa on September 1, 2021, where he currently serves as an Assistant Professor and Interventional Physiatrist with special focus on conservative care of the spine and musculoskeletal conditions through rehabilitation, medication management, OMT, and minimally-invasive injections and procedures. He is board certified by the American Osteopathic Board of Physical Medicine and Rehabilitation.

Dong Rim Seol, PhD

Dr. Dong Rim Seol is a Research Assistant Professor who completed a PhD degree in Biomedical Engineering at the University of Iowa as well as a master’s degree at Inje University. His research interests are in the prevention and therapy of post-traumatic osteoarthritis and intervertebral disc degeneration, tissue regeneration and repair, drug delivery system, exosome therapy, gene therapy, and arthrofibrosis. He originally came from the Republic of Korea and has lives in Iowa City with his wife and three kids. In the his free time, he enjoys playing tennis and soccer.

Ling Wang, MD, PhD

Dr. Wang joined the Department of Orthopedics and Rehabilitation as a Research Assistant Professor since July 2021. Dr. Wang received her PhD degree in China and completed postdoctoral trainings in Vanderbilt University and University of Pittsburgh. She became a research faculty in Department of Medicine at University of Pittsburgh later. Dr. Wang has extensive basic research experience in cell and molecular biology and redox biology in vascular medicine. Her current research interests include nitrite-NO mediated signaling pathway in muscular dystrophy and metabolic roles of vascular endothelial cells in bone growth and regeneration in various musculoskeletal degenerative animal models.
The University of Iowa Department of Orthopedics and Rehabilitation, along with the Iowa Orthopaedic Society, sponsors two research awards involving medical students.

The Michael Bonfiglio Award originated in 1988 and is named in honor of Dr. Bonfiglio who had an avid interest in students, teaching and research. The award is given annually and consists of a plaque and a stipend. It is awarded to a senior medical student in the Carver College of Medicine who has done outstanding orthopedic research during his or her tenure as a medical student. The student has an advisor in the Orthopedic Department. However, the student must have played a major role in the design, implementation, and analysis of the project. He or she must be able to defend the manuscript in a public forum. The research project may have been either a clinical or basic science project, and each study is judged based on originality and scientific merit. The winner presents their work at the spring meeting of the Iowa Orthopaedic Society as well as at a conference in the Department of Orthopedics and Rehabilitation.

The Iowa Orthopaedic Society Medical Research Award for Musculoskeletal Research is an award for a student in the Carver College of Medicine who completes a research project involving orthopedic surgery during one of his or her first three years of medical school. The award consists of a $2000 stipend, $500 of which is designated as a direct award to the student and $1500 of which is designated to help defray continuing costs of the project and publication. The student must provide an abstract and a progress report on the ongoing research. The aim is to stimulate research in the field of orthopedic surgery and musculoskeletal problems. This award is also presented at a medical convocation. In addition, the student presents his or her work at the spring meeting of the Iowa Orthopaedic Society and at a conference in the Department of Orthopedics and Rehabilitation. This award is supported through the generosity of the Iowa Orthopaedic Society.

This year the selection committee consisted of Drs. Charles R. Clark, Joseph A. Buckwalter IV, Heather R. Kowalski. They recommended that Nathan Saxby, MPH4, receive the 2022 Michael Bonfiglio Student Research Award. Nathan's award was based on his project, “Local recurrence of soft tissue sarcoma revisited: Is there a role for “selective” radiation?” His advisor was Dr. Benjamin Miller.

The selection committee recommended that the 2022 Iowa Orthopaedic Society Medical Student Research Award be given to John Davison, MPH1, for his research titled “Conditionally Essential Amino Acid Supplements Reduces Postoperative Complications & Muscle Wasting After Fracture Fixation: A Randomized Controlled Trial.” His advisor was Dr. Michael Willey.

The Michael Bonfiglio Award and the Iowa Orthopaedic Society Medical Student Research Award for Musculoskeletal Research are very prestigious, recognizing student research on the musculoskeletal system. These awards have indeed attained their goal of stimulating such research and have produced many fine projects over the years.

-Benjamin J. Miller, MD, MS
Director of Orthopedic Medical Student Education
OPPORTUNITIES AND VISION: MY EXPERIENCES WITH OTA LEADERSHIP

Heather A. Vallier, MD

Have you ever said or thought, “it was the opportunity of a lifetime...” Opportunities abound in our lives, some larger and more meaningful than others; some earned, others given, or perhaps not even initially recognized or embraced for the tremendous value and impact they ultimately provide when acted upon. We share a common pathway of opportunity into and within the world of orthopaedic surgery, though individual circumstances may vary.

My journey further includes opportunities within the Orthopaedic Trauma Association, the professional society of my subspecialty choice. Over twenty years ago, it was natural for me to aspire to attend the OTA Annual Meeting, and to submit research work as a fellow and a young surgeon for consideration for presentation there. As a traumatologist in my early years of practice, I was one of a much, much smaller group of colleagues than we have today—in 2000, the Annual Meeting had but one room for all presentations, no simultaneous engagements, and although a smaller attendance and engaging community, there was no less commitment to excellence of the care of injured people. What a thrill to be there, among pioneers in our field, mentors, and even a handful of peer colleagues. I had the good fortune to be encouraged to get involved by several leaders, including Dr. Paul Tornetta who supported my election to the Membership Committee of the OTA. This occurred concurrently with a few lab instructor and other teaching assignments, along with opportunities within the trauma center where I worked under the leadership of Dr. Brendan Patterson. He supported and promoted by career, including collaboration with colleagues on research projects, which opened more doors for our team, and for me to work with others in our specialty to develop clinical research agendas, and to slowly move our field forward together. Several years later I got to know Dr. Tim Bray, through the OTA, and by common interests we had in the business side of orthopaedic trauma. He encouraged me to get more involved within the OTA, resulting in my election to the Board of Directors as Secretary. At that time, and over the past 10 years, the OTA has experienced a rapid growth of membership and scope. The Board has been a tremendous opportunity for me to work with like-minded colleagues committed to the mission, vision and values we share. The mission of the OTA is to promote excellence in care for the injured patient, through provision of scientific forums and support of musculoskeletal research and education of orthopaedic surgeons and the public. The vision of the OTA is to be the authoritative source for the optimum treatment and prevention of musculoskeletal injury, and to effectively communicate this information to the orthopaedic and medical community to influence health care policy that impacts care and prevention of injury. OTA members provide worldwide leadership through education, research, and patient advocacy. It has been an incredible honor to have served as the President of the OTA last year.

One of the new initiatives we generated during the past two years is a task force on physician well-being, moral injury and advocacy. Career longevity, sustainability, and impact relate directly to the health and well-being of the surgeon. Key purposes of this task force are to draw attention to importance of our own limitations and
Another key area of OTA strategic investment is in broadening our excellence in patient care—to go beyond the treatment of musculoskeletal injury, even the traditional team-based care of the multiply-injured patient to embrace the mental and social health opportunities most all of our injured patients have. Pre-existing mental illness is common among our injured patients, and it pre-disposes to heightened pain and catastrophizing. Mental illness is associated with less patient satisfaction, prolonged recovery, more pain, more complications, worse patient-reported outcomes, and more trauma recidivism. Recently some trauma centers have developed programs to educate patients and to treat mental illness. These types of recovery programs often lack institutional financial and operational support to get off the ground; however, when in place, the rewards are tremendous. From a financial perspective, better adherence to treatment recommendations, lower utilization of the ED, in favor of maintaining outpatient scheduled visits leads to lower complication rates and less costs of care. From a personal perspective, this directly improves the outcomes and the lives of injured people. Better satisfaction scores are reported, lower rates of recidivism are seen, and patients often volunteer to return to become part of the peer mentorship programs which influenced them. The OTA developed a task force to provide resources to support wellness in patients following trauma and to develop strategies for program implementation. This group is also charged with educating and engaging the trauma community regarding mental health needs of our patients and promoting best practices. Each of us can learn more about caring for the whole patient and identify ways to work with colleagues in our own trauma centers, perhaps developing new programs or enhancing use or scope of existing programs.

Opportunities within the OTA and resulting from OTA initiatives are abundant. Each of us can access these resources and services and identify ways to augment to care we already provide; perhaps broadening extent of patient education, encouraging patient engagement in care, affording opportunities for mental health care, or more. These issues are not unique to trauma surgeons or trauma patients, but they are issues of our lives, and opportunities to find fulfillment by enriching the recovery and the lives of others.

dr. Vallier attended the AAOS Annual Meeting with her daughter, Natasha Simske, who delivered her first podium presentation.
GLASS CEILING IN HAND SURGERY: PUBLICATION TRENDS BY GENDER

Joshua T. Bram, BS; Lacey C. Magee, BA; Andrew Parambath, BA; Andrea S. Bauer, MD; Ericka A. Lawler, MD; Patricia E. Miller, MS; Apurva S. Shah, MD, MBA

ABSTRACT

Background: Women are frequently underrepresented across surgical subspecialties and may face barriers to academic advancement. Abstracts presented at American Society for Surgery of the Hand annual meeting (ASSH-AM) highlight some of the top research in hand surgery. We sought to explore differences in abstract characteristics and publication rates based on senior author gender.

Though there have been increasing efforts at inclusivity in orthopedic and plastic surgery, women face several barriers to entering the field, publish less frequently, and are underrepresented in leadership positions. Understanding the stages at which discrepancies in research productivity exist may help to address these challenges.

Methods: Abstracts from the 2010-2017 ASSH-AMs were reviewed to determine basic characteristics. Author gender was determined through both a search of institutional websites for gender-specific pronouns and inference of gender based on first name. Subsequent full manuscript publications corresponding to the abstracts were identified through a systematic search of PubMed and Google Scholar.

Results: A total of 560/620 (90.3%) abstracts from 2010-2017 had an identifiable senior author gender (14.5% female). No differences were noted between male- and female-authored abstracts regarding study design including sample size or level of evidence. Female senior authors were more likely than males to author abstracts focused on pediatrics (19.8% vs 9.4%, p=0.01) and were more likely to collaborate with female first authors (41.3% vs 20.0%, p<0.01). Abstract publication rates were lower for female senior authors versus male senior authors (61.7% vs 74.5%, p=0.02).

Conclusion: The number of abstracts with female senior authors had similar representation to the membership proportion of women in the ASSH. There were few differences in abstract characteristics based on senior author gender, though senior authors tend to collaborate with investigators of the same gender. Abstracts authored by females were published 13% less frequently overall, meriting further exploration.

Level of Evidence: III

Keywords: surgery, publication trends, gender

INTRODUCTION

Despite an increasing proportion of female medical school graduates,1 surgical residents across nearly all subspecialties are predominantly male.2 Orthopaedic surgery in particular lacks female representation, with only 14% of all orthopaedic surgery residents identifying as female (from 2016-17) compared to 40% representation (from 2010-16) in plastic surgery residencies.3,4 Further, women compose just 6.5% of all American Academy of Orthopaedic Surgeons (AAOS) members and 24.0% of American Society of Plastic Surgery (ASPS) members.4,5 This gender discrepancy is even more evident among leaders in the field, with only 1.7% and 8.7% of academic orthopaedic and plastic surgery department chairs identifying as female, respectively.5,6 Female orthopaedic surgeons more frequently pursue hand (24%) and pediatrics (23%) subspecialty training,7 and therefore the American Society for Surgery of the Hand (ASSH) saw a rise in female representation among their active membership from 9% in 2010 to 14% in 2016.8

Several studies have attempted to explain not only the low proportion of women in surgical specialties, but also the gap in leadership roles.9,10 Proposed theories include systemic discrimination and a lack of career role models that prevents or deters women from pursuing careers in surgery,2 with up to 88% of female surgical residents reporting gender-based discrimination during residency.11 Furthermore, 91% of female attending surgeons experience gender bias in their careers, including discrimination, bullying, and sexual harassment, leading
to negative effects on career promotion and job satisfaction that may lead them to leave the field entirely. Some strides in hand surgery have been made in recent years, with female members of the ASSH applying for and achieving leadership positions at greater rates and earlier time points than male colleagues, respectively. However, it takes time for efforts aimed at addressing these inequalities to lead to measurable changes in representation.

Publication productivity is one well-known marker of success in academic medicine. Productivity in the fields of medical education and research are considered crucial for accomplished academic physicians, with the magnitude and quality of research contributing significantly to advancement recommendations. Historically, male faculty members have, on average, higher research productivity than their female colleagues, with varying reports on the impact of gender on academic promotion when adjusted for the total magnitude of research.

While past work in orthopaedic and plastic surgery has explored discrepancies in indices of research productivity such as the H-index, no study has examined differences in abstract characteristics based on senior author gender or the resulting publication rates at a prominent academic society’s annual meeting. American Society for Surgery of the Hand annual meeting (ASSH-AM) podium presentations are known to be published at rates approaching 50-70%. Given the higher likelihood for women to subspecialize in hand surgery, the ASSH-AM presents an ideal venue to explore this concept. The primary aims of this study therefore were to examine differences in abstract characteristics and rates of abstract publication with a female or male senior author with a focus on differences that might explain any observed discrepancies. We hypothesized that female senior-authored abstracts would have lower publication rates compared to their male colleagues.

METHODS

An observational study was performed examining all abstracts presented at the podium (i.e. only podium presentations) at each ASSH-AM from 2010 to 2017. Abstracts were reviewed by two investigators to determine basic characteristics including first author gender, last author gender (the last author was assumed to be the senior author), subject age-group (i.e. adult versus pediatric), number of subjects, and study design (level of evidence, single-center vs. multicenter, randomized-controlled design [RCT], use of a large national database). Though what constitutes a high-quality study is debatable, many of these characteristics have been cited in the literature as contributing to higher quality research, or at the very least, research that is more generalizable. Author gender was determined through a search of institutional websites for gender-specific pronouns (he/him/his/himself and she/her/hers/herself) when available and inference of gender based on author first name when gender-specific pronouns were unavailable. If the gender of the senior author could not be determined with this methodology, the abstract was excluded from further analysis.

Abstracts were then classified based on broad topic categories with particular attention paid to topics that have received increased exposure in the hand surgery literature, including: basic science, anatomy or biomechanics (non-clinical abstracts); cost analysis; opioids and pain management; and medical education. Abstracts were also categorized using more specific, hand surgery-focused categories – in part based on categories used by two 2019 studies by Kuczynski et al. and Lemme et al. – including: distal radius fracture; flexor tendon injury or repair; carpal tunnel syndrome; cubital tunnel syndrome; Dupuytren’s contracture; thumb carpometacarpal (CMC) arthritis; peripheral nerve injury or repair; and congenital hand or upper extremity anomalies. Abstracts focusing on CMC arthritis, Dupuytren’s contracture, carpal tunnel release, and flexor tendon injury or repair were marked as adult-focused for instances when a specific age-range was not noted, given that the overwhelming proportion of these studies focused on adult patients.

Subsequent full manuscript publications corresponding to the abstracts (i.e., excluding abstracts published in supplemental form) were identified by two authors (JTB and AP) through a systematic search of PubMed and Google Scholar using the abstract title or a combination of author names. For instances where the first investigator could not identify an abstract with a corresponding journal publication, a second investigator performed the search utilizing a similar methodology. Time to publication was then calculated as the difference between the month of publication (when they first appeared online) and the month of the presenting meeting. Only abstracts presented at the 2010-2017 ASSH meetings were analyzed, despite more recent abstracts being available, in order to permit a minimum follow-up window of at least two years. Journal impact factors were determined from the Journal Citation Reports produced by Clarivate Analytics.

Chi-squared and Fisher’s exact tests were utilized to compare categorical variables, while Mann-Whitney U tests were used to compare continuous variables. Binomial testing was used to compare the proportion of female senior authors to the reported proportion of US female membership in the ASSH. Binary logistic multivariable regression analysis was used to assess the variables predictive of publication. All analyses were conducted using a significance threshold of p<0.05.
RESULTS
A total of 620 of 623 abstracts identified from 2010 to 2017 were evaluable, with three having been withdrawn or not available. Only 560 of these 620 (90.3%) evaluable abstracts (Table 1) had a senior author with an identifiable gender. Of these, there were 81 abstracts (14.5%) with a female senior author, which was similar to the reported proportion of US female membership in the ASSH (14.3%, 1-sided p=0.47). Abstracts with a female senior author were significantly more likely than abstracts with a male senior author to have a female first author (41.3% vs 20.0%, p<0.01). The proportion of female senior authorship was similar across all years evaluated, with a low in 2017 at 10.1%, high in 2013 at 19.0%, and a mean across all study years of 14.3 ± 3.1% (Figure 1). There was no change in female senior author proportion between the first half (2010-2013) and the second half (2014-2017, p=0.40) of the study period. No differences were noted between male and female-authored abstracts with regard to study design including sample size, level of evidence (LOE), RCT proportion, or multicenter collaboration (Table 1). Women and men also utilized large national databases as a data source in equal proportion. Women were more likely to author abstracts focused on

Table 1. Characteristics of ASSH Abstracts by Gender of Senior Author, 2010-2017

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Abstracts</td>
<td>479 (85.5)</td>
<td>81 (14.5)</td>
<td></td>
</tr>
<tr>
<td>Percent Published</td>
<td>357 (74.5)</td>
<td>50 (61.7)</td>
<td>0.02</td>
</tr>
<tr>
<td>Time to Publication (months)</td>
<td>13.0 (18.0)</td>
<td>17.5 (21.0)</td>
<td>0.36</td>
</tr>
<tr>
<td>Impact Factor</td>
<td>2.1 (0.5)</td>
<td>2.1 (0.3)</td>
<td>0.97</td>
</tr>
<tr>
<td>Level of Evidence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 or 2</td>
<td>93 (19.4)</td>
<td>12 (14.8)</td>
<td>0.33</td>
</tr>
<tr>
<td>3, 4, 5, or Not Clinical</td>
<td>386 (80.6)</td>
<td>69 (85.2)</td>
<td></td>
</tr>
<tr>
<td>Median Number of Patients*</td>
<td>51 (97)</td>
<td>48 (82)</td>
<td>0.99</td>
</tr>
<tr>
<td>Focus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal radius fracture or repair</td>
<td>57 (11.9)</td>
<td>11 (13.6)</td>
<td></td>
</tr>
<tr>
<td>Flexor tendon injury or repair</td>
<td>19 (4.0)</td>
<td>5 (6.2)</td>
<td></td>
</tr>
<tr>
<td>Carpal tunnel syndrome or release</td>
<td>21 (4.4)</td>
<td>3 (3.7)</td>
<td></td>
</tr>
<tr>
<td>Cubital tunnel syndrome or release</td>
<td>6 (1.3)</td>
<td>1 (1.2)</td>
<td></td>
</tr>
<tr>
<td>Dupuytren's contracture</td>
<td>24 (5.0)</td>
<td>1 (1.2)</td>
<td></td>
</tr>
<tr>
<td>Thumb CMC Arthritis</td>
<td>17 (3.5)</td>
<td>6 (7.4)</td>
<td></td>
</tr>
<tr>
<td>Peripheral nerve injury or repair</td>
<td>64 (13.4)</td>
<td>12 (14.8)</td>
<td></td>
</tr>
<tr>
<td>Congenital upper extremity deformity</td>
<td>15 (3.1)</td>
<td>5 (6.2)</td>
<td></td>
</tr>
<tr>
<td>Topics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic science, anatomy, or biomechanics</td>
<td>100 (20.9)</td>
<td>18 (22.2)</td>
<td></td>
</tr>
<tr>
<td>Cost analysis</td>
<td>10 (2.1)</td>
<td>3 (3.7)</td>
<td></td>
</tr>
<tr>
<td>Opioids and pain management</td>
<td>10 (2.1)</td>
<td>2 (2.5)</td>
<td></td>
</tr>
<tr>
<td>Medical education or publication</td>
<td>5 (1.0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Randomized controlled trial</td>
<td>30 (6.3)</td>
<td>5 (6.2)</td>
<td>0.98</td>
</tr>
<tr>
<td>Age Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pediatrics</td>
<td>45 (9.4)</td>
<td>16 (19.8)</td>
<td>0.01</td>
</tr>
<tr>
<td>Adult</td>
<td>252 (52.6)</td>
<td>42 (51.9)</td>
<td></td>
</tr>
<tr>
<td>Unclassified</td>
<td>182 (38.0)</td>
<td>23 (28.4)</td>
<td></td>
</tr>
<tr>
<td>Multicenter collaboration</td>
<td>27 (5.6)</td>
<td>7 (8.6)</td>
<td>0.30</td>
</tr>
<tr>
<td>Large National Database</td>
<td>22 (4.6)</td>
<td>5 (6.2)</td>
<td>0.54</td>
</tr>
<tr>
<td>Female First Author†</td>
<td>92 (20.0)</td>
<td>33 (41.3)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Values reported as number (%) or median (IQR)
*Excluded large sample database studies
†Only available for 540 abstracts with both first and last author gender determined
abstracts with known author gender, 407 (72.7%) were published as of January 1, 2020. The most common journals of publication were the Journal of Hand Surgery, American Volume (N=161), The Journal of Bone and Joint Surgery (N=33), and HAND (N=30, Table 2). Abstracts with male senior authors were more likely to have been published overall (p=0.02) compared to those authored by women, with publication rates of 74.5% and 61.7%, respectively. However, male senior authors were not necessarily faster to publication than females (13.0 ± 18.0 months vs 17.5 ± 21.0 months, p=0.36), and there was no difference in the impact factor of publishing journals between genders (2.1 ± 0.5 vs 2.1 ± 0.3, p=0.97). In multivariable analysis when accounting for presenting year, abstract focus and topic, pediatrics versus adult focus, level of evidence, multicenter collaboration, and senior author gender, only female senior author gender (OR 0.549, 95% Confidence Interval [CI] 0.327-0.925, p=0.02) and a peripheral nerve injury or repair focus (OR 0.480, 95% CI 0.271-0.848, p=0.01) were predictive of a lower likelihood of publication.

**DISCUSSION**

Despite ongoing efforts, gender disparities persist in surgery, though female representation is improving for students and residents.10,20 For hand surgery in particular, this has translated to increased representation among leadership positions. Understandably there will be a lag in appropriate female representation at the highest levels of academic leadership as reforms are made.12 Over our eight-year study, female senior authors produced a
nearly identical proportion of abstracts (14.5%) compared to a reported 14.3% composition of US-based ASSH membership.\(^8\) This is nearly twice that of female membership in the AAOS, which may indicate that the field of hand surgery is making strides towards inclusivity.\(^4\)

Prior studies on abstract publication rates in medicine are mixed, with some finding lower publication rates for female senior authors\(^{21}\) and others observing no difference.\(^{22}\) Our study shows that male senior-authored ASSH abstracts were published 13% more often (p=0.02), though there were no observed differences in design (e.g. RCT, multicenter, etc.) or level of evidence, here used as proxies of study quality. Noting the difficulties that exist in determining what constitutes higher research quality, we should point out that this study evaluated ASSH-AM podium presentations, which likely have a higher baseline study quality than traditional journal submissions because all abstracts undergo a thorough submission and review process. Other reasons for this difference must therefore be explored, as academic promotion relies at least in part on research productivity.\(^{13,14}\)

Previous investigations demonstrate that women publish less frequently,\(^{13-15,22}\) receive less research funding\(^{24}\) and are less frequently promoted\(^{23}\) compared to men. While there was no difference in LOE or design by gender, female authors more often produced pediatric-focused abstracts. This finding is consistent with data showing higher rates of pediatric subspecialization for women across nearly all fields\(^2\) and past studies demonstrating female orthopaedic surgeons most frequently subspecialize in hand or pediatrics.\(^7\) Thus, one potential reason for the lower publication rates of female-authored abstracts is this focus on pediatric patients and congenital topics. Pediatric hand conditions may be considered “too specialized” for certain journals and could face higher rejection rates,\(^{25}\) which could explain, at least in part, the observed difference in publication rates. Interestingly, we also identified a focus on peripheral nerve injury or repair as an independent predictor of lower publication likelihood, separate from author gender, which similarly could be too specific for many journals.

Gender bias in any form presents an obstacle to both advancement and recruitment. We found that female senior-authored abstracts were twice as likely to have a female first author, which suggests that established female hand surgeons more commonly mentor young female investigators. Previous studies have noted the key role of mentorship in deciding future specialty as well as career satisfaction and success.\(^7\) Mentors not only recruit women into surgery, but also encourage aspiring female surgeons to pursue academic promotion.\(^{20}\) Unfortunately, a lack of women in leadership roles results in decreased likelihood of choosing surgical specialties among female medical students\(^2\) and contributes to the difficulties women face in finding mentors with similar experiences.\(^{20}\) A common reason women may not pursue academic medicine is a lack of female mentors in a generally male-dominated field, with strong mentorship noted as a top motivator of subspecialty choice among female orthopaedists.\(^7\) Fewer mentors could lead to lower research productivity and the observed discrepancy in publication rates by senior author gender. While significant strides have been made to promote diversity in the field of hand surgery, it is important to recognize that, unfortunately, it will take time to see the full effect of these efforts with regard to research, mentorship, and leadership.\(^8,12,27\)

Another important barrier that women in medicine may face – one that has been posited by some as a significant cause of fewer publications and leadership roles – is career disruption relating to maternity leave and parenting. Several studies report that female physicians work fewer hours\(^{28}\) and spend more time on familial obligations\(^{25}\) than their male counterparts, inevitably leaves less time for research. This could be particularly true for longer manuscript writing in comparison to relatively faster abstract preparation. However, many female surgeons continue scholarly pursuits during maternity leave, working similar hours (>60/week) to male colleagues and pursuing advanced degrees or continuing full-time research.\(^{30}\) While Schroen et al. reported no difference in the number of publications between female surgeons with and without children, this does not eliminate the possible impact of traditional gender roles on academic productivity.\(^{31}\)

Another possible contributor to the observed difference in publication rates is bias at the level of the journal against female authors. Unfortunately, an increased proportion of women in orthopaedic surgery has not been matched by rates of senior authorship.\(^{29}\) Some have therefore called for a global review of editorial blinding to ensure journal-level decisions are not contributing to a gender publication gap. Although peer review is often “double-blinded” for authors and reviewers, editors in some cases are not blinded. While most journals have a rigorous editorial and reviewer blinding protocol, there are likely differences in protocols for some journals. Further research into whether this bias truly exists and how it may affect the surgical literature is needed.

Several limitations should be noted. We explored abstract characteristic differences presented between 2010-2017 in an effort to allow for adequate time for publication, though naturally more recent abstracts from 2016-2017 had shorter eligible “follow-up” than those from 2010-2017. Time to publication is also difficult to assess based on differences between the date an article

Volume 42 Issue 1  7
first appears online versus its inclusion in a formal issue, which we standardized in this study to the former. Additionally, we attempted to classify author gender through the use of gender-specific pronouns on institutional websites first, followed by author first name, though this was not always possible due to a lack of website availability and because of a lack of familiarity with certain names. We also chose to evaluate the impact of senior author gender on publication rates as they more typically determine study topic/design. For this analysis, the last author was assumed to be the senior author, but we cannot entirely know the role each author played in design and publication. Last, the observed publication rates in this study were in line with or slightly higher than previously reported for ASSH podium presentations.\(^{16,17}\) This could be due to a combination of factors, including (1) an increased number of predatory-type journals allowing for publication of more studies than might have been possible previously, (2) exclusion of abstracts where senior author gender could not be determined (~10%), which were anecdotally more likely to be those from international authors that may publish in non-English journals, and (3) perhaps a more thorough search for and inclusion of manuscripts published in non-indexed journals. That said, it is possible that some articles published in non-indexed journals were additionally missed.

**CONCLUSION**

Our work demonstrates that ASSH abstracts with female senior authors are published 13% less frequently compared to those with male senior authors. Although it is difficult to determine the cause of this discrepancy, study level of evidence and work resulting from RCTs was not different between female and male-authored abstracts. More work in this area is needed to identify the reasons for gender inequality in orthopaedic publications.

**REFERENCES**


25. Pierson DJ. The top 10 reasons why manuscripts are not accepted for publication. Respir Care. 2004;49(10):1246-1252.


INTRODUCTION

Family planning is a challenge for physicians at all stages of their careers, but particularly difficult during residency. Residency commonly occurs during prime childbearing years and is associated with long work hours and inflexible schedules. A commonly cited deterrent for women entering orthopaedic surgery is the inability to achieve a healthy and fulfilling work-life balance. Further, those women who pursue starting a family during residency have been shown to have higher rates of pregnancy-related complications including infertility with complication rates as high as 30%. In a recent AAOS article, a call to action for modified policies to prioritize the health of pregnant orthopaedic surgeons and their unborn children was made to decrease the overall risk to women who wish to have children during residency and early practice.

The University of Iowa has a history of attracting women into the orthopedic training program. We asked past graduates of the University of Iowa Orthopedic Residency program who had children during residency to share their personal experiences and opinions. We asked past graduates to answer five questions surrounding their pregnancy during residency. We have included the good, the bad, and the ugly with real-life testimonies in hopes that despite the statistics, women in our field considering pregnancy will find comfort in those that have been through it.

Four prior residents were kind enough to share their experiences. Dr. Sarah Schippers (SS) completed residency in 2021 and is currently finishing a hand and upper extremity fellowship and will soon be starting private practice in Kansas. She shares on her experience regarding two pregnancies during residency. Dr. Tina Hajewski (TH) completed residency in 2021 and is also currently finishing a spine fellowship and will soon be starting private practice in Washington, sharing on her experience having two children during residency. Dr. Elizabeth Weldin (EW) completed residency in 2018 and is a current hand and upper extremity attending in Oklahoma and shares her experience having a child during residency and the contrast to having children during practice. Finally, Dr. Heather Campion (HC) completed residency in 2012 and is a current hand and upper extremity attending in Oregon and shares her experience as being the first Iowa orthopaedic resident to have a child during residency.

Level of Evidence: V

Keywords: pregnancy, residency, university of Iowa

PANEL QUESTIONS

Question 1: How would you describe your experience while being pregnant during residency?

SS: Overall, I could not have asked for a better experience. That said, I was blessed with easy pregnancies and healthy babies, which does make a huge difference. The rotations that I completed while pregnant were some of the more exhausting times in residency, but I was fortunate in that the culture, set by leadership, was that which promoted and supported women.

TH: As a resident I thought I was always tired, and that was redefined while pregnant. The physical difficulties being pregnant in residency were things I didn’t anticipate. With both pregnancies the fatigue and nausea in the first trimester were challenging, and those symptoms returned to rear their heads later in pregnancy too. Just when I thought I was in the clear, I distinctly remember having to scrub out of a call fasciotomy case to vomit outside of OR 26 in my third trimester. It seemed temperature regulation in the OR was important for my body to keep from going vasovagal and it was a delicate balance of nutrition and hydration as well.

EW: My experience was largely positive. As a senior resident, I had a reasonable call schedule and supportive residents on difficult rotations. I did have some negative experiences, such as staff disclosing my pregnancy without my consent, but this was in the minority.

HC: I remember how stressful it was to tell my co-residents, attendings, and staff that I was pregnant, because I didn’t know how they would react. Thankfully the program was very supportive. I remember Dr. Buckwalter and Dr. Marsh both making sure my rotations were re-arranged to allow for as little disruption as possible to my training. I was fortunate to have an ‘easy’ pregnancy where I was able to continue working, I only remember two instances where I needed to leave the OR for nausea.
Question 2: What barriers do you feel existed to being pregnant and then having a baby in residency?

SS: The biggest determinant of when we chose to have children was when I thought I could most easily take time away from rotations and call without causing too much of a burden on my co-residents. Luckily, the call schedule was such that you could plan months (even years) in advance.

TH: I think the stress of call and affiliated lack of sleep were what taxed my body the most during pregnancy. It is impossible to determine why I went into preterm labor but I think the frequency of call as a PGY-3 had something to do with it. Unfortunately, I do think pregnancy is the easy part, and being a new mother is a whole different ball game. Balancing the priorities of your new family and demands of your training is incredibly stressful and was probably the hardest thing I had to overcome during residency.

EW: Barriers included limited experience with pregnant residents (had been several years since the most recent pregnant resident), inflexibility of attendings to alter team structures (such as the 4th year resident on joints, I wished to avoid cement during my pregnancy. One staff member was very upset about this). Barriers to have a baby in residency (and really any time) was finding childcare that accommodated difficult residency hours, making appointments during regular business hours due to residency obligations.

HC: The ABOS does not allow residents to take more than 6 weeks off in a calendar year. (I’m not sure if that has changed). I wanted to make sure to finish residency on time! I was only able to take 5 weeks of maternity leave, which included recovering from a C-section. My first rotation back from maternity leave was rough. I remember getting two 3 hours ‘naps’ most nights, as I was up nursing or pumping at some point. Then having to get back to the hospital by 5am to round. I slept through my alarm a few times. Nursing and pumping also felt like a full-time job. I would find a stall in the locker room to pump in while dictating notes and checking patient labs. One of the ortho nurses let me borrow her office during clinic to take a pump break.

Question 3: What did you find the most helpful or supportive while being pregnant during residency?

SS: Having a department chair who seemed genuinely happy for me when I announced the pregnancy and who never once made me feel like I was an inconvenience. Having female staff mentors who understood the trials of pregnancy and motherhood and could offer personal advice about how to balance that and the demands of our career. Having a supportive husband who did everything he could to make my transition back to work easier after maternity leave.

TH: The support of my co-residents with both pregnancies. There were times toward the end of my second pregnancy that I was not feeling well, and I feared going into preterm labor again. There were people who stepped up and offered to cover my call, which is helpful. Having someone to talk to who has been through it really helped me through. Although others are supportive, no one re-
ally understands what you are going through as a new mother and orthopedic surgeon other than the few who have also been through it.

**EW:** I found it helpful to advocate for myself. One day on trauma team I went several hours without eating, drinking, or going to the bathroom. I had severe contractions at the end of the day. Following that incident, I made a point to take a break between each case to have a snack, drink water, and use the bathroom. I continued this practice while breastfeeding to advocate for times to express milk and never met resistance. It is also helpful to reach out to other physician moms for support.

**HC:** I was also stressed about not burdening my co-residents. (I will note all of the other residents I shared a call pool with were male. There were no female residents in the two classes above me, or in the class below me). In the 4th and 5th years of residency we averaged taking call every 12th night. I wanted to make sure to cover my share. I was able to arrange my call schedule so that I took no call one month before my due date, and I didn’t start taking call again until I was back from maternity leave. I also tried to avoid bone cement for total joints. I was able to have co-residents help cover cases so that I could leave the OR when cement was used. My co-residents were very supportive! Many of them had children too, so they understood the challenges I was having.

**Question 4: What advice would you give to female residents considering timing of pregnancy during residency?**

**SS:** While it is our ‘right’ to have children and there is a finite amount of time during which this can happen, I also feel strongly in that, as physicians, we make a commitment to our patients (both current and future) and our training program in terms of dedicating the amount of time necessary to be as best a provider as we can. While precise timing of something as monumental as a pregnancy is not always possible, it is important to try and take this into consideration given that in the grand scheme of life, five years of training passes quickly.

When considering the call shifts that will be missed (or other duties that others will have to take on), remember that you are choosing to take time away and should be gracious about how you make up that time (ie, accepting a less desirable call shift or rotation schedule).

**TH:** Make decisions about what is best for you and your family. The rest will find a way to fall into place.

**EW:** Believe it or not, residency is a great time to have children. Having children in practice can be very expensive, it is difficult to leave your own patients, and leave policies are often nonexistent in private practice. Having had 2 children in practice, I can say that my least stressful maternity leave was in residency.

**HC:** Waiting until I was in the senior resident call pool made the most sense to me, since it was easier to arrange the call schedule around maternity leave.

**Question 5: Would you do anything differently looking back?**

**SS:** No. Two pregnancies in residency taught me that you have time for whatever you make time for, and everyone has their priorities.

**TH:** I feel I was more assertive about my needs to keep myself and my pregnancy healthy with my second pregnancy. Others will be supportive, but you must be your own best advocate and you can’t be afraid to ask for
things you need (advice that should be followed outside of childbearing as well).

EW: No.

HC: I have had two more children since residency. My second daughter was born in my first year of private practice when I was on salary. My son was born after I had become partner. It was more stressful on my practice and more difficult financially having a child once I was a full-time hand surgeon! Looking back, having a child in residency was stressful but easier than having a child as a full-time surgeon. In residency you are taking care of your attending’s patients, out of training those patients become yours and your partners cover for you. My group has since revamped their policy on maternity leave, so that it is not as financially difficult.

REFERENCES

3. Haskins J. Where are all the women in surgery? AAMC 2019.
4. Valone LC, Lightdale-Miric N, O'Shaughnessey MA. Surgeons trying to conceive may may suffer higher rates of infertility and pregnancy complications. AAOS 2021.
Irrespective of the origin and initial intentions of the US News & World Report hospital rankings, the annual report is firmly established as a source of anticipation and debate in the American healthcare conversation. This yearly event garners the attention of the public, practitioners, medical trainees, and hospital administrators and informs innumerable marketing publications, application lists, and back-room conversations. Personally, I have used these rankings in the past - not as a patient, but as a prospective medical student and resident. Without knowing what was behind it or what abstract terms like “quality” and “best” truly imply, this list was a starting point to identify potential medical institutions for training and employment. It is only since I have been solidly in my faculty position that I have given any thought to the meaning and methodology of the effort, although admittedly “quality” and “best” remain enigmatic concepts.

Ordinal categorization is common in our society in countless forms and various levels of implied importance, but the crux is always how to compile the relevant factors correctly so that the subsequent result possesses meaning and reflects truth. A relative ranking to a peer group often results from an objective score calculated by some combination of subjective and observed measurements. The utility and significance of any ranking derives directly from the appropriateness, relevance, and reliability of the predictive factors included. US News states in its methodology that the scores are derived from a combination of outcomes (37.5%), structure (30%), process/expert opinion (27.5%), patient experience (5%).¹ On face value, these distinctions appear appropriate, and potentially important if one were to create a numbered list of the highest quality medical institutions in the country.

From my personal experience with sarcoma, a rare tumor where the universal recommendation is to be seen at a specialty center for all aspects of diagnosis and treatment, I can attest to the training, knowledge, enthusiasm, and experience of my colleagues, many of whom are skilled and competent but may not be employed by a hospital represented by the published rankings. To bypass these individuals and seek care at a center that provides similar expertise and delivers standard-of-care treatment would be an avoidable hardship for patients that is not often discussed. Perhaps this would be justifiable if an institution’s relative ranking corresponded to measurable differences and improved outcomes like pain relief, functional optimization, health restoration, and quality-of-life. However, there is no evidence that this is the case.

There are many criticisms regarding the methodology behind the rankings, salient issues such as the accuracy of risk stratification and attribution of deaths to subspecialties that may not have managed the patients in question.² These are even secondary to the overarching question of whether the power of these rankings (and they are powerful) are guiding patient care and institutional attention in the right direction.² Recent iterations of the rankings algorithm that place more emphasis on patient experience and discharges to home suggest two areas that are potentially targetable, but raise questions about whether institutions should dedicate finite time and resources to improve metrics of unproven significance in patient outcomes, potentially at the sacrifice of other more meaningful initiatives.

Ultimately, it is not really relevant what any one of us thinks of the US News methodology, its triumphs or flaws, or how representative it is of the true picture of superior healthcare. US News is a business, these rankings are what it is best known for, and it is very unlikely that it would change or significantly alter its methodology or intent without an extraordinary stimulus. Similarly, healthcare institutions are businesses, and a high ranking in US News is notable, promotable, and difficult to resist. It is hard to ignore the 20-foot-high banners flanking hospital entrances, prominent certificates displayed in patient care areas, and seals on the front page of institutional websites. When deciding how to respond to a US News ranking, we should at least
agree that it is disingenuous to selectively celebrate the instances where one excels while criticizing those where one fails.

The briefest of internet queries yields a number critiques of US News, but the majority of search results are individual institutions advertising a high ranking in the most recent publication. Therefore, it is a waste of time and energy to argue about whether or not US News matters. It does. It is evidenced by decades of annual rankings that have become entrenched in our society as a legitimate resource and notable event when a new version is available. Hospitals have signaled that they are important, because they will proudly broadcast favorable rankings. It is unclear how the decisions of patients are guided by the rankings – perhaps there is an effect on the choice of institution, but other factors, such as personal experience, proximity, or recommendations from others, would also hold substantial influence. Regardless, US News is stable and predictable, and the task of clinician leaders and administrators is to determine the amount of energy and resources that should be dedicated to improving rankings.

To take action implies that the rankings are modifiable and improvement is possible. Of the four categories informing the rankings, “structure” appears to be the hardest to change. This is intended to represent the environment of the institution and includes details such as hospital volume, available technology, and nursing Magnet status. These factors are important, certainly, but also the most immobile and difficult to improve quickly. “Outcomes” similarly would be difficult to target to initiate change, at least partially because institutions are assumedly already working to decrease their patient mortality and deliver the highest quality care that they are capable. Notably, one potential downfall of these rankings would be the possibility that institutions would take on fewer complex cases or refuse treatment of unhealthy patients in attempt to improve their calculated score.

This leaves the categories of “process/expert opinion” and “patient experience.” These are more theoretically modifiable. A department or institution could make the choice to engage the 12.2% of physicians that fill out the survey (10.5% for orthopaedics) and try to sway opinion and become one of the five hospitals listed in their specialty that provides the best care to patients with serious conditions. This is a marketing challenge of unknown effect or benefit, rather than an issue of patient care, and it is certainly reasonable to question if this is really the best use of institutional resources. Opposing incentives, such as avoiding recognition of a regional competitor, may also influence an individual’s decision and is not so easily overcome. The final component is patient experience, certainly important to an extent, but again not clear on the true association with quality medical care or durable health-related outcomes. The improvement in patient experience may be limited by hospital facilities, endowments, and other factors unrelated to patient care and difficult to modify, and only accounts for 5% of the hospital’s score.

Although there is not an option to withdrawal from participation in the rankings since all the data is gathered externally, institutions can decide to take no action in response to hospital rankings. It is likely that all institutions have internal programs and initiatives to address many of the factors used in the rankings, such as improving patient experience, providing cost efficient care, and optimizing discharge to home. The other extreme would be to completely prioritize improving US News rankings. An efficient means to do this would be to focus on diligent coding of secondary diagnoses in traditional Medicare patients (the only patients included in the calculations) in hopes to inflate the apparent complexity of patients to optimize the risk stratification for 30-day mortality and discharge to home (the only two “outcomes” recorded). Institutions over time have already trended toward this, assumedly for financial reasons, but could continue the effort with an additional goal to improve rankings. Clearly, this is an administrative initiative and has nothing to do with actually improving patient care.

Perhaps the reasonable solution is somewhere in the middle. US News should not be ignored – the rankings are in the public sphere and it does no good to pretend they do not exist. Further, the methodology, while subject to valid critique with much room for improvement, does address many important areas in health care that all would agree are important to focus on and improve. Wisdom and serenity must be utilized to identify areas that are either outside the direct control of an individual, department, or institution, or have no bearing on improving the quality of care. Work to improve efficient and effective care delivery and patient experience should continue, as it should even in the absence of rankings. In addition, a nod to reputation could be addressed with a small effort to engage former trainees (for instance, with a letter from the department chair) or regional referring hospitals (emphasizing provider-to-provider communication and an efficient scheduling process) in hopes that a few more will include the institution on the annual Doximity survey. Given the limited participation in this component of the ranking methodology, this would be the easiest intervention with the most potential to improve the composite score.

Regardless of how an institution or department chooses to handle the specter of the annual US News “best hospitals” report, the guild of healthcare practitioners
should be unified in assessing the utility of the hospital rankings. They are a mirage, an illusion of authority in assessing quality healthcare that has never been correlated with better results after medical treatment. We can be amused by them, but we should never confuse these rankings for something meaningful or representative of a goal equivalent to our primary responsibilities of improving health, providing compassion, and alleviating suffering in those who need our expertise and skill. So, hang the banner, work on the things that make sense, send a few letters, but do not do so at the cost of distracting from the true role healthcare providers – we’re better than that.

REFERENCES
CURRENT STATE OF RESEARCH GAP-YEARS IN ORTHOPEDIC SURGERY RESIDENCY APPLICANTS: PROGRAM DIRECTORS’ PERSPECTIVES

Eric J. Cotter, MD; Evan M. Polce, BS; Kathryn L. Williams, MD; Andrea M. Spiker, MD; Brian F. Grogan, MD; Gerald J. Lang, MD

ABSTRACT

Background: The purpose of this study was to determine how orthopedic residency program directors (PDs) evaluate residency applicants who participated in a research gap-year (RGY).

Methods: A 23 question electronically administered survey was created and emailed to all Accreditation Council for Graduate Medical Education (ACGME) orthopedic residency PDs for the 2020-21 application cycle. PDs were emailed directly if active contact information was identifiable. If not, program coordinators were emailed. The survey contained questions regarding the background information of programs and aimed at identifying how PDs view and evaluate residency applicants who participated in a RGY. Descriptive statistics for each question were performed.

Results: Eighty-four (41.8%) of 201 PDs responded. Most respondent programs (N=62, 73.8%) identified as an academic center. The most common geographic region was the Midwest, N=33 (39.3%). Few programs (N=3, 3.8%) utilize a publication “cut-off” when screening residency applicants. When asked how many peer-reviewed publications were necessary to deem a RGY as “productive,” responses ranged from 0-15 publications (median interquartile range 4.5 [3-5]). Forty-one (53.3%) PDs stated they would counsel medical students to take a RGY with USMLE Step 1 scores being the #1 factor guiding that advice. More PDs disagree than agree (N=35, 43.6%; vs N=22, 28.2%) that applicants who complete a RGY are more competitive applicants, and 35 PDs (45.5%) agree research experiences will become more important in resident selection as USMLE Step 1 transitions to Pass/Fail.

Conclusion: Program directors have varying views on residency applicants who did a RGY. While few programs use a publication cutoff, the median number of publications deemed as being a “productive” RGY was approximately 5. Many PDs agree that research experiences will become more important as USMLE Step becomes Pass/Fail. This information can be useful for students interested in pursuing a RGY and for residency programs when evaluating residency applicants.

Level of Evidence: IV

Keywords: research, gap-year, residency applicants, program directors, publications

INTRODUCTION

Orthopedic surgery continues to be one of the most competitive fields in medicine. The percentage of applicants successfully matching to an orthopedic residency position is consistently between 75%-82%. Numerous studies have analyzed National Residency Match Program (NRMP) publicly available residency applicant data to determine applicant factors associated with match success. Commonly reported findings include higher United States Medical Licensing Exam (USMLE) Step 1 scores (mean 248 for matched applicants compared to mean 239 for unmatched in 2020), a greater mean number of applicant self-reported research activities in matched applicants (4.6 vs 3.0 for matched compared to unmatched applicant data 2007-2014), membership in Alpha Omega Alpha (AOA) honor society, and attendance at a top-40 National Institutes of Health funded medical school. USMLE Step 1 scores have received significant attention as an objective, standardized metric to screen applicants as the number of applications submitted per available residency position is by far the highest across all medical specialties (124 applications per position). On February 12, 2020, it was announced that the USMLE Step 1 scoring will become pass/fail as early as January 1, 2022. This change removes one of the most commonly utilized objective evaluation metrics used by residency program selection committees. A recent survey study of orthopedic residency program directors (PDs) inquired about how this change might affect the weight of other applicant variables, including research productivity, in resident selection. The results...
of the study by Cohn et al. demonstrated that USMLE Step 2 clinical knowledge (CK) will become the factor that increases the most in importance; however, several other variables, including published research experience, were noted to increase in importance as compared to a similar study conducted in 2002.9,11

In recent years, the residency selection committee at our institution has noticed a significant number of applicants who have done research gap-years (RGY) during medical school, often resulting in a robust number of peer-reviewed publications in addition to cultivating mentor relationships. Other competitive medical specialties have reported 16%-33% of applicants taking a year off of medical school to accrue research experience.12–14 The goal of a RGY for many medical students is to strengthen their residency application; however, it is unknown how PDs view and evaluate this aspect of a student’s application. To date, the sole orthopedic study investigating this topic was a review of a single, large academic institution's 18-year experience offering RGY opportunities. The authors noted a higher match rate for students completing the RGY at their institution compared to published NRMP data.15

The purpose of this study was to determine how orthopedic surgery PDs evaluate residency applicants who participated in a RGY. A secondary aim was to evaluate for any differences in how residency applicants who participated in a RGY are evaluated based on if a program identified as an academic center or not. The hypothesis was that PDs view students who had productive RGYs as stronger applicants for orthopedic surgery residency selection and academic centers will view RGY applicants more favorably than non-academic centers.

METHODS

This study received exemption status from our Institutional Review Board. Accredited orthopedic surgery residency programs for the 2020-2021 application cycle were identified through the Accreditation Council for Graduate Medical Education (ACGME). Program websites and contact information for program coordinators (PCs) and PDs were obtained through numerous methods including residency program websites, Doximity, and back-tracing contact information from PubMed. A total of 201 ACGME-accredited orthopedic residency programs were identified. We were unable to identify an active PD email address for 18 programs (9.0%) and therefore PCs were emailed instead at those programs. No programs were excluded from this study.

Survey Content

The authors collectively formulated a 23 question electronically administered survey (SurveyMonkey®, San Mateo, CA). Nine questions regarding the background information of the responding PDs and their programs were adapted from a recent study by Cohn et al.9 These questions inquired about the geographic location of the residency program, the type of program (academic, private practice, community, or county), residency class size, research requirements of the program, if a research track is offered during residency, number of current residents who participated in a research gap-year, years served as PD, age of the PD, and gender of the PD. Twelve questions were created by consensus of all authors a combination of yes/no questions, Likert scales, multiple choice, and free text all aimed at identifying how PDs across the country view and evaluate residency applicants who participated in a research gap-year. The complete survey can be found in Appendix I.

Survey Administration

Similar to Cohn et al.,9 a survey link embedded in a short email was sent to all PDs and PCs, with identifiable contact information, by the senior author who is also the PD at the study institution (GJL). The survey was open for a total of 40 days with one follow up email sent to PDs if they had not responded within the first 14 days, and one follow-up phone call if no response within 28 days.

Statistical Analysis

Prior to analysis, all data were assessed for normality using Shapiro-Wilks tests. Descriptive statistics including means and standard deviations, or medians and interquartile ranges were calculated for continuous variables depending on whether the assumption of normality was met. For categorical data, frequencies and percentages were reported. Questionnaire responses were reported in narrative text, tabular format, and visually with pie charts. Likert plots were constructed for select questions using the likert (v1.3.5; Bryer & Speerschneider, 2016) package.16 Sub-analysis was performed comparing responses between programs that identified as academic centers vs programs that did not identify as academic centers. For the purposes of analysis, community programs, private practice, and county programs were considered a single group, non-academic. Wilcoxon Rank Sum Tests were used to compare continuous variable responses between the academic centers and non-academic subgroups. Categorical response data was evaluated using Chi-squared tests and Fisher's exact tests when observed counts were less than 5. P <0.05 was considered statistically significant. All statistical analyses were performed using RStudio software version 4.0.4 (R Foundation for Statistical Computing, Vienna, Austria).
Table 1. General Residency Program and Program Director Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of respondents(^a)</td>
<td>84 (41.8)</td>
</tr>
<tr>
<td>Geographic region</td>
<td></td>
</tr>
<tr>
<td>Northeast</td>
<td>20 (23.8)</td>
</tr>
<tr>
<td>Southeast</td>
<td>7 (8.3)</td>
</tr>
<tr>
<td>South</td>
<td>7 (8.3)</td>
</tr>
<tr>
<td>Midwest</td>
<td>33 (39.3)</td>
</tr>
<tr>
<td>Northwest</td>
<td>5 (6.0)</td>
</tr>
<tr>
<td>Southwest</td>
<td>12 (14.3)</td>
</tr>
<tr>
<td>Program type</td>
<td></td>
</tr>
<tr>
<td>Academic center</td>
<td>62 (73.8)</td>
</tr>
<tr>
<td>Private practice</td>
<td>4 (4.8)</td>
</tr>
<tr>
<td>Community</td>
<td>18 (21.4)</td>
</tr>
<tr>
<td>County</td>
<td>0</td>
</tr>
<tr>
<td>No. of residents per residency class (median [IQR])</td>
<td>5 [4-6]</td>
</tr>
<tr>
<td>Research year required or offered to residents(^b)</td>
<td>17 (20.5)</td>
</tr>
<tr>
<td>Minimum research requirement to graduate</td>
<td></td>
</tr>
<tr>
<td>No research requirement</td>
<td>3 (3.6)</td>
</tr>
<tr>
<td>1 research project whether published or not</td>
<td>50 (59.5)</td>
</tr>
<tr>
<td>1 published manuscript</td>
<td>14 (16.7)</td>
</tr>
<tr>
<td>2 published manuscripts</td>
<td>12 (14.3)</td>
</tr>
<tr>
<td>3 or more published manuscripts</td>
<td>5 (6.0)</td>
</tr>
<tr>
<td>Require residents to submit at least 1 grant during training</td>
<td>8 (9.5)</td>
</tr>
<tr>
<td>No. of current residents who completed a research gap year (median [IQR])(^c)</td>
<td>2 [0-3]</td>
</tr>
<tr>
<td>No. of years spent as PD (median [IQR])(^d)</td>
<td>6.0 [3.0-12.0]</td>
</tr>
<tr>
<td>PD age (median [IQR])(^e)</td>
<td>51.0 [43.0-58.0]</td>
</tr>
</tbody>
</table>

\(^a\)Survey administered to a total of 201 program directors
\(^b\)One program director (1.2%) did not answer this question
\(^c\)Five program directors (6.0%) did not answer this question
\(^d\)Five program directors (6.0%) did not answer this question
\(^e\)Seven program directors (8.3%) did not answer this question

Abbreviations: IQR, interquartile range; PD, program director; No.: number

RESULTS

Respondent Program Information & Program Director Characteristics

Eighty-four (41.8%) of 201 total PDs and 45.9% (84 of 183) of PDs with known contact information responded to the survey and were included in analysis. It took PDs on average, 4 minutes and 27 seconds to complete the survey. The most common geographic region of respondent programs was the Midwest, N=33 (39.3%).

Table 2. Program Director Prose Responses to Question #14: How Many Peer-Reviewed Publications Are Necessary For You to Consider a Research Gap-Year as “Productive?”

<table>
<thead>
<tr>
<th>Program Director Textual Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Letters of recommendation from that research year is more important</td>
</tr>
<tr>
<td>• No strict cut-off number</td>
</tr>
<tr>
<td>• Not sure</td>
</tr>
<tr>
<td>• No set minimum</td>
</tr>
<tr>
<td>• Depends on location of gap year</td>
</tr>
<tr>
<td>• At least one! We will give a nod to presentations (natl mtgs) in place of PMID's</td>
</tr>
<tr>
<td>• 10 submitted</td>
</tr>
<tr>
<td>• It depends on the type of research, the journals that are published, and where they are doing the research. If at a big power house and they didn't publish a lot it is a red flag</td>
</tr>
<tr>
<td>• Likely 4-5, with about 10 'deliverables' which includes abstracts/posters/podiums. More important: learning skills they can continue to apply</td>
</tr>
</tbody>
</table>

Abbreviations: natl: national; mtgs: meetings; PMID: PubMed Identification Numbers

The median number of residents per class of respondent programs was 5 (range 2-14) with a mode of 5 residents. There was a wide range in the number of years respondent PDs have been in their role (1-30 years). Table 1 details program background information and PD characteristics for respondent programs.

Research Gap Year Information

Very few programs (N=3, 3.8%) utilize a “cut-off” for the number of published research articles when screening residency applicants. There was a wide range of responses to the question regarding how many peer-reviewed publications were necessary to deem a RGY as “productive.” Responses ranged from 0-15 publications (median interquartile range (IQR) 4.5 [3-5]) with 7 PDs responding in prose. Those responses can be found in Table 2.

Regarding the importance of letters of recommendation (LOR) from RGY mentors, most PDs (N=47, 61.0%) responded that clinical LOR are stronger, 26 (33.8%) responded that research LOR and clinical LOR are of equal value, and 4 (5.2%) believe research LOR are stronger. More respondent PDs (N=35, 44.9%) either “strongly disagree” or “disagree” that applicants who complete a RGY are more competitive applicants compared to those who “agreed” or “strongly agreed” (N=22, 28.2%). Thirty-five PDs (45.5%) agree research experiences will become more important in residency applicant selection as USMLE Step 1 transitions to Pass/Fail. Figure 1 dem-
The Iowa Orthopedic Journal

Figure 1. Likert plot representation of program director responses to questions #10, #18, and #20. Corresponding colors are immediately to the left of each response level.

Figure 2. Likert plot representation of program director responses to questions #11 and #17. Corresponding colors are immediately to the left of each response level.

onstrates in graphic format the responses to questions regarding LOR, competitiveness of applicants who have a RGY experience in comparison to those who do not, and if research experiences will gain further importance in residency applicant selection as USMLE Step 1 transitions to Pass/Fail in 2022.

Only 16 PDs (20.5%) responded that published research is either “extremely important” or “very important” in creating their applicant rank-lists. In contrast, 35 PDs (45.5%) felt that an applicant’s explanation for why they did a RGY in framing how the PD views the impact of that year was either “extremely important” (N=18) or “very important” (N=17). Figure 2 is a Likert plot representation of responses to these two questions.

There was a wide range of responses regarding the most beneficial time for applicants to seek a RGY experience. The most common response (N=33, 33.8%) indicated that after USMLE Step 1 was the most optimal time. Eleven PDs, 14.3%, prefer applicants do not do a RGY at all. Figure 3 and Figure 4 graphically depict PD responses to questions 15 and 16.

There was a near equal response amongst PDs regarding whether they counsel medical students to seek RGY opportunities. For the 41 PDs (53.3%) who responded “yes,” the most important variables guiding that advise was USMLE Step 1 score, lack of research experiences, and clerkship grades. Table 3 summates responses to those questions.

The final question (#23) was a free text response asking PDs “if you have any further comments regarding research gap-years for medical students, please feel free to enter them below.” Sixteen PDs (19.0%) responded with comments other than commenting on their interest in the results of the survey and can be found in Appendix 2.
Sub-analysis Based on Program Type

A total of 62 programs (73.8%) identified as an academic center and 22 (26.2%) identified as either a community program, private practice, or county program (collectively termed “non-academic centers”). There were no significant differences between programs who identified as academic centers and non-academic centers based on responses to questions about minimum research project requirement for residents, a requirement of residents to submit a grant application, and if students who participated in a RGY were considered more competitive applicants (P>0.05, each). Further, there were no differences in responses to the scenario question comparing a RGY applicant to an applicant who did not participate in a RGY, and no difference in responses to when is the most beneficial time to take a RGY (P>0.05, each). No significant findings were identified regarding PD’s response on strength of RGY letters or importance of an applicant’s reason for why they took a RGY (P>0.05, each). Thirty-two programs (55.2%) identifying as academic centers reported that they counsel applicants, if deemed appropriate, to take a RGY compared to 9 non-academic programs (47.4%; p=0.744). There were two notable findings. Academic centers were found to have significantly more residents who did a RGY (median IQR: 2 [1.0-5.0]) as compared to non-academic centers (median IQR: 0.5 [0.0-1.0]; P<0.001). In addition, academic centers reported a greater number of peer-reviewed publications to consider a RGY as “productive” (median IQR: 5 [4.0-6.0]) as compared to non-academic centers (median IQR: 3 [2.8-4.3]; P=0.007).

DISCUSSION

The main findings of this study collectively demonstrate that program directors’ views on residency applicants who took a RGY vary widely. Few programs (N=3, 3.8%) utilize a “cut-off” for the number of published research articles when screening residency applicants. There was a wide range of responses to the question regarding how many peer-reviewed publications were necessary to deem a RGY as “productive.” Responses ranged from 0-15 publications with the median response at around 5 publications. Most PDs responded that clinical LOR are stronger than research mentor LOR. In addition, more PDs disagreed than agreed that RGY applicants are stronger residency applicants. Only 53.3% of respondent PDs stated they would counsel medical students to take a RGY, with the applicant’s USMLE Step 1 score being the most important factor guiding that advice. Finally, 45.5% of PDs agreed research experiences will become more important in residency applicant selection as USMLE Step 1 transitions to Pass/Fail in 2022. While few significant differences were noted between PD responses from academic centers and non-academic centers, programs identifying as academic centers were found to have a greater number of current residents who participated in a RGY than non-academic centers.

Orthopedics remains one of the most competitive specialties in medicine and will likely continue to be for the foreseeable future.1-5 It has been our experience that more applicants have taken a year out from medical school to pursue research experiences, and it has been challenging to know how to evaluate these students. Of the 36 orthopedic PDs who responded to the NRMP’s
The Iowa Orthopedic Journal

2020 PD survey regarding factors important when ranking applicants, the mean importance rating for “evidence of continuous medical education without gaps” was rated 5% on a 0-100% scale. This indicates that PDs who responded to the NRMP survey do not necessarily believe taking a gap year is adversarial to an applicant’s competitiveness. The results of this survey study of ACGME accredited orthopedic residency PDs highlights the variability of how these RGY experiences are viewed. A similar wide range of perspectives clearly expressed in the written responses of 16 PDs to the final question of the survey, which prompted PDs to add any additional comments. One PD wrote, “A research gap year with our department is considered favorably,” while another responded, “I and my program see this as a weakness.” However, a common theme was notable in many responses. Specifically, the PDs’ perception of these applicants depends in large part on the reason for pursuing a RGY. While this was already apparent from the written comments, 18.2% of PDs also responded, “Depends on reason” to the scenario question comparing an applicant who did a “productive” RGY to a similarly competitive applicant who did not pursue a RGY. Some PDs noted that they have found these applicants to have weaknesses in other areas of their applications and may be hoping a productive RGY and strong connections increase their match success. In addition, on sub-analysis by program type, academic centers reported having significantly more current residents who pursued a RGY suggesting that certain types of programs may view RGY applicants more favorably. These findings while interesting, should be interpreted with caution given the small sample size (N=22) of non-academic centers.

Within the orthopedic literature, there is a dearth of research on the topic of RGY in general, but specifically as it pertains to whether these experiences lead to higher match rates. Within plastic surgery, a recent national survey study of integrated plastic surgeon residency applicants from 2013 to 2016 (N=198 respondent applicants) reported that 25% of all applicants did a RGY, and those who did a RGY had a 97% match success rate into plastic surgery compared to 81% for those who did not (P<0.05). Further, in a cross-sectional study of otolaryngology-head and neck surgery (OHNS) applicants from 2014-2015 to 2019-2020, 16% of all applicants had a RGY experience on their application. However, OHNS applicants who had a RGY experience did not have significantly greater odds of matching than those applicants who did not do a RGY (86.9% vs 83.5%, P=0.161). The authors did identify a significantly greater odds of matching into a top 25 OHNS residency program as ranked on Doximity in applicants who participated in a RGY (predicted probability: 58.6% vs 30.5%, adjusted odds ratio: 3.24, P<0.001). These data demonstrate that among other highly competitive surgical subspecialties, RGY are common and, for certain specialties, those applicants who did a RGY may have higher match rates into top programs than those applicants who did not.

The timing of a RGY may also provide context as to why it was pursued by an applicant, and in turn, influence how programs view that experience. In this study, the most common response to the question of “When do you think a research gap-year experience is most beneficial to increase the competitiveness of an applicant for a residency position?” was after USMLE Step 1. This was a response we were anticipating based upon previously published data demonstrating those with a higher USMLE Step 1 score have a higher match success rate (mean 248 for matched applicants compared to mean 239 for unmatched in 2020). The importance of a student’s USMLE Step 1 score in deciding on pursuing a RGY, or not, is demonstrated in the responses to the survey question regarding counseling of medical students. Of the 53.3% of respondent PDs who stated they do counsel medical students to pursue RGY, if appropriate, the USMLE Step 1 score of the applicant is the most common variable guiding that advice. As USMLE Step 1 becomes pass/fail, it is unknown how this advice may change, and whether it may affect both an applicant’s decision to pursue a RGY and the timing of a RGY. Similar to findings by Cohn and colleagues, 45.5% of PDs in the present study agreed research experiences may become more important once USMLE Step 1 becomes pass/fail.

There was little PD consensus on what constituted a “productive” RGY. When asked directly regarding how many peer-reviewed publications during a RGY that they would consider “productive,” the median response was 4.5 publications with a range from 0-15. We allowed respondents to comment on their answer, and several PDs noted that they have no set minimum when evaluating RGY applicants. On sub-analysis by program type, programs identifying as academic centers did report a higher median number of publications necessary to deem a RGY as “productive” (5 publications vs 3 publications) relative to non-academic centers. Others noted the importance of where the student did their RGY, as this may affect the ease with which a greater number of publications are achievable in a single RGY. In addition, one PD noted that, “letters of recommendation from that research year are more important.” This opinion can be explained by the fact that research mentors may spend more time with applicants during a RGY than clinical instructors during a clerkship. This may allow research mentors to comment more accurately on important attributes such as work ethic, social skills, time management, and ability to follow through on tasks. When asked about
Research Gap-Years in Orthopedics

how LOR are evaluated from a RGY mentor in comparison to clinical letters, the majority of PDs (N=47, 61.0%) responded that clinical letters of recommendation (LOR) are stronger, 26 (33.8%) responded that research LOR and clinical LOR are of equal value, and 4 (5.2%) believe research LOR are stronger. This data highlights that the majority of PDs weight letters based on applicant’s clinical performance more heavily.

Strengths of this study include the diversity of survey questions and responses on an important topic with a paucity of existing data. Further, the response rate was comparable to a recent study of orthopedic PDs across the country.9

Limitations
This study is not without limitations. The data presented herein is reflective only of those program directors who responded to the survey. The data may not be representative of all programs and may be subject to selection bias. Further, only 41.8% of all ACGME accredited programs responded, and an active email address was unable to be identified for 18 PDs. Similar to the study by Cohn et al.,9 PDs were surveyed in this study, and their responses may not be representative of all members of their programs’ residency selection committee. Responses were anonymous, so further analysis based on research prowess of programs was not performed.

CONCLUSION
Program directors have varying views on residency applicants who did a RGY. While few programs use a publication cutoff, the median number of publications to have a “productive” RGY was about 5. Many PDs agree that research experiences will become more important as USMLE Step 1 becomes Pass/Fail. This information can be used by applicants who may be interested in pursuing a RGY and programs when evaluating residency applicants.

REFERENCES

Table 3. Program director responses to questions 21 and 22 regarding counseling of medical students to seek research gap-year opportunities

<table>
<thead>
<tr>
<th>Rank(^a) (N = 38)</th>
<th>Median [IQR]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>USMLE Step 1 score 1.0 [1.0–3.0]</td>
</tr>
<tr>
<td>2</td>
<td>Lack of research experience 3.0 [2.0–4.0]</td>
</tr>
<tr>
<td>3</td>
<td>Clerkship grades 3.0 [2.0–5.0]</td>
</tr>
<tr>
<td>4</td>
<td>USMLE Step 2 score 4.0 [3.0–5.0]</td>
</tr>
<tr>
<td>5</td>
<td>Class rank 4.5 [4.0–6.0]</td>
</tr>
<tr>
<td>6</td>
<td>Life circumstances 5.0 [3.0–6.8]</td>
</tr>
<tr>
<td>7</td>
<td>Medical school reputation 6.0 [4.0–7.0]</td>
</tr>
</tbody>
</table>

\(^a\)N = 77 responses (91.7%)

\(^b\)For those responding yes, what component of their application indicates to you that a research gap-year would make them more competitive? Factors rated from 1 to 7, with 1 being the most important and 7 the least important

\(^c\)No. (%)
10. United States Medical Licensing Examination. USMLE Timeline for Step 1 Pass/Fail Score Reporting. USMLE Announc 2020;at <https://usmle.org/announcements/?ContentId=290>.
APPENDIX - Survey of Orthopedic Residency Program Directors

Program Information (Okay for program coordinator to complete this section)

1. Please enter the geographic region of your program based on the above diagram. (circle one)
   1. Northeast
   2. Southeast
   3. South
   4. Midwest
   5. Northwest
   6. Southwest

2. How would you identify your program (majority of the time spent)?
   a. Academic center
   b. Private practice
   c. Community
   d. County

3. Please enter the number of residents per residency class in your program.
   a. Free text
4. Does your residency program have a research year requirement or offer one for residents who are interested?
   a. Yes
   b. No
   c. Sometimes (25-50%)
   d. Almost Never (<25%)

5. What is the minimum research project requirement to graduate from your residency program?
   a. No research requirement
   b. 1 research project whether published or not
   c. 1 published manuscript
   d. 2 published manuscripts
   e. 3 or more published manuscripts

6. Do you require residents to submit at least 1 grant application during residency?
   a. Yes
   b. No

7. How many current residents in your program did a research gap-year?
   a. (free text)
   b. Yes - Once at first follow-up
   c. Yes - Once at end of treatment
   d. No - Unless reinjury, continued pain or complication occurs

Program Director Section

PD Information

8. How many years have you been in the role of Program Director?
   a. Free text

9. Please enter your age:
   a. Free text

Research Gap Year Information

10. Please indicate the extent to which you agree or disagree with the following statement: in general, applicants who complete research gap-years are more competitive than those who do not.
    a. (5 option response scale: strongly disagree, disagree, unsure, agree, strongly agree)

11. How important is published research in selecting a candidate for your residency rank list?
    a. (5 option response scale: strongly disagree, disagree, unsure, agree, strongly agree)

12. Do you utilize a minimum “cut-off” for the number of published research articles when screening residency applicants? (yes/no)

13. If you answered “Yes” to question #12, please indicate how many publications (accepted or in print) on a CV you consider as your cut-off?

14. How many peer-reviewed publications are necessary for you to consider a research gap-year as “productive?”
    a. Free text #

15. How do you compare applicants who have a research gap-year experience with those who don’t? Scenario: There are two applicants with similar USMLE Step scores, grades, letters, and experiences. Student 1 has no research gap-year experience but has participated meaningfully in a research project while Student 2 has what you consider a “productive” research gap-year experience. (Circle one)
    a. I view these candidates as equally competitive
    b. Student 1 is a more competitive applicant
    c. Student 2 is a more competitive applicant
    d. The competitiveness of Student 2’s application is in part determined by the reason for taking the research gap-year
16. When do you think a research gap-year experience is most beneficial to increase the competitiveness of an applicant for a residency position, if at all?
   a. Before medical school
   b. Before USMLE Step 1
   c. After USMLE Step 1
   d. After M4 year, if an applicant doesn’t match
   e. Timing does not matter
   f. I prefer applicants do not do a research gap-year

17. How important is an applicant’s explanation for taking a research gap-year in framing how you view the impact of that year on their application?
   a. (5 option response scale: Extremely important, very important, somewhat important, not so important, not important at all)

18. Please indicate the extent to which you agree or disagree with the following statement: in general, applicants have stronger letters of recommendation as a result of their research gap year.
   a. (5 option response scale: strongly disagree, disagree, unsure, agree, strongly agree)

19. How do you compare strength of letters of recommendation, that are equally glowing in nature from a research gap-year mentor commenting solely on performance with research related tasks to those from clinical faculty?
   a. Research letters are stronger
   b. Clinical letters are stronger
   c. The letters are of equal value

20. Please indicate the extent to which you agree or disagree with the following statement: With USMLE Step 1 scoring changing to pass/fail, research experiences will increase in importance when evaluating candidates for your residency program.
   a. (5 option response scale: strongly disagree, disagree, unsure, agree, strongly agree)

21. Do you ever counsel medical students to seek a research gap-year opportunity?
   a. Yes
   b. No

22. If you answered “Yes” to question #21, what component of their application indicates to you that a research gap-year would make them more competitive? Please rank the factors below in order of importance (1=most important and 7=least important). Click and drag variables.
   i. USMLE Step 1 score
   ii. USMLE Step 2 CK score
   iii. Clerkship grades
   iv. Lack of research experience
   v. Life circumstances (death of loved one, growing family, medical leave, couple’s match)
   vi. Class Rank
   vii. Medical School Reputation

23. If you have any further comments regarding research gap-years for medical students, please feel free to enter them below.
   a. Free text
APPENDIX 2 - Program director prose responses to question #23: if you have any further comments regarding research gap-years for medical students, please feel free to enter them below.

Program Director Textual Responses

- I understand why applicants are doing it more often and why PDs are stressing research productivity more. I don't see a strong correlation between productive research experience and quality of resident quite yet but that may change because now a days even the strong candidates are doing research years whereas usually a gap year was done only if you were considered an otherwise weaker applicant.
- Most students, in my experience, who seek research gap-years do so because their applications are otherwise relatively weak for orthopedic applicants. What are the historical matching data for “gap-year” applicants compared to applicants in general?
- Gap year research should be seen as a positive but when students that are not competitive in SEVERAL of the other parameters that are measured (not just test scores but grades, class rank, letter of recommendation) it is seen as a last-ditch effort and then I believe a research gap year should be discouraged. Research gap year for a student with a solid application can be very helpful, shows level of interest and commitment and helps this type of candidate tremendously.
- I personally did a research gap year, and found it valuable because I was interested in research, which I have continued. I did not need the research fellowship to get into residency. (I was accepted and postponed residency 1 year.) Research gap year is most valuable for individuals who are authentically interested in research. Research gap year can help someone who has poor Step 1 scores be more visible, and someone with weaker 3rd year grades. However, research gap year will not make a poor candidate a strong one. I evaluate research gap year as one factor out of all in evaluating applicants. Our APD also did a research gap year as well as having an MPH. Both of us look very carefully at applicants who did a gap year, with the goal of not being lulled into considering them better/stronger only because of doing a year of research. Many citations in one’s CV does not necessarily make a good candidate.
- For our community-based program, someone who chooses a research gap year because they love research will not be a good fit. If they did the gap year to reapply, then we expect it to be productive.
- I can’t help but think some research gap year applicants are hiding a less than spectacular application coming out of medical school.
- I and my program see this as a weakness. We, as academicians must balance research with clinical (especially in trauma) and most of us do not have ‘protected time’ which I have never seen work in incentivizing anyway. thus, the idea that to be involved in research, while only a med student with so few obligations and stress, requires time off is a good indicator that they do not “have the drive”. there are exceptions, but rare.
- None of this is as important on the resident selection process as audition rotations.
- A research gap year with our department is considered favorably.
- Research experience was useful in the past when it was unusual and allowed a candidate to separate themselves from others. It is no longer useful in that capacity with many having experience and many schools having built-in research requirements. A research year cannot overcome bad grades, bad class rank or bad scores at our institution. This may change in the future when these all become pass/fail.
- Research gap-years after not matching typically are out of desperation (although may give somebody an opportunity to prove themselves). A research gap-year between M2 and M3 or before medical school (assuming acceptance was already secured prior to starting gap-year) indicates genuine interest in research and increases importance of gap-year.
- I think a research year that’s unproductive is more detrimental than not doing a research year at all. In my mind, the utility of an applicant’s ability to do research is that if they can publish, do well on scores and on their clerkships SIMULTANEOUSLY it shows good ability to time manage and prioritize which i think are extremely important in residency. The ability to publish research during a year devoted to research especially at a place that is structured to pump out research is less impressive to me. If a resident has a real interest in research, I think it’s great, but that doesn’t prove to me that someone will be a strong resident.
- I am at a big research powerhouse program and there are some on the committee who put a lot of weight on the research. There is NOTHING in our residents that have shown any increased in productivity or quality of residency performance with a gap year. I think it’s ridiculous however, it does make students more competitive for programs and if a student has lower scores (now going away), middle/lower tiered med school with average grades, I encourage them to take a year because of how it is perceived by many programs. We have had some years where we have had a lot of residents who have done research and others not so much and only a few have continuing on with productivity during residency. Nice study.
- The training pipeline is already so long. If a student wants to get a Masters to help with future career, I think that is good. But a cottage industry of research fellowships I think is not good for the students and not good for research in orthopaedics overall. Better, I’d say, to have a six or 12 month track open to students in residency. Being productive with research during a research year, and being productive as a resident or future faculty, are very different! I remind applicants that a year of their life, is not a small thing. I suspect most competitive applicants would still be competitive applicants without a research year. Likewise, many who aren’t that competitive won’t suddenly become more competitive through the extra time. It is a narrow group for whom I think it is helpful for getting into an orthopaedics residents - not zero, but not very big.
ABSTRACT

Background: Residency is known to consist of rigorous training that has contributed to increased rates of resident burn out, depression, and suicide. There have been recent efforts to attempt to combat and solve the rising levels of mental health concerns amongst physicians and physicians in training. While studies have examined the adverse effects of medical training on mental health, few have examined the associated changes in physical health. This study aimed to identify and compare baseline body composition and hand grip strength of orthopaedic surgery residents. The second aim was to identify and compare changes that may occur over the course of the training program.

Methods: First year orthopaedic surgery residents (“interns”) were recruited to undergo body composition measurements via bioimpedance analysis (BIA) during their first, third, and twelfth month of post-graduate training. At each interval, three hand-grip-strength measurements per hand were captured. Additionally, orthopaedic surgery residents who had already completed their first year (“non-interns”) were recruited to undergo baseline and 12-month BIA for comparison.

Results: Six interns and six non-interns were recruited. The interns lost 2.88 ± 4.26 kg (-3.31% ± 4.75%) of their initial body mass with most of the loss being body fat mass (1.97 ± 2.62 kg) by three months. Interns recovered a fair amount of mass loss by 12 months with a net change of -0.78 ± 3.14 kg (-1.09% ± 3.90%). Non-interns experienced an overall net weight gain (1.20 ± 3.64 kg; 1.68% ± 5.55%) over the same period. Intern HGS changed by -1.92 ± 2.49 kg and 3.39 ± 2.34 kg at 3- (n=6) and 12-months (n=3), respectively.

Conclusion: This study demonstrates that there is an appreciable decrease in overall body mass, lean tissue mass, and body fat throughout the orthopaedic resident’s intern year. The results demonstrate an initial fall in each body metric and strength by 3-months followed by partial recovery by 12-months. This pattern contrasts the average gain of body mass in each measured metric by non-interns. This study is limited by population sizes and by incompleteness of HGS data.

Level of Evidence: II

Keywords: resident health, residency, body composition

INTRODUCTION

The pathway to becoming an independently practicing physician is well known to be a time-intensive, mentally straining, and physically draining experience. The intensity of training has been linked to increased rates of mental health concerns, such as depression and burnout. In addition, suicide has been reported as the second leading cause of death in all residents (behind malignancies), and the leading cause of death in male residents. Studies have also identified that the highest incidence of suicide occurs in the early years of training, and is believed to be the most prevalent preventable cause of death in medical trainees. In addition to the dangers imposed by worsening mental health, studies have reported that medical training impacts cellular processing including cellular damage and telomer-associated accelerated aging.

The preventable nature of mental health issues has led to efforts to quell the fatigue felt by many resident physicians including the Accreditation Council for Graduate Medical Education (ACGME) instituting an 80-hour/week cap on residents’ time in 2003 (with later revision in 2011). The institution of duty hour restrictions have not been universally accepted as effective, and long duty hours have contributed to sleep deprivation and declined physical activity for residents despite the policy. Furthermore, changes have been attempted at the institutional level, as individual residency programs have designed and implemented multiple efforts to address their residents’ mental health concerns. Programs include didactic courses in stress management, sleep hygiene discussions, peer resident mentorship, and time-off programs.
While attention has been focused on combating mental health concerns, actions targeting physical health have not been popularized. Just as sentinel investigations identified the extent of mental health concerns amongst residents, similar studies are required to quantify the changes in residents’ physical health.

Bioimpedance analysis (BIA) is an accepted, convenient, and low-risk method of monitoring physical health. By utilizing high-frequency electrical currents, BIA calculates valuable body composition data including body fat mass (BFM), skeletal muscle mass (SMM), and lean body mass (LBM). In addition to body composition analysis, dynamometer determined hand grip strength (HGS) has been well-established as an indicator of overall muscle strength as well as being utilized in the diagnosis of muscle function and nutritional status.17,18

While previous studies have identified that physical activity levels decline during the first year of residency,12 no studies have examined the evolution of residents’ physical health throughout their training. Furthermore, while BIA has been studied to quantify body composition in specific patient populations, it has not been utilized for examining the body composition of residents. This pilot study aims to identify changes in body composition of resident physicians during their orthopaedic surgery training and compare changes in the residents’ body composition between post graduate year (PGY1 “interns” compared to PGY2-5 “non-interns”). It is hypothesized that orthopaedic surgical residents will experience decreases in body mass and skeletal muscle mass during their intern year.

**METHODS**

At the beginning of the academic year, PGY1 orthopaedic surgery residents were recruited to undergo body composition measurements via segmental, high frequency bioimpedance analysis (InBody 770; InBody USA; Cerritos, CA, USA) during their first, third, and twelfth month (±1 month) of post-graduate training. Metrics obtained and analyzed from BIA include skeletal muscle mass (SMM), body fat mass (BFM), dry lean mass (DLM), and lean body mass (LBM). Additionally at each interval, three HGS measurements (Jamar Hydraulic Hand Dynamometer; Sammons Preston Rolyan; Bolingbrook, IL, USA) per hand were captured.

As a control cohort, orthopaedic surgery residents who had already completed their intern year were recruited to undergo baseline and 12-month BIA for comparison. Due to the sample size and lack of power, statistical difference determination was not possible. Descriptive statistics were calculated for statistical analysis. This study was approved by IRB prior to study initiation.

**RESULTS**

Two cohorts were recruited: six interns consisting of five males (enrollment age 30.33 ± 4.84), and six non-interns consisting of three males (enrollment age 29.67 ± 1.86). The interns completed their two follow-up BIA scans at 3.15 ± 0.20 months and 11.96 ± 0.48 months. The non-interns completed their follow-up BIA scan at 12.25 ± 0.89 months. Cohort characteristics are summarized in Table I.

Interns experienced a body mass change of -2.88 ± 4.26 kg (-3.31% ± 4.75%) at 3-months followed by -0.78 ± 3.14 kg (-1.09% ± 3.90%) at 12-months. At 3-months, BFM change was -1.97 ± 2.62 kg (-2.19% ± 3.17%), while LBM change was -0.91 ± 2.09 kg (-1.12% ± 2.14%). At 12-months, BFM change was -0.33 ± 1.98 kg (-0.20% ± 2.93%), while LBM change was -0.45 ± 2.41 kg (-0.87% ± 2.56%). Interns saw a change in SMM of 0.47 ± 1.4 kg and 0.26 ± 1.45 kg at 3- and 12-months, respectively. Intern HGS changed by -18.80 ± 24.39 N and 33.25 ± 22.92 N at 3- (n = 6) and 12-months (n = 3), respectively.

After one-year, non-interns experienced a gain in overall body mass (1.21 ± 3.77 kg; 1.68% ± 5.55%), where 17% of the body mass increase was BFM (0.20 ± 1.51 kg; 0.43% ± 2.02%), and 83% was an increase in LBM (1.01 ± 3.27 kg; 1.37% ± 4.65%). Non-interns saw an increase in SMM of 0.6 ± 1.8 kg over the same period. Intern body composition changes at 3- and 12-months are summarized in Figure 1. The comparison of interns to non-interns at 12-months is depicted in Figure 2.

**DISCUSSION**

With rates of physician burnout rising, health and wellness initiatives are becoming commonplace at many institutions. It is well known that physicians in surgical specialties are particularly vulnerable to burnout given their demanding schedules and associated stress. Junior trainees may not be accustomed to the intensity of workload and therefore it was hypothesized that their physical health would suffer. This study demonstrated that there is an appreciable decrease in overall body mass, lean tissue mass, and body fat throughout the orthopaedic surgery intern year. Most of the overall body mass loss was determined to be body fat mass.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>n</th>
<th>M:F</th>
<th>Enrollment Age (years)</th>
<th>12-month Follow-up (months)</th>
<th>3-month Follow-up (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interns</td>
<td>6</td>
<td>5:1</td>
<td>30.33 ± 4.84</td>
<td>11.96 ± 0.48</td>
<td>3.15 ± 0.20</td>
</tr>
<tr>
<td>Non-interns</td>
<td>6</td>
<td>3:3</td>
<td>29.67 ± 1.86</td>
<td>12.43 ± 0.89</td>
<td></td>
</tr>
</tbody>
</table>
The results demonstrate an initial fall in each body metric by 3-months followed by partial recovery by 12-months. This fall then rise pattern is mirrored in the interns’ HGS changes, which showed a net increase by 12-months. The eventual positive change in HGS may point to development of hand strength and dexterity through their initial surgical rotations.

The changes experienced by interns contrasts their non-intern colleagues, who, on average, increased mass in each body composition category. This could indicate that residents and their bodies adapt to the intensity of training, or perhaps that the rigor of training is most severe in intern year. Interns’ overall body mass change was a higher proportion of BFM compared to LBM, where in non-interns, LBM was a higher proportion. This pattern, paired with the increase in non-interns’ SMM, indicates a potential insult early in training followed by physical adaptation related to rigorous training through development of surgical skills.

Few studies have aimed to assess physical health and nutrition status in residency. Perrin et al. compared BMI and aerobic fitness of surgical and medical residents; they showed that surgical residents had a higher BMI with lower aerobic fitness level that the authors attributed to increased duty hours. A study involving a cohort of Brazilian psychiatry residents (Melo et al.) demonstrated that a majority of their subjects lived a sedentary lifestyle and nearly a quarter exhibited “harmful” alcohol use. To the authors’ knowledge, there has only been one longitudinal study performed by Kalmbach et al. that quantified physical activity in medical residents. However, those authors only compared the differences in step counts in an intern cohort during their first six months of training versus those interns step counts in the two months prior to their residency training. While they reported a > 10% decrease of average daily activity during the interns first six months of residency, they did not focus on this measured factor’s impact on the residents physical health.

This pilot data identified a possible need for interventions during the first year of residency training. To mirror the mental health resources provided to residents, services aimed at improving or maintaining physical health including allotted fitness equipment and time for use, supplying readily available nutritional meals/snacks, and offering regular physical health monitoring could be provided.

This study had many limitations. Foremost, it is limited by population size in each cohort and by incompleteness of HGS data. Additionally, information on the participants’ daily habits, diet, and activities was not collected nor was it controlled. Finally, while there exists uniformity of orthopaedic services that the residents rotate through, the team roles vary and with the variation of responsibilities comes variation in activity level. Further body composition studies expanding on

![Figure 1. Body composition changes experienced by interns throughout their first year of post-graduate training. Interns lost 2.88 ± 4.26 kg of their initial body mass with most of the loss being BFM (1.97 ± 2.62 kg) by 3 months. Interns also lost more SMM at 3-months (0.47 ± 1.4 kg) compared to 12-months (0.26 ± 1.45 kg). DLM was the metric with the most minimal loss at each interval (3-month: 0.2 ± 0.64 kg; 12-month: 0.11 ± 0.63 kg). SMM = skeletal muscle mass; BFM = body fat mass; DLM = dry lean mass; LBM = lean body mass. Data labels correspond with standard deviations of the displayed means.](image1)

![Figure 2. Body composition changes experienced by interns after their first year of post-graduate training compared to non-intern residents over the same interval. Over 12 months, interns averaged weight loss (-0.78 ± 3.14 kg) compared to non-interns’ weight gain (1.2 ± 3.64 kg). Among the individual metrics, both cohorts experienced the greatest change from baseline in LBM (intern: -0.45 ± 2.41 kg; non-intern: 1.01 ± 3.27 kg). SMM = skeletal muscle mass; BFM = body fat mass; DLM = dry lean mass; LBM = lean body mass. Data labels correspond with standard deviations of the displayed means. Negative values denote mass loss.](image2)
this pilot data, employing interventions (nutrition supplements, prescribed activity, etc.), and examining a wider breadth of residents in various medical and surgical specialties are needed.

CONCLUSION
In conclusion, this study identified an appreciable decrement in overall body mass, body fat mass, and lean body mass during the first post-graduate year of orthopaedic surgery training. Residency departments should recognize that training, especially the intern year, has the potential to decrease the physical health of residents.

REFERENCES
DO PEDIATRIC HOSPITALS IMPROVE OPERATIVE EFFICIENCY?

Michael Russell, MD, MBA, MPH; Joshua Holt, MD; Lori Dolan, PhD; Trevor Gulbransen, MD; Stuart Weinstein, MD

ABSTRACT

Background: In recent years there has been a push towards developing free standing pediatric facilities to provide care specifically towards pediatric patients. The purpose of this study was to determine if moving pediatric cases from a general hospital to a dedicated pediatric facility improved the quality and efficiency of surgical procedures.

Methods: A retrospective review of pediatric patients undergoing posterior spinal fusion (PSF) was performed. All procedures were performed by one orthopaedic surgeon (SLW) from 2015 to 2019. The procedures were performed at a general hospital (GH) the first two years, and at a pediatric hospital (PH) the subsequent years. Data extracted included patient sex, age, and procedure type as well as procedure duration, operative turnover time, hospital length of stay, transfusion requirements, and operative delay. Exclusively pediatric adolescent idiopathic scoliosis (AIS) patients undergoing PSF were included due to the high volume and consistent surgical procedures therefore limiting confounding variables.

Results: A total of five hundred PSF pediatric procedures were performed during the time period. After excluding non-adolescent idiopathic scoliosis cases, a total of 208 procedures were reviewed (105 at GH; 103 at PH). There was no statistical difference between the groups in regards to operative time (GH: 200 min, PH: 200 min; p=0.91), room turnover time (GH: 38 min, PH: 38 min; p=0.801), or rate of transfusion (GH: 20% PH: 30%; p=0.09). Length of stay was significantly shorter in the PH cohort compared to the GH cohort (4.35 vs. 3.84 days, p=0.0001). However, a smaller proportion of cases at the PH started on time compared to the GH (34% vs. 58%; p=0.0005).

Conclusion: Overall, this study demonstrated that AIS procedures at the PH did show a statistically significant reduction in hospital length of stay. However, timely start of the procedure was less likely at this particular facility.

Level of Evidence: III

Keywords: pediatrics, peds ortho, ortho, orthopaedics, scoliosis, adolescent idiopathic scoliosis, ais, hospital efficiency

INTRODUCTION

There has been a long history of providing medical care specific to children in the United States and Canada. In 1855 the Children’s Hospital of Philadelphia developed a facility dedicated to children. Since then this trend has rapidly spread throughout the developed world.1 Over the next century, health care continued to evolve and previously high-volume childhood ailments that resulted in high childhood mortality and handicap decreased. In light of this changing healthcare landscape, the role of freestanding pediatric facilities started to be called into question. This, coupled with the increased cost of healthcare, caused many health care organizations to seek opportunities for cost saving initiatives. As a result, many previously free-standing children’s hospitals either closed completely or merged with adult based hospitals.1

While this occurred on a wide scale, a number of pediatric hospitals have been able to thrive, both economically and with providing high quality patient care.2 These pediatric hospitals have typically been associated with academic institutions as well as continued to maintain strong connections with their general hospital counterparts.3 Orthopaedic surgeries are the second most common pediatric inpatient procedures and dedicated hospital facilities and operating room personnel geared specifically to this age demographic have been shown to be beneficial.3 The injuries and illnesses encountered by this population are unique, requiring technically-demanding surgical procedures and carefully planned post-operative care. In light of this, a specialized health care team familiar with the particular needs and post-operative protocols for this population can maximize results while minimizing complications.3

Adolescent idiopathic scoliosis (AIS) is one of the
most common clinical conditions treated by pediatric orthopaedic surgeons. This condition is characterized by a coronal curvature of the spine measuring greater than 10 degrees utilizing the Cobb angle in the absence of underlying structural or syndromic causes. It has been reported to affect roughly 3% of the general population from age 10-16 and more commonly affects females than males. Of this number, only 0.3% to 0.5% of those affected will have a curve greater than 20 degrees at which point treatment would be recommended. These treatments have typically consisted of bracing treatment for curve angles from 20-40 degrees to help prevent curve progression in skeletally immature individuals. Surgical intervention has typically been reserved for curves measuring greater than 45 degrees. Surgical techniques have certainly evolved over the years, but the current gold standard of treatment is a posterior spinal fusion utilizing a pedicle screw construct and connecting rods. These surgical interventions are undertaken to avoid the long term sequelae of untreated AIS which can include curve progression, back pain, pulmonary restrictive effects, and psychosocial issues.

In the United States, roughly thirty thousand scoliosis surgeries are performed annually. These are typically very involved and intricate procedures with surgical case times very much surgeon dependent. Similarly, post-operative length of stay is certainly variable is often quite lengthy.

While previous studies have examined the beneficial impact of having a dedicated OR team in decreasing procedure length and minimizing blood loss in pediatric AIS cases, no studies were found investigating these differences between general and pediatric hospitals settings. The purpose of this study was to determine if AIS corrective procedures performed at a pediatric specific hospital affects operating room variables by investigating procedure duration, hospital length of stay, transfusion requirements, and operative cases starting time and comparing these to previously obtained data from the general hospital. The second aim was to evaluate the difference in cost efficiency between the two facilities.

From an experimental set up perspective, the senior staff surgeon (SLW) was constant between the two facilities and was well familiarized with the operative procedure. There were no changes in operative technique, instrumentation, or preoperative work up. A third year orthopaedic resident continued to serve in the first assist role and was responsible for instrumenting his/her side of the spine. From additional staffing perspective, a dedicated AIS scrub nurse and circulator continued to be utilized. The only difference between the two facilities was the usage at the pediatric hospital of a preoperative timeout requiring representation from the surgical and anesthesia team along with the patient’s family prior to transport to the operating room. Based upon these operative constants, we hypothesized that there would be no difference in operative variables between the cases completed at the general hospital to those completed at the stand-alone pediatric facility.

METHODS

After institutional review board approval, we queried the electronic medical record database for all procedures identified by CPT codes 22843 and 22844 (Posterior spinal instrumentation including less than 13 vertebral segments and posterior spinal instrumentation including 13 or more vertebral segments) during the years 2015-2019, inclusive. This interval included the 2 years prior to, and 2 years after, transition of all pediatric procedures from a general hospital to a stand-alone children’s hospital associated with the same academic medical center. All procedures in the sample were performed by one pediatric orthopedic surgeon with greater than 30 years’ experience in the same institution. This initial data search resulted in over 500 results. This scope was further narrowed by applying exclusion criteria that limited results to solely patients aged 10 years or older and without syndromic or structural causes of scoliosis. This resulted in 105 cases in the GH cohort and 103 cases in the PH cohort. For each procedure we extracted the patient age and sex, extent of the fusion (<13 levels or >/=13 levels) as well as whether the case started on time, length of time from patient in room to procedure start (minutes), length of the procedure from incision to final closure (minutes), turnover time measured from patient out of room to next patient in room (minutes), hospital length of stay (days), transfusion requirements in the immediate postoperative period as recorded in the surgical and post-operative clinic notes, pediatric specific anesthesiologist staffing, and certified registered nurse anesthetist (CRNA) staffing.

The distributions of the variables within each sample were characterized using the median and interquartile range for ordinal-level variables, and proportions for nominal-level variables. The Wilcoxon two-sample test was used to compare continuous variables including age, operative time, turnover time, blood loss, and length of stay. Fisher’s exact and Pearson chi-square tests were used to evaluate differences in sex and occurrence of complications. Stata (version 15.1; Stata Corp, College Station, TX, USA) was used for all statistical analysis; differences associated with a p-value <0.05 were considered to statistically significant.

RESULTS

A total of 500 patients underwent PSF by the surgeon during the 4-year time frame. Of these, 292 were
excluded due to age less than 10, or a diagnosis other than AIS. This resulted in a final cohort of 208 patients, with 105 cases performed at the GH and 103 at the PH. Females made up 84% of the sample at the GH compared to 76% at the PH (p=0.13). The median operative time (incision to closure in minutes) was 193 min (IQR=174–215 min) at the GH and 196 min (IQR=172–213 min) at the PH (p=0.91). There was likewise no statistical difference in median turnover times (time elapsed between one patient leaving the OR and the next entering) between the facilities (36.5 min (IQR=32.5–44 min) and 37.5 min (IQR=33–39 min) at the GH and PH, respectively, p=0.99). However, the mean in-room-time to case-start time was 5.6 minutes faster at the PH compared to the GH (mean 48.9 minutes GH vs. 54.5 minutes PH, p<0.0001). There was an average delay of cases starting on time of 42 minutes at the pediatric facility compared to 13 minutes at the general hospital (p<0.0001), resulting in a lower proportion of on-time starts (34% vs. 58%) as measured by cases starting within 5 minutes of their scheduled start time. Variances in type of anesthesia staff utilized were also analyzed, with a statistically significant difference in CRNA utilization (91% PH vs. 61% GH) and pediatric-trained anesthesia staff (99% PH vs. 84% GH) when comparing the two facilities (p<0.0001). There was also a slightly higher incidence of longer
fusion constructs in the children’s hospital with 84% of procedures being >13 levels as compared to 71% at the general hospital (p=0.04). Similarly, there was a slightly higher incidence of transfusion requirement in the pediatric hospital with 30% requiring a transfusion compared to 20% in the general hospital, however these findings were not significant (p=0.09). In terms of hospital length of stay, there was a statistically significant difference with the designated children’s hospital length of stay being 0.5 days shorter on average (p=0.0001) at 3.7 days compared to 4.2. These results are summarized in Figure 1 and Figure 2.

DISCUSSION

This study provides valuable data on specific indicators of OR efficiency and clinical outcomes, allowing us to target areas for improvement at the pediatric specific facility. Specifically, migration to the PH was associated with cases typically starting thirty minutes later than similar procedures at the GH. On the positive side, LOS was decreased by approximately 0.5 days after migration to the pediatric hospital but given the national trends toward shortened hospital stays, this was likely to occur without a change in facility. Additionally, a higher percentage of CRNA utilization and pediatric board certified anesthesiologists was also noted following the migration to the pediatric hospital. This was relatively unsurprising to the authors given the increasing utilization of CRNA’s in the surgical realm and the pediatric-specific facility.

Recent literature has focused on operative efficiency from several different perspectives. Some studies have evaluated the role of consistent OR personnel, use of dedicated operating rooms for specific procedures, and incorporating surgical co-management services in improving procedural efficiency. To the best of our knowledge, procedural efficiency as a function of type of facility – PH vs GH - has not been evaluated to date.

This study suggests that at our institution, utilizing the same staff surgeon with resident assistance model, procedural length was unaffected by the move to the PH. This supports the authors’ original hypothesis that procedure length is a function of the staff surgeon’s strong familiarity with adolescent idiopathic scoliosis and posterior spinal fusion. It was of keen interest to the authors that there was a statistically significant difference in procedures starting on time. With migration to the dedicated pediatric facility, there was an average twenty-nine minute longer delay relative to that at the general hospital. While it is impossible to isolate one reason for this, it is likely largely attributable to a mandated pre-procedural time out conducted in the preoperative holding area. This time out is unique to the pediatric hospital and requires that all members of the surgical team be present prior to transporting the patient to the operating room suite. This requirement was implemented in an attempt to minimize surgical errors and to ensure that parents were fully informed of the procedure about to be undertaken. We agree with the intent, however, due to the various schedules and responsibilities delays delaying transport until all members are present does this process has been largely successful at this aim, but with stipulating that all members of the surgical team must be present prior to patient transport delays in patient transport have been abundant.

Length of stay decreased from a median of 4.3 at the GH to 3.8 days after the move to the PH. This 0.5 day savings in patient length of stay represents a significant cost savings to the patient and a significant cost savings to the hospital when under bundled care plans where a flat fee is reimbursed for all services provided. In addition to this, earlier discharge also allows for increased patient bed availability. This length of stay decrease also compares favorably to the national average for length of stay from 2017 of 4.1 days for AIS procedures in patients age 10-17.

We cannot assume that the experience of other hospital systems would be similar to ours due to the highly individualized nature of each hospital system. Our situation was very unique in that our institution predominately utilizes one surgeon for all AIS cases and his operative case volume is very high. This study does provide insight into the importance of ensuring pre-operative checklists are effective at eliminating preventable complications and improving communication between the patient, family and surgical team, without routinely causing unnecessary delays. Additionally, this study provides some evidence that the familiarity of a surgeon with a particular procedure is more important in operative efficiency than dedicated facilities for particular age groups.

There are limitations to be considered when evaluating the results of this study. Data was collected retrospectively, and we cannot make any claims about the accuracy of the times recorded by the OR personnel. In addition, this study was very specific with regards to our particular institution and is likely not generalizable to other facilities. With these problems being known, this study does provide valuable information for our institution regarding targets for efficiency improvement moving forward. It demonstrated that while operative procedure length may not have varied with migration to a new facility, this migration did result in a larger number of cases not starting on time and that the preoperative timeout prior to transition to the operating room was likely responsible for this.
REFERENCES

ABSTRACT

Background: Childhood obesity affects nearly one fifth of all children in the United States. Understanding the unique injury characteristics and treatment of tibia fractures in this population has become increasingly important. This study aims to explore the different injury characteristics between tibia fractures in obese and non-obese children.

Methods: 215 skeletally immature children aged 2-18 who sustained tibia fractures between 2007-2019 were retrospectively reviewed. Patients were analyzed by weight group: underweight, normal weight, overweight, and obese as defined by body mass index (BMI) percentile based upon age. Analyses were performed on dichotomized groups: underweight and normal weight versus overweight and obese. Chi-square or Fisher’s exact test was used to compare differences in categorical outcome between the 2-category BMI class variables; Wilcoxon test was used to compare continuous outcomes. A multivariate logistic regression model was used to evaluate BMI associations while controlling for age, sex, race, and mechanism of injury.

Results: Distribution of BMI in the cohort included 6.5% underweight, 45.6% normal weight, 16.7% overweight and 31.2% obese. Overweight and obese children sustained fractures from low energy mechanisms at more than double the rate of normal and underweight children (20.5% versus 9.7%, p=0.028). Overweight and obese children sustained physeal fractures at a rate of 54.4% in comparison with 28.6% in their normal and underweight peers (p<0.0001, OR 2.50 (95% CI, 1.26-4.95)). Overweight and obese children sustained distal 1/3 tibia fractures at a higher rate of 56.9% compared to under and normal weight children at 33.9% (p=0.003, OR 2.24 (95% CI, 1.17-4.30)). Overweight and obese children underwent unplanned changes in treatment at a lower rate than normal and underweight children at 1% versus 8% rates of treatment change, respectively (p=0.013, OR 0.076 (95% CI, 0.009-0.655)). No significant differences were found in the rates of operative treatment, repeat reduction, post-treatment complications, or physical therapy.

Conclusion: Overweight children sustain tibia fractures from low energy mechanisms at higher rates than their peers. Similarly, obese and overweight patients have higher rates of physeal injuries and higher rates of distal 1/3 tibia fractures. Complication rates are similar between obese and non-obese children undergoing treatment for tibia fractures.

Level of Evidence: III

Keywords: pediatrics, obesity, trauma, tibia fracture

INTRODUCTION

Childhood obesity is a national epidemic; the most recent CDC data demonstrates that 17.2% of all youth in the United States are classified as obese based on body mass index (BMI). Previous literature has reported that obese children are at increased risk of fracture, while others have not found a significant association between obesity class and fracture incidence. Several studies have reported that obese pediatric patients have different fracture patterns, more commonly require surgical treatment, and have higher rates of post-procedural complications. Auer et al. demonstrated that obese children had higher rates of malreduction of distal radius fractures requiring subsequent manipulation with closed reduction and casting when compared to their peers of normal BMI. Another study reported that obese children were significantly more likely to sustain loss of reduction in closed treatment and casting for radial and ulnar diaphyseal fractures than their normal-weight peers.
Understanding the differences between treating obese and non-obese children is important for orthopaedic surgeons, children and their families.

There is a paucity of literature investigating the effects of obesity on lower extremity fractures. One review demonstrated that obese children were significantly more likely to sustain lower extremity injuries than upper extremity injuries. Obese children also tend to have more severe femur and tibia fractures and higher inpatient morbidity and mortality after trauma than their normal-weight peers. While several studies suggest obese children have higher treatment failure in common upper extremity injuries, there are few studies evaluating the treatment outcomes for obese children sustaining tibia fractures. Pediatric tibial shaft fractures are treated nonoperatively in up to 95% of cases, though operative intervention may be increasing in prevalence.

The purpose of the study is to further evaluate differences in injury characteristics, treatment algorithms, and treatment outcomes in tibia fractures in obese children versus children with normal BMI to add to a growing body of literature evaluating this topic. With increasing rates of obesity, a better understanding of potential differences in epidemiology and treatment of these populations is essential.

**METHODS**

After obtaining approval from the Institutional Review Board, we identified all patients aged 2-18 years old who presented to our institution with a tibia fracture between January 2007 and December 2019. The initial cohort of patients included 497 patients. Patients with undocumented height or weight, incomplete follow-up or underlying bone pathology (e.g. osteogenesis imperfecta, malignancy) were excluded. Patients that were skeletally mature based on initial imaging were also excluded. After exclusions, 215 children met criteria for inclusion (Figure 1). Prospectively collected data from initial presentation, subsequent operative interventions, and clinic follow-up was retrospectively reviewed.

Demographic information including age, gender, and body mass index was reviewed. Patients were classified into BMI categories based upon BMI for age. A BMI for age greater than 85th percentile was classified as overweight, greater than 95th percentile for obese, and less than 5th percentile for underweight based upon the guidelines from the Center for Disease Control's expert committee on childhood obesity. Injury characteristics were collected including mechanism of injury, location of fracture (proximal, middle, or distal third), and Salter-Harris type, if physeal. Mechanisms of injury were further divided into high and low energy mechanisms with high energy mechanisms comprising motor vehicle collisions, pedestrian versus auto, and downhill activities (skiing, skateboarding, etc.). Low energy mechanisms included ground level falls and sporting injuries.

Patients that were seen in the emergency room underwent closed reduction by an orthopaedic surgery resident under conscious sedation if indicated based on unacceptable alignment as described by Ho and Mooney, or in the presence of clinical deformity or malrotation. Additional treatment including operative intervention or repeat closed reduction was under the discretion of the attending orthopaedist. A patient was deemed to have failed initial management if they had loss of reduction requiring additional intervention including cast wedges.
The Effect of Obesity on Pediatric Tibia Fractures

Post treatment complications were reviewed including pressure injury, refracture, stiffness requiring therapy, premature closure of physes, infection and chronic pain. Additionally, total number of radiographs, need for formal physical therapy and the length of treatment or immobilization was recorded.

Median (Q1, Q3) were used to summarize continuous patient characteristics and frequencies and percentages were used to summarize categorical patient characteristics. Chi-square or Fisher’s exact test was used to compare differences in categorical outcome between the 2-category BMI class variables; Wilcoxon test was used to compare continuous outcomes.

Multivariable logistic regression was performed to evaluate associations between overweight/obese status vs normal/underweight status and outcomes controlling for the following variables: age, sex, race, and mechanism of injury. All analyses were performed in SAS 9.4 (Cary, NC). Two-sided p-values were deemed statistically significant.

**RESULTS**

The median age at injury was 10 (Q1, Q3: 5, 12). The majority were male (67.4%) and approximately half were white (50.7%). Distribution of BMI categories were as follows: 6.5% underweight, 45.6% normal weight, 16.7% overweight and 31.2% obese. Demographic comparison of the two weight groups can be found in Table 1. The only significant finding was obese and overweight children sustained their fractures at an older age in comparison with their normal and underweight peers.

### Table 1. Comparison of Demographics Between Weight Groups

<table>
<thead>
<tr>
<th></th>
<th>Normal/Underweight (n = 112)</th>
<th>Obese/Overweight (n = 103)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y), Median (Q1, Q3)</td>
<td>7 (3, 13)</td>
<td>10 (8, 12)</td>
<td><strong>0.009</strong></td>
</tr>
<tr>
<td>Sex n (%)</td>
<td></td>
<td></td>
<td><strong>0.655</strong></td>
</tr>
<tr>
<td>Male</td>
<td>74 (66.1)</td>
<td>71 (68.9)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>38 (33.9)</td>
<td>32 (31.1)</td>
<td></td>
</tr>
<tr>
<td>Race/Ethnicity n (%)</td>
<td></td>
<td></td>
<td><strong>0.739</strong></td>
</tr>
<tr>
<td>White</td>
<td>58 (51.8)</td>
<td>51 (49.5)</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>23 (20.5)</td>
<td>27 (26.2)</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>20 (17.9)</td>
<td>21 (20.4)</td>
<td></td>
</tr>
<tr>
<td>Other/Not Listed</td>
<td>11 (9.8)</td>
<td>4 (3.9)</td>
<td></td>
</tr>
</tbody>
</table>

Significant values in bold. Table comparing demographics between the two weight groups. Values are represented as number and percentage in parentheses (%).

Low energy mechanisms of fracture were more common in the obese and overweight children. Normal and underweight children sustained high energy mechanisms at a rate of 20.5% in our cohort compared with 9.7% in overweight and obese children (p = 0.028, Table 2).

Overweight and obese children sustained more physeal fractures than normal weight children. Overweight and obese children sustained physeal fractures at a rate of 54.4% in comparison with 28.6% of their normal and underweight peers (p<0.0001, Table 2). After adjusting for other variables, a multivariate analysis demonstrated an odds ratio of 2.50 (CI, 1.26-4.95, Table 3), indicating
Table 3. Multivariable Associations of Overweight and Obese BMI With Outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>OR (95% CI)*</th>
<th>P-value**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal third fracture</td>
<td>2.24 (1.17, 4.30)</td>
<td>0.0147</td>
</tr>
<tr>
<td>Physeal Involvement</td>
<td>2.50 (1.26, 4.95)</td>
<td>0.0088</td>
</tr>
<tr>
<td>Operative treatment</td>
<td>0.60 (0.293, 1.21)</td>
<td>0.1541</td>
</tr>
<tr>
<td>Unplanned change in treatment</td>
<td>0.076 (0.009, 0.655)</td>
<td>0.0190</td>
</tr>
</tbody>
</table>

*OR = Odds Ratio, comparing odds of each outcome for Overweight/Obese compared to Normal/Underweight.
**P-value calculated with multivariable logistic regression model for each outcome with predictors of BMI, age, sex, race, and mechanism of injury.

overweight and obese children are 2.5 times more likely to sustain a physeal fracture of their tibia (p=0.0088). Those who were overweight or obese had more distal tibia fractures compared to underweight children (56.9% vs 33.9%, p=0.0029, Table 2). Again, after adjusting for other variables, overweight and obese children in our cohort were more than twice as likely to sustain a distal third tibia fracture in comparison with their normal and underweight peers (OR=2.24, CI, 1.17-4.30, p=0.0147, Table 3). The majority of physeal fractures involved the distal physis; only 6 patients in our cohort sustained proximal tibial physeal fractures.

Overweight and obese children were at a significantly lower risk of undergoing an unplanned change in treatment in comparison with normal and overweight children (1% versus 8%, OR=0.076 (CI, 0.009-0.655), p=0.019). Overweight and obese children were immobilized for longer periods than their normal and underweight peers. On average, overweight children were immobilized for one additional week, averaging 8 weeks of treatment in the overweight children compared with 7 weeks in normal and underweight children (p = 0.045). There were no other significant differences in the rates of complications, failure of closed treatment or need for post-treatment physical therapy between the dichotomized groups.

**DISCUSSION**

Understanding the unique challenges that arise when treating fractures in obese children has become increasingly important as the world’s obesity epidemic becomes more prevalent. There is a relative paucity of literature investigating the effect of obesity on tibia fractures in pediatric patients. Our data suggest that overweight and obese children are at a higher risk for tibia fractures sustained during everyday activities such as a ground-level falls or sporting activities. In this cohort, overweight children were two times more likely to have low energy mechanisms of tibia fracture compared to their peers.

Tibia fractures in overweight and obese children involve the physis at a higher rate. This is an important finding that adds to a growing body of literature investigating the effects of obesity on physeal development. Obesity is an established risk factor for several conditions affecting the physis including slipped capital femoral epiphysis and tibia vara. A prior registry study has demonstrated that obese children are at increased risk of traumatic physeal injuries, obese patients were twice as likely (risk ratio 2.20) to have lower extremity fractures involving the physis when compared to non-obese children. Our results corroborate this finding. The biomechanics of these differences are not understood and require further investigation. Some have suggested the physeal abnormalities in obese children may be secondary to advanced bone age or increased adiposity in the bone. To our knowledge, this is only the second case series evaluating the risk of physeal injury in obese children. Clinicians should be aware of this association when evaluating obese trauma patients.

There is a correlation between increasing BMI and a propensity for distal tibia fractures; with underweight patients sustaining distal third fracture at a rate of 15% and obese children at a rate of 60%. Controlling for confounding factors, a multivariate analysis demonstrated an odds ratio of 2.24 (95% CI, 1.17-4.30) for obese children sustaining a distal 1/3 fracture in comparison to normal and underweight children in our cohort. Obese children in our cohort demonstrated the highest rate of complications including pressure injury, refracture, stiffness requiring therapy, premature closure of physes, infection and chronic pain. However, the study was underpowered to demonstrate statistical significance.

Overall, 25.2% of the children in the cohort required an intervention in the operating room; either a closed reduction in the surgical suite or an open surgical procedure. Interestingly, underweight and normal weight children underwent unplanned change in treatment at a higher rate than their overweight and obese counterparts. This finding contrasts with other studies in the pediatric literature that demonstrate higher rates of treatment change in obese children due to their habitus and difficulty in controlling the fracture with immobilization alone. Overall, the number of patients with treatment failure, defined as unplanned change in treatment (n = 10), was small in this study precluding causative analysis. There is no clear etiology for this difference.

Overweight and obese children underwent, on average, one additional week of immobilization at 8 weeks (Q1, Q3: 6.5, 11) in comparison with 7 weeks (Q1, Q3: 4.5, 10) for underweight and normal weight individuals.
undergoing treatment for tibia fractures. Rates are similar between obese and non-obese children how obesity affects the developing physis. Complication distal physis, which adds to a growing understanding of have higher rates of physeal injuries, particularly of the ally, overweight and obese children with tibia fractures from low energy mechanisms at double addition, which decreased the overall power of the study. Additional large, multi-center studies are needed to determine if the results of this study are generalizable to other populations. Further evaluation of factors including bone age, functional outcomes, and more precise data on time to healing would enhance our understanding of tibia fractures in this population.

In conclusion, overweight and obese children sustain tibia fractures from low energy mechanisms at double the rate of normal and underweight children. Addi-tionally, overweight and obese children with tibia fractures have higher rates of physeal injuries, particularly of the distal physis, which adds to a growing understanding of how obesity affects the developing physis. Complication rates are similar between obese and non-obese children undergoing treatment for tibia fractures.

REFERENCES


ABSTRACT

Background: Research has shown that postoperative shoulder imbalance is a common problem after spinal fusion in adolescent idiopathic scoliosis (AIS). The best radiographic predictor has not yet been determined and results are inconsistent. This study was to investigate whether using medial and lateral shoulder parameters can effectively achieve postoperative shoulder balance.

Methods: A prospective database of AIS undergoing posterior spinal fusion were reviewed. Patient demographics and radiological parameters including radiographic shoulder height (RSH), clavicle angle, T1-tilt and first-rib angle at baseline, 6 weeks and last minimal follow up of 2 years were recorded. Correlations between radiological parameters were assessed using Pearson’s correlation coefficients. Multivariable linear models identified predictors associated with increased RSH.

Results: 219 patients (mean age:13.7 years; 81.7% female) were included. The mean follow-up time was 2.8 years (range:2.0-7.0). The mean RSH at baseline, 6 weeks and last follow up was improved significantly at 95.8%. Preoperative (r=0.8; p<0.001) and post-operative measurements of RSH at 6-week (r=0.9; p<0.001) and last follow up (r=0.9; p<0.001) correlated strongly with clavicle angle measured at respective time-points. In a multivariable linear model, we noted marginal increase in clavicle angle (+4.3°; p<0.001) to be associated with increased RSH. On the contrary, first rib angle and T1-tilt demonstrated moderate to weak correlation with RSH.

Conclusion: Clavicle angle is strongly consistent with RSH. First rib angle and T1-tilt as demonstrate medial shoulder balance are moderate to weak correlation. Leveling T1 tilt and first rib angle do not guarantee the postoperative shoulder balance.

Level of Evidence: IV

Keywords: adolescent idiopathic scoliosis, medial shoulder, lateral shoulder, shoulder balance, radiographic shoulder height

INTRODUCTION

The goals of surgical treatment for adolescent idiopathic scoliosis (AIS) are to obtain a solid fusion while maintaining correction and balance in the coronal and sagittal planes. Shoulder imbalance is a major concern after posterior spinal fusion (PSF) for AIS as it is associated with patient appearance and patient satisfaction. Moreover, the patients with severe scoliosis were characterized by insecurity and hypersensitivity, and that their psychosocial adjustment was negatively correlated with the severity of their deformity. These reasons make shoulder balance be more important and become a major concern after the surgery.

Although the Lenke classification is widely used to determine the extent of spinal arthrodesis levels, it was reported that some patients had postoperative shoulder imbalance even when the curves are well corrected. To attain shoulder balance following spinal fusion, it is important to determine the factors associated with shoulder balance. These factors have been widely described in the literature. However, the best radiographic predictor has not been determined and the results are inconsistent.

Common radiographic shoulder parameters have been described in the literatures including radiographic shoulder height (RSH), clavicle angle, T1 tilt and first rib angle. Intraoperative shoulder assessment is difficult because of the limitation and narrow view of intra-operative imaging. In addition, prone positioning and the non-physiological positioning of shoulders and arms during surgery make clinical assessment impossible. Only T1 tilt, first rib angle and clavicle angle can be seen from intraoperative fluoroscopy.

The purpose of this study was to analyze common radiographic parameters in a large group of AIS patients.
who underwent PSF by single surgeon at a single institution to identify the best correlation with post-operative shoulder balance. And to determine whether T1 tilt, first rib angle and clavicle angle could be effectively use for postoperative shoulder balance.

METHODS

After obtaining institutional review board approval, the medical records and spinal radiographs of patients with AIS surgically treated from 2006 to 2015 were retrospectively reviewed. 219 patients from the data base of our previous study were analyzed. All patients had minimum 2 years follow-up and were operated by a single surgeon.

The radiographs were evaluated preoperatively, immediately after surgery (at first postoperative visit 6 weeks after surgery), and at a minimum of 2 years after surgery with whole-spine erect postero-anterior and lateral EOS radiographs focused on the shoulder balance parameters (RSH, Clavicle angle, T1 tilt and first rib angle). All radiographs were taken in a standardized fashion. Data were collected on age, sex, weight and Lenke classification. All radiographic measurements were made by 2 of the authors who were not involved in the patient treatment.

Shoulder balance was described based on two distinct components which were medial shoulder and lateral shoulder parameters. RSH was determine shoulder balance or imbalance. Clavicle angle was used to represent lateral shoulder balance. And T1 tilt and first rib angle were used to represent medial shoulder balance.

Radiographic shoulder height

The difference in the soft tissue shadow directly superior to the acromioclavicular joint. A positive RSH value was defined as right shoulder was higher, whereas a negative value was defined as left shoulder was higher (Fig. 1).

Clavicle angle

A line drawn connecting the cephalad margin of both lateral clavicles and a horizontal reference line. The positive clavicle angle was defined as tilting or opening to the right, whereas a negative value was defined as tilting or opening to the left (Fig. 2).

T1 tilt

Angle subtended by a line drawn along the cephalad endplate of T1 and a horizontal reference line (Fig. 3). The positive T1 tilt was defined as tilting or opening to the right, whereas a negative value was defined as tilting or opening to the left.

First rib angle

Angle subtended by a line drawn along the cephalad edge of the first rib and a horizontal reference line (Fig. 4). The positive value was defined as tilting or opening to the right, whereas a negative value was defined as tilting or opening to the left.
Statistical Analysis
Continuous data were described as means and standard deviations. Categorical data were indicated as percentages. The absolute correction in shoulder parameters were then calculated using these absolute values. Correlations between RSH and clavicle angle, first rib angle and T1-tilt were assessed using Pearson's correlation coefficients. Multivariable linear models identified predictors associated with increased RSH. The statistical analysis was performed using the SPSS 22.0 software. Values of p < 0.05 were considered to be statistically significant.

RESULTS

Demographic Data
From the database of 219 patients. The mean follow-up of 2.8 years (range, 2.0 – 7.0) (Table 1). There were 179 females (81.7%) and 40 males (18.3%). The average age at the time of surgery was 13.7 years (range, 13.0-16.0). The majority of patients presented with a Lenke type 1 curves (43.0%). The remainder were (13.2%) Lenke 2, (7.3%) Lenke 3, (4.1%) Lenke 4, (9.5%) Lenke 5 and (8.6%) Lenke 6. The mean main thoracic (MT) Cobb angle and proximal thoracic (PT) Cobb angle were 53.4° and 24.5° respectively. Both PT and MT curves has statistically significant corrections after surgery. The mean postoperative SRS-22 outcome scores at final follow up were 4.2(3.8-4.6). No neurological complications occurred in any of the patients.

Radiographic Shoulder parameters
The mean preoperative RSH was 14.7 ± 10.3 mm. At 6 weeks after surgery the mean RSH was 9.2 ± 7.7 mm. At the final follow up, the mean RSH was 8.0 ± 6.9 mm. The median preoperative clavicle angle was 2.1° (range 1.9-2.4). The median clavicle angle at 6 weeks after surgery was 1.7° (range 1.5-1.9). At the final follow up, the median clavicle angle was 1.3° (range 1.1-1.5). The median preoperative T1 tilt was 5.6° (range 6.9-5.2). The median T1 tilt at 6 weeks after surgery was 4.1° (range 3.5-4.6). At the final follow up, the median T1 tilt was 2.2° (range 3.6-4.6). The mean preoperative first rib angle was 37.6°±10.7° before surgery, 37.1°± 11.8° in the immediate postoperative period, and 36.1°±9.8° at the latest follow-up. (Table 2).

Relationships between medial and lateral radiographic parameters of shoulder balance
Preoperative (r=0.8; p<0.001) and post-operative measurements of RSH at 6-week (r=0.9; p<0.001) and last follow-up (r=0.9; p<0.001) correlated strongly with clavicle angle measured at respective time-points (Fig 5). On the contrary, first rib angle and T1-tilt demonstrated moderate to weak correlation with RSH measurements at baseline as well as follow up.

In multivariable linear model adjusting for patient demographics, Lenke classification and radiological metrics, we noted marginal increase in clavicle angle (+4.3°; p<0.001) to be associated with increased the RSH.

<table>
<thead>
<tr>
<th>Table 1. Demographic Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of patients</strong></td>
</tr>
<tr>
<td><strong>Follow-up (months)</strong></td>
</tr>
<tr>
<td><strong>Age (year)</strong></td>
</tr>
<tr>
<td><strong>Sex</strong></td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td><strong>Race</strong></td>
</tr>
<tr>
<td>White</td>
</tr>
<tr>
<td>African Americans</td>
</tr>
<tr>
<td>Others</td>
</tr>
<tr>
<td><strong>Body Mass Index (Kg/m2)</strong></td>
</tr>
<tr>
<td><strong>Lenke type</strong></td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2. Radiographic Outcomes by Time Point</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiographic shoulder height (RSH)</strong></td>
</tr>
<tr>
<td><strong>T1 tilt</strong></td>
</tr>
<tr>
<td><strong>First rib angle</strong></td>
</tr>
<tr>
<td><strong>Clavicle angle</strong></td>
</tr>
<tr>
<td><strong>Main thoracic Cobb angle</strong></td>
</tr>
<tr>
<td><strong>Proximal thoracic Cobb angle</strong></td>
</tr>
<tr>
<td><strong>Lumbar Cobb angle</strong></td>
</tr>
</tbody>
</table>
DISCUSSION

Shoulder balance after spinal fusion of AIS is a major concern and the predictors are not fully understood. In addition, evaluation of shoulder balance intraoperatively is difficult because of limited intraoperative imaging and prone positioning during surgery. Our purpose was to evaluate a variety of common radiographic measurements to determine the most predictive radiographic parameters for postoperative shoulder balance.

This study determined to use radiographic measures of shoulder balance by RSH because soft tissue shadow was one of most reliable parameters for shoulder balance evaluation. The improvement of RSH was 95.8% by our technique that has been described in the previous study. Kuklo et al. analyzed numerous radiographic parameters and correlated these parameters with postoperative shoulder balance. They found that clavicle angle and coracoid height were significant predictors. Our study found that clavicle angle was strongly correlated with RSH. In multivariable linear model adjusting for patient demographics, Lenke classification and radiological metrics, we noted marginal increase in clavicle angle (+4.3°; p<0.001) to be associated with increased RSH. In other words, the greater the clavicle angle the more shoulder imbalance among preoperative and at the at least 2 years after surgery. This numerical analysis has not been described before. Patients with severe post-operative shoulder imbalance (RSH more than 30.0 mm) showed higher pre-operative clavicle angle (mean 15.0°). Some, however, clavicle angle is impacted by the patients’ position during surgery makes it difficult in interpretation.

Unlike clavicle angle, the first rib angle and T1-tilt are better interpreted intraoperatively because they are not impact by the prone position. T1 tilt has been studied to predict shoulder imbalance but the results are inconsistent. It was significantly correlated with postoperative shoulder imbalance according to the study by Ginsburg et al. On the contrary, Lee et al. found that positive T1 tilt did not correlate with left shoulder elevation. Akel et al. studied on normal population, they found that T1-tilt was mildly correlated with shoulder balance, making T1-tilt a weak candidate for shoulder evaluation. A recent multicenter study by Luhmann et al. reported that there was no correlation between T1 tilt and shoulder balance. Our study found that T1 tilt and first rib angle were moderate to weak correlation with RSH at baseline as well as at the last follow-up. Our study supports the two components of shoulder (medial shoulder and lateral shoulder). The medial and lateral shoulder balance concept was reported by Ono et al. They found that T1 tilt, first rib angle, and proximal thoracic Cobb correlate with trapezoidal prominence (medial balance) but not lateral shoulder balance. Be-
cause the spine is not connected to shoulders directly as it articulates to the ribs.

This study showed the strong correlation between clavicle angle and RSH. Clavicle angle was the best predictor for postoperative lateral shoulder balance. However, clavicle angle is difficult to assess intraoperatively. In our view, T1 tilt is still useful for intra-operative predictor. Although leveling T1 tilt does not guarantee lateral shoulder balance, it can improve medial trapezial prominence. Secondly, shoulders lay on the rib cage and connect loosely to clavicle and scapular. Correction spine deformity in this area including T1 tilt might help some shoulder balance as well.

Our study has some limitations, this is retrospective radiographic analysis and clinical shoulder parameter was not analyzed. However, the strengths of this study are that all patients included in this study were treated at the same institution by a single surgeon, providing consistency in surgical technique. Further studies are needs to investigate other intraoperative parameters with purpose of aiding surgeon in prediction the postoperative lateral shoulder balance.

CONCLUSION

Clavicle angle is strongly consistent with RSH. First rib angle and T1-tilt as demonstrate medial shoulder balance are moderate to weak correlation. Leveling T1 tilt and first rib angle do not guarantee postoperative shoulder balance.

REFERENCES

INTRATEHAL MORPHINE USE IN ADOLESCENT IDIOPATHIC SCOLIOSIS SURGERY IS ASSOCIATED WITH DECREASED OPIOID USE AND DECREASED LENGTH OF STAY

Kevin P. Feltz, MD; Nicklaus Hanson, BA; Nathan J. Jacobson, MD
Paul A. Thompson, PhD; Geoffrey F. Haft, MD

ABSTRACT
Background: Length of stay (LOS) in the hospital following posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS) has decreased over the past decade due to well-defined postoperative clinical pathways, earlier mobilization, and improved pain control methods. Historically, liberal use of parenteral and oral opioids for pain control caused side effects, resulting in delayed discharge. Intraoperative intrathecal morphine (ITM) has been posited to reduce the need for postoperative opioids and to expedite the discharge process. This study examines the relationship between the use of ITM with average required postoperative opioid usage and with average LOS.

Methods: This IRB-approved retrospective cohort study examined 105 patients with AIS who received PSF with instrumentation split into two cohorts. One cohort underwent PSF via standard surgical protocol (n=40) while the other cohort received intraoperative ITM with the standard surgical protocol (n=65). Power analysis demonstrated a study power of 0.8. LOS and total postoperative opioid analgesic medication (morphine milligram equivalent, MME) data were collected. Age at surgery, gender, number of spinal levels fused, estimated intraoperative blood loss (EBL), preoperative Cobb angle, and any complications related to the use of ITM were also recorded. Continuous variables were analyzed with Student’s t-test and categorical variables were analyzed with chi-square independent-sample tests using SAS 9.4 (α = 0.05).

Results: Patients who were treated with ITM displayed shorter LOS (p<0.0001) and reduced postoperative analgesic requirement (p<0.0001). Patients who received ITM spent an average of 1.8 fewer midnights in the hospital and received an average of 221.2 MME less than patients who received standard protocol (57% decrease). There were no significant differences between the two groups for any other variable.

Conclusion: Intraoperative ITM is a simple and effective treatment for scoliosis surgeons to better control postoperative pain in patients, reduce the risk of dependency, and achieve earlier discharge from the hospital. Shortened LOS reduces the overall cost of care, benefitting patients, hospitals, and insurance companies. Based on the results of this study and several earlier studies, the authors recommended that scoliosis surgeons consider incorporating use of ITM into their standard operative protocols.

Level of Evidence: IV

Keywords: intrathecal morphine, adolescent idiopathic scoliosis, posterior spinal fusion, scoliosis, length of stay, opioid

INTRODUCTION
Over the past decade, providers have made strides to decrease the length of stay (LOS) in the hospital following posterior spinal fusion (PSF) surgery for adolescent idiopathic scoliosis (AIS) in order to improve patient outcomes.1 Increased LOS has been associated with higher cost to the patient, increased risk of 90-day postoperative complications, increased risk of all-cause 90-day readmission, and increased risk of readmission within 90 days.2 Well-defined postoperative clinical pathways, earlier mobilization, and improved pain control methods all contributed to this shortened LOS.3

The hospital in this study, a major Midwest tertiary care center, utilizes an established clinical pathway to facilitate earlier discharge of patients following AIS surgery. To be discharged home, patients must meet three criteria: independent mobility, normal oral food and water intake, and satisfactory pain control with oral medications. As part of the standard recovery protocol, each patient is mobilized as early as possible with assistance from nursing and physical therapy and eating and drinking is encouraged as soon as the patient can...
tolerate oral intake. In addition, multimodal pain control measures, including oral non-steroidal anti-inflammatory agents, anti-spasmodics, acetaminophen, and ice have been in standard use. Historically, the liberal use of parenteral and oral opioids was necessary to control pain after surgery. This resulted in frequent opioid-induced lethargy and gastrointestinal motility problems as side effects, preventing patients’ readiness for discharge and prolonging LOS. Reduction of opioid use and its resulting complications expedites the discharge process; therefore, every effort should be made to maximize pain control without excess use of opioid analgesics.

This retrospective study examined the routine use of intraoperative intrathecal morphine (ITM) and its role in reducing postoperative pain and LOS in AIS surgical patients. The safety and effectiveness of ITM administration has been extensively described, facilitating its incorporation into the surgical protocol. It was hypothesized that incorporation of intraoperative ITM would result in a shorter hospital LOS and decreased postoperative opioid use.

METHODS

This study was an IRB-approved retrospective cohort study of 105 patients with diagnosed AIS who received PSF with instrumentation from a single surgeon between 2005 and 2016. Two cohorts were defined and compared. Patients in the first cohort underwent PSF with the standard surgical protocol (n=40). Patients in the second cohort received intraoperative ITM with the standard surgical protocol (n=65). Patients in both cohorts underwent the institution’s recovery pathway, which emphasized early mobilization as tolerated. All surgery was performed at a single large, academic, tertiary care hospital in the Midwestern United States. Data on operative procedure and hospital stay for all patients was obtained via access and detailed review of hospital electronic medical records.

Inclusion criteria consisted of a diagnosis of AIS and an age between 10 and 20 at the time of surgery. Patients with non-idiopathic scoliosis were excluded from the study. All patients were treated with posterior spinal fusion and were discharged once they met the following three criteria: ability to ambulate and transfer independently, tolerance of solid and liquid oral intake, and adequate pain control with oral medications. Standard post-operative pain control for all patients in the study included use of three non-scheduled intravenous and oral opioids as needed as well as intermittent non-scheduled anti-inflammatory and anti-spasmodic medications.

In May 2011, patients began receiving a single dose of intraoperative ITM, administered by the operating surgeon. A 27-gauge needle was used to inject 6 μg/kg (patient weight) of preservative-free morphine sulphate (Hospira Inc. Lake Forest, IL) into the thecal sac at the most caudal interlaminar space included in the fusion construct. If the target interlaminar space was located at or cephalad to the L1–2 level, a wider laminotomy was created to ensure injection of the lateral thecal sac, avoiding direct injection of the spinal cord.

Length of stay (LOS, number of nights spent in the hospital) and total postoperative opioid analgesic medication (in morphine milligram equivalent, MME3) data were collected as primary outcomes. Age at surgery, gender, number of spinal levels fused, estimated intraoperative blood loss (EBL), preoperative Cobb angle, and any complications related to the use of ITM (i.e. severe allergic reaction, respiratory distress, or spinal headaches) were also collected for analysis.

A power analysis demonstrated that our study power is 0.8. Student’s t-test was used to compare continuous variables (age, number of spinal levels fused, Cobb angle, analgesic equivalence, and number of midnights in the hospital). Chi-square independent-sample tests were used to compare proportions for categorical variables. There were no missing subgroups or missing data. All tests were performed using SAS 9.4. Significance was determined using $\alpha = 0.05$.

RESULTS

Patients who were treated with ITM displayed shorter LOS [t(103)=7.5, p<0.0001] and reduced postoperative analgesic requirement [t(103)=6.1, p<0.0001]. Patients who received ITM spent an average of 1.8 fewer midnights in the hospital and received an average of 221.2 mg less compared to patients who did not receive intraoperative ITM (57% decrease) (Table 1).

There were no significant differences between the two groups for any other variable (gender, age, number of spinal levels fused, preoperative Cobb angle, EBL). One patient experienced a postoperative spinal headache that resolved after a week of bedrest. No other complications were reported.

<table>
<thead>
<tr>
<th>Variable</th>
<th>No ITM (n=40)</th>
<th>ITM (n=65)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PO Analgesic Equivalence (MME)</td>
<td>388.4 ± 195.2</td>
<td>167.2 ± 106.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Number Of Midnights In Hospital</td>
<td>6.0 ± 2.0</td>
<td>4.2 ± 1.1</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>
DISCUSSION

Previous studies of ITM use in spine surgery have shown ITM to be an effective method for managing pain and reducing side effects postoperatively for PSF patients recovering from surgery. Milbrandt et al. compared three methods of pain control in PSF for AIS and determined a preoperative ITM injection provides equal pain control for the first 24 hours to patient controlled analgesia and epidural catheter infusion (EPI) in addition to reducing the occurrence of adverse events. In a retrospective study by Poe-Kochert et al., the authors concluded that continuous ITM use during PSF for patients with idiopathic scoliosis (IS) was a safe and effective method of postoperative pain control. Another study found that the optimal postoperative dosage of ITM for PSF in IS patients was 9-19 μg/kg and that the incidence of adverse events increased with higher dosage past this range. In a systematic review and meta-analysis of 645 surgical patients who received ITM in either an abdominal, cardio-thoracic, or spine procedure, Meylan et al. found ITM decreases pain intensity up to 24 hours postoperatively. Despite these positive findings regarding the introduction of ITM into the pre, intra, or postoperative spine procedure, routine use of ITM is still not standard practice in many centers.

Additional studies of ITM use in spine surgery have found that the administration of ITM is associated with a reduction in postoperative opioid requirements as well as EBL. Eschertzhuber et al. determined through a prospective, randomized, single-blinded study of AIS patients undergoing PSF, which compared high-dose and low-dose ITM that high-dose ITM resulted in both reduced EBL and postoperative opioid requirements. A retrospective cohort study of 256 pediatric IS cases by Lesniak, Tremblay, et al. found ITM was associated with a 20% reduction in EBL, and increased intraoperative hemodynamic stability. Another retrospective chart review done by Ibach et al. explored the effect of ITM in pediatric PSF cases for IS and found ITM improved analgesia for at least 12 hours following surgery.

Other studies evaluating the use of EPIs placed during scoliosis surgery have found an EPI reduces pain for the longest duration of time postoperatively while also allowing for quicker return to solid food consumption. Ravish et al. found an ITM/EPI combination was a safe and effective method of pain management in AIS patients undergoing a PSF, and the ITM/EPI combination significantly reduced pain, lowering total opioid use. Another study found there was no significant difference between the use of an EPI or ITM in IS patients undergoing PSF.

This study confirms the previous findings that routine utilization of intraoperative ITM safely reduces postoperative opioid use and is the first study to demonstrate a clear statistically significant association between ITM and reduced length of hospital stay after AIS surgery. Immediate and dramatic improvements in postoperative pain levels were noted following implementation of the new surgical protocol. Patients were able to mobilize independently and obtain adequate pain control earlier in the postoperative course with diminished opioid-induced lethargy and ileus. These results were achieved with a relatively low dose of ITM, six micrograms per kilogram of body weight, and no other changes were made in the perioperative pain regimen. The use of ITM was associated with a nearly two-day decrease in average LOS and a fifty-seven percent decrease in average postoperative narcotic consumption. No major complications were identified with use of ITM. One patient developed a spinal headache, but it resolved over the course of a week with non-surgical management.

In conclusion, the intraoperative administration of ITM is a simple and effective method for scoliosis surgeons to better control postoperative pain in their AIS patients and achieve earlier discharge from the hospital. ITM introduction leads to a decrease in opioid exposure for patients, possibly reducing the likelihood of developing dependence postoperatively. Patients, hospitals, and insurance companies benefit from the routine use of ITM as reduced LOS reduces the cost of care for any patient and care center. Based on the results of this study and several other previously published studies, we recommend that scoliosis surgeons consider incorporating use of ITM into their standard operative protocols.

REFERENCES


THE IMPACT OF ISOLATED BASELINE CANNABIS USE ON OUTCOMES FOLLOWING THORACOLUMBAR SPINAL FUSION: A PROPENSITY SCORE-MATCHED ANALYSIS

Neil V. Shah, MD, MS; Joshua D. Lavian, BS; Cameron R. Moattari, BS; Hassan Eldib, BS; George A. Beyer, MD, MS; David H. Mai, MD, MPH; Vincent Challier, MD; Peter G. Passias, MD; Renaud Lafage, MSc; Virginie Lafage, PhD; Frank J. Schwab, MD; Carl B. Paulino, MD; Bassel G. Diebo, MD

ABSTRACT

Background: There is limited literature evaluating the impact of isolated cannabis use on outcomes for patients following spinal surgery. This study sought to compare 90-day complication, 90-day readmission, as well as 2-year revision rates between baseline cannabis users and non-users following thoracolumbar spinal fusion (TLF) for adult spinal deformity (ASD).

Methods: The New York Statewide Planning and Research Cooperative System (SPARCS) database was queried between January 2009 and September 2013 to identify all patients who underwent TLF for ASD. Inclusion criteria were age ≥18 years and either minimum 90-day (for complications and readmissions) or 2-year (for revisions) follow-up surveillance. Cohorts were created and propensity score-matched based on presence or absence of isolated baseline cannabis use. Baseline demographics, hospital-related parameters, 90-day complications and readmissions, and two-year revisions were retrieved. Multivariate binary stepwise logistic regression identified independent outcome predictors.

Results: 704 patients were identified (n=352 each), with comparable age, sex, race, primary insurance, Charlson/Deyo scores, surgical approach, and levels fused between cohorts (all, p>0.05). Cannabis users (versus non-users) incurred lower 90-day overall and medical complication rates (2.4% vs. 4.8%, p=0.013; 2.0% vs. 4.1%, p=0.018). Cohorts had otherwise comparable complication, revision, and readmission rates (p>0.05). Baseline cannabis use was associated with a lower risk of 90-day medical complications (OR=0.47, p=0.005). Isolated baseline cannabis use was not associated with 90-day surgical complications and readmissions, or two-year revisions.

Conclusion: Isolated baseline cannabis use, in the absence of any other diagnosed substance abuse disorders, was not associated with increased odds of 90-day surgical complications or readmissions or two-year revisions, though its use was associated with reduced odds of 90-day medical complications when compared to non-users undergoing TLF for ASD. Further investigations are warranted to identify the physiologic mechanisms underlying these findings.

Level of Evidence: III

Keywords: cannabis, thoracolumbar fusion, spine, adult spinal deformity, substance use, outcomes, marijuana

INTRODUCTION

Cannabis is the third most commonly used recreational substance in the United States (US), following alcohol and tobacco.¹ As of May 2021, 36 states and four territories have medical marijuana programs, with

INTRODUCTION

Cannabis is the third most commonly used recreational substance in the United States (US), following alcohol and tobacco.¹ As of May 2021, 36 states and four territories have medical marijuana programs, with...
18 states having legalized it for nonmedical use. This wider acceptance of cannabis at the statewide level may reflect its use as a recreational or therapeutic drug. In 2018, there were 11.8 million estimated young adults who had used cannabis in the past year.2 The increasing acceptance of cannabis as a medical therapy has led to an expanding list of prescribed indications, including sleep cycle dysrhythmias, chemotherapy-induced nausea and vomiting, chronic pain, and multiple sclerosis.3 While its efficacy has been demonstrated for these applications, chronic adverse events have also been described, including increased risks of stroke and cardiovascular accidents.4,7

Adult spinal deformity (ASD) is classified as a spectrum of disorders that present in late adolescence or adulthood, and include adult spinal scoliosis, iatrogenic spinal deformity, and primary degenerative sagittal imbalance.8 With increasing life expectancies, the prevalence of ASD is rising, and more surgical corrections are expected to occur.9 Although risk factors such as smoking and hypertension are known to increase rates of infection, neurological, and cardiopulmonary complications, very few studies describe potential perioperative ramifications of cannabis in this orthopaedic patient population.10 Recently, one study of patients undergoing common orthopaedic procedures identified an association between cannabis use and decreased risk of postoperative mortality. However, it also showed an increased risk of certain morbidities (e.g. cardiac disease, stroke, and heart failure).11 Similarly, other studies found that cannabis use was associated with increased perioperative risk of myocardial infarction, thromboembolism, neurologic complications, respiratory complications, and sepsis.12,13 Best et al.14 observed a high prevalence of cannabis consumption among total joint arthroplasty patients and described associated postoperative complications of polysubstance misuse. Others report associated cannabis use with lower bone mineral density and increased fracture risk.14,15 However, some patients with musculoskeletal injuries have endorsed cannabis in conjunction with their postoperative care as a potentially effective analgesic.16 There is much still unknown and debated about the post-surgical effects of cannabis in patients undergoing orthopaedic procedures.

With shifting public sentiment, expanding decriminalization, and a lack of objective data on the potential consequences of cannabis use, it is imperative to identify how baseline cannabis use impacts postoperative outcomes of patients with adult spinal deformity (ASD) undergoing thoracolumbar fusion (TLF). This study sought to compare demographics, hospital-related parameters, 90-day complications, 90-day readmissions, and revision surgery between isolated baseline cannabis users and non-users in such circumstances.

**METHODS**

**Study Design**

This was a retrospective cohort study using propensity score-matched patients from a large, all-payer, statewide database. Due to the deidentified nature of the data, this study was deemed to be exempt by the IRB and no informed consent was needed given the deidentified nature of the data queried.

**Data Source**

Data was extracted from the New York State Statewide Planning and Research Cooperative System (SPARCS) database. SPARCS is a comprehensive, statewide database reporting system that tracks and collects de-identified patient characteristics, diagnoses, treatments, services, and charges for all inpatient and outpatient visits at Article 28 licensed hospitals in New York State. All patients are assigned a distinct tracking identification number, and patient data can be readily extracted and analyzed across multiple admissions. Diagnostic and procedural data are classified according to the International Classification of Diseases, 9th revision, Clinical Modifications (ICD-9-CM).

**Patient Population**

All patients aged ≥18 years with ASD who underwent TLF surgery of two or more vertebral levels from January 2009 to September 2013 were identified by ICD-9-CM codes (81.00, 81.04, 81.05, 81.06, 81.07, 81.08, 81.30, 81.34, 81.35, 81.36, 81.37, 81.38, 81.62, 81.63, 81.64). ASD was defined using an established set of ICD-9-CM codes (idiopathic scoliosis [737.30, 737.32] or degenerative disc disease [737.10, 737.20, 756.19, 754.2, 737.19, and 737.29]).17,18 Subjects were only included for analysis if they had 90-day surveillance for complications and all-cause readmissions as well as minimum two-year follow-up surveillance for revision surgery. Within this cohort, any patient with an ICD-9-CM code of nondependent or dependent cannabis use prior to and/or including the day of their primary TLF surgery was categorized as an isolated baseline cannabis user (304.30, 304.31, 304.32, 305.20, 305.21, and 305.22). Patients ≥18 years of age undergoing ≥2-level TLF with absent history of cannabis use were also identified.

**Exclusion Criteria**

Patients were excluded for any of the following conditions or pathologies: rheumatoid arthritis, osteomyelitis, traumatic fracture, pathologic fracture, any type of cancer or metastasis, Charcot-Marie-Tooth disease, mucopolysaccharidosis, osteitis deformans, fibrosa cystica, osteoporosis, poliomyelitis, rickets, Pott’s disease, tuberculosis, recognized scoliotic conditions of spina bifida/myelomeningocele, neurofibromatosis, cerebral
palsy, Prader-Willi syndrome, Marfan syndrome, or any congenital musculoskeletal disease. They were also excluded if they had a co-diagnosis of another substance or poly-substance dependence/abuse (alcohol, cocaine, barbiturates, opioids, amphetamines, hallucinogens, antidepressants, and mixed/other substances) and if they did not meet follow-up surveillance criteria.

**Data Collection**

Extracted data included patient demographics and baseline factors (age, sex, race, Charlson/Deyo score, and primary insurance), hospital-related parameters (length of stay, hospital charges), surgical approach and number of levels fused, rates of 90-day complications (individual and overall medical and surgical complications, and overall complications), 90-day all-cause readmissions, and subsequent revisions with at least two-year follow-up surveillance.

**Statistical Analysis**

Cannabis users were 1:1 propensity score-matched to individuals undergoing the same index TLF procedure without a baseline diagnosis of cannabis use by age, sex, race, primary insurance, Charlson/Deyo score, number of fused spinal levels, fusion approach, and history of tobacco use. Multivariate binary stepwise logistic regression models were then performed to identify independent predictors of postoperative outcomes (covariates: cannabis use, age, sex, race, primary insurance, Charlson/Deyo score, number of levels fused, fusion approach, and tobacco use history). All analysis was performed using SPSS® version 24.0 (IBM Corp., Armonk, NY, USA). A p-value < 0.05 was considered statistically significant.

**RESULTS**

A total of 704 propensity score-matched patients were included in this study, with 352 patients in each of the Cannabis and Non-Cannabis groups. No significant differences were identified between the two patient groups according to their age, sex, race, primary method of payment, Charlson/Deyo scores, surgical approaches, and number of levels fused (p>0.160) (Table 1).

Cannabis users exhibited comparable individual 90-day medical complications when compared to non-cannabis users, including cardiac complications, infection, acute respiratory distress syndrome, and pneumonia (Table 2). However, Cannabis users experienced lower rates of overall 90-day medical complications than Non-Cannabis users (2.0% vs. 4.1%, p=0.018). The Cannabis and Non-Cannabis cohorts had comparable individual and overall 90-day surgical complications (p=0.317). Overall complication rates were higher among Non-Cannabis compared to cannabis users (4.8% vs. 2.4%, p=0.013). 90-day readmissions and two-year revision rates were similar between cohorts (p=0.157).

Regression analysis revealed that baseline cannabis use was not associated with an increase in odds of incurring 90-day surgical complications, 90-day readmissions, or two-year revisions. Baseline cannabis use was observed to be negatively associated with 90-day medical complications (OR=0.5, 95% CI: 0.3–0.8, p=0.005).

| Table 1. A Summary of The Differences in Patient Demographics, Operative Parameters, and Hospital-Related Parameters Representation Between a 1:1 Propensity Score-Matched Cohort of Non-Cannabis and Cannabis Users Who Underwent Thoracolumbar Fusion For Adult Spinal Deformity |
|-------------------|------------------|-----------------|-----------------|-------------------|-----------------|
|                  | Non-Cannabis | Cannabis | p-value |
| n                 | 352         | 352       | –      |
| Age (years)       | 42.6 ± 12.6 | 42.7 ± 12.1 | 0.895  |
| Charlson/Deyo Score | 0.1 ± 0.4 | 0.1 ± 0.4 | 0.686  |
| Approach          |             |           | 0.663  |
| Anterior          | 6.8%       | 7.7%      |        |
| Posterior         | 91.2%      | 92.3%     |        |
| Number of Levels Fused |      |           | 0.583  |
| 2 or 3            | 85.2%      | 85.8%     |        |
| 4 to 8            | 11.9%      | 11.6%     |        |
| ≥9                | 2.8%       | 2.6%      |        |
| Sex               |             |           | 0.936  |
| Male              | 68.2%      | 67.9%     |        |
| Female            | 31.8%      | 32.1%     |        |
| Race              |             |           | 0.785  |
| White             | 61.8%      | 61.9%     |        |
| Black             | 20.2%      | 19.9%     |        |
| Hispanic          | 9.4%       | 10.2%     |        |
| Asian or Pacific Islander | 0.6% | 0.6% | |
| Native American   | 0.0%       | 0.6%      |        |
| Other             | 8.0%       | 6.8%      |        |
| Primary Insurance |             |           | 0.160  |
| Medicare          | 27.8%      | 27.6%     |        |
| Medicaid          | 7.5%       | 11.3%     |        |
| Private Insurance | 47.4%      | 40.6%     |        |
| Self-Pay          | 1.1%       | 2.3%      |        |
| No Charge         | 0.0%       | 0.0%      |        |
| Other             | 16.2%      | 18.2%     |        |
| History of Smoking | 13.9%  | 15.3%     | 0.594  |
| Total Charges (US dollars) | $82,135 | $78,492 | 0.454 |
| Length of Stay (days) | 4.2 ± 4.0 | 4.3 ± 4.8 | 0.730 |

*Volume 42 Issue 1* 59
DISCUSSION

As the favorable perception of cannabis use continues to grow and more states in the US pass decriminalizing legislation, the prevalence of cannabis usage is expected to increase. With an expanding pool of individuals with ASD and a persistent debate about the effect of cannabis in neuropathic pain management, it is essential to investigate the cannabis use and its potential effects on surgical outcomes. This study focused on the impact of isolated baseline cannabis use on patients who underwent thoracolumbar spinal fusion. This study found that cannabis use was negatively associated with 90-day medical complications. This is consistent with a previous study, by Moon et al., that noted an associated decrease in mortality among cannabis users undergoing common orthopaedic procedures. Another study, by Nguyen et al., involving traumatic brain injury patients found that cannabis users had reduced odds of death than non-users. These findings are also corroborated by Singer et al., who reported on an intensive care unit (ICU) analysis of trauma patients, demonstrating lower mortality rates among cannabis users compared to non-users. However, this is not consistent with a study by Jakoi et al., that showed no significant differences in complications between cannabis users and non-users undergoing lumbar spinal fusion, however this study was performed with only 102 patients from a single surgeon.

The present study found that isolated baseline cannabis users undergoing TLF had lower 90-day medical and total complication rates than non-cannabis users. This differs from the results of the previous literature, which observed an association between cannabis use and cerebrovascular as well as cardiovascular diseases. In contrast to these studies, this investigation excluded patients with multi- or poly-substance use from the analysis, potentially explaining the disparity in results observed by the removal of possibly confounding substance use outside of cannabis. This approach is particularly important, as highlighted by a study by Best et al., in which, poly-substance-consuming patients undergoing TKA and THA had higher rates of surgery-related complications, including acute infection and anemia compared to non-users. The current study did not reveal difference in surgical complications between the two cohorts.

The cohorts in the present study demonstrated lower readmission rates when compared to the spine literature. A recent meta-analysis looking at 30-day readmission rates of spine surgeries found that single institutions reported the highest 30-day readmission rate at 6.6%, while multicenter studies reported the lowest at 4.7%. Overall rates ranged between 4.2% and 7.4%. Bajaj et al. reported a 24.8% 90-day readmission rate for patients who underwent lumbar spinal fusion using the same data source (SPARCS) between 2005 and 2014. The discrepancies between these findings may be attributed to the stringent exclusion criteria for the patient cohort, strictly excluding patients with poly-substance use disorder patients and those with a variety of systemic comorbidities.

This study was not without limitations. As a retrospective review of a single statewide database, there is information associated with cannabis use that is not present in the database. For example, the purpose of cannabis use (medical versus recreational), cumulative exposure, and administration routes (inhalation,
vaporization, ingestion, etc.) all could contribute to outcomes. Ultimately, such parameters would have allowed a more comprehensive assessment of isolated baseline cannabis use and further characterization of respective TLF patients. With the onset of the ICD-10-CM coding system giving providers broader diagnoses of cannabis use disorders, patients may be better stratified in future studies. Given the legal status of cannabis at the time this data was recorded, cannabis use was likely underreported and the percentage of users was likely higher than reported in this study. As such, the full spectrum of users may not entirely be represented by the study sample herein. The sample size (n=352 per cohort) stemmed in part from the exclusion of patients with any other documented drug use. Tobacco users were not part of the exclusion criteria, as this would have eliminated a large proportion of patients, and was instead controlled for in the propensity score-matching.

CONCLUSION

Compared to patients with ASD who underwent TLF without baseline cannabis use, patients with isolated baseline cannabis use were found to have no increase in odds of incurring 90-day surgical complications or readmissions or revisions two years postoperatively, though reduced odds of experiencing 90-day medical complications were observed. Future prospective, randomized-controlled studies could help further characterize the impact of isolated cannabis use on the postoperative course of surgical patients undergoing complex procedures such as thoracolumbar fusion for adult spinal deformity.

REFERENCES


ABSTRACT

Background: Patients with psychiatric comorbidities represent a significant subset of those sustaining pilon fractures. The purpose of this study is to examine the association of psychiatric comorbidities (PC) in patients with pilon fractures and clinical outcomes.

Methods: A multi-institutional, retrospective review was conducted. Inclusion/exclusion criteria were skeletally mature patients with a tibia pilon fracture (OTA Type 43B/C) who underwent definitive fracture fixation utilizing open reduction internal fixation (ORIF) with a minimum of 24 weeks of follow-up. Patients were stratified into two groups for comparison: PC group and no PC group.

Results: There were 103 patients with pilon fractures that met the inclusion/exclusion criteria of this study. Of these patients, 22 (21.4%) had at least one psychiatric comorbidity (PC) and 81 (78.6%) did not have psychiatric comorbidities (no PC). There was a higher percentage of female patients (PC: 59.1% vs no PC: 25.9%, p=0.005), smokers (PC: 40.9% vs no PC: 16.0%, p=0.02), and drug users (PC: 22.7% vs no PC: 8.6%, p=0.08) amongst PC patients. Fracture comminution (PC: 54.5% vs no PC: 32.1%, p=0.05) occurred more frequently in PC patients. The PC group had a higher incidence of weightbearing noncompliance (22.7% vs 7.5%, p=0.04) and reoperation (PC: 54.5% vs no PC: 29.6%, p=0.03).

Conclusion: Patients with psychiatric comorbidities represent a significant percentage of pilon fracture patients and appear to be at higher risk for postoperative complication. Risk factors that may predispose patients in the PC group include smoking/substance use, weightbearing noncompliance, and fracture comminution.

Level of Evidence: III

Keywords: mental illness, psychiatric, orif, pilon, complication

INTRODUCTION

Representing <10% of all tibial fractures, pilon fractures occur most frequently in males and have bimodal peaks of incidence from ages 20 to 30 and 50 to 60.1 They tend to occur secondary to both high (impaction) and low (rotational) energy mechanisms of injury. Concurrent fibular and soft tissue trauma can also be seen in these patients and are signs of the energy imparted to the limb. Surgical treatment of these fractures may be difficult, and outcomes remain poor.23

Existing studies have identified the prevalence of psychiatric illness in orthopaedic trauma patients and an association with poor postoperative outcomes after orthopaedic surgery.4-14 A study using thousands of Humana and Medicare patients found significantly higher rates of readmission, revision, and complication after treatment of pilon fractures in patients with pre-existing mental health conditions.4 This study lacked details regarding injury mechanism, AO/OTA fracture type, soft tissue status, type of operative fracture management, development of complications beyond the 90 days postoperative period, and non-fusion revisions.

Acknowledging this patient population’s predisposition for poor outcomes, we aim to offer greater insight into the effects of psychiatric comorbidities (PC) on patients with pilon fractures through a retrospective, multi-institutional cohort study. We hypothesize that patients with psychiatric comorbidities have worse outcomes because of higher rates of tobacco/substance use, more severe initial injury, and greater weightbearing noncompliance.

METHODS

A retrospective chart review of pilon fractures treated with open reduction internal fixation (ORIF) was conducted at three large urban academic institutions with...
level I trauma centers between 2012 and 2020. Skeletally immature patients and patients with fewer than 24 weeks of follow-up were excluded from evaluation of outcome measures.

Psychiatric comorbidities were identified through reviewing the electronic medical record for documented DSM-5 diagnoses including major depressive disorder, generalized anxiety disorder, panic disorder, schizophrenia, schizoaffective disorder, and bipolar disorder on or before the admission on which the patient presented with a pilon fracture.

Patient demographics included patient age, sex, body mass index (BMI), smoking status (within one year of surgery), diabetes mellitus, and Charlson Comorbidity Index (CCI).

Injury-specific information gathered included mechanism, AO/OTA classification, comminution (AO/OTA B3/ C3), soft tissue status as classified by the system of Gustilo et al.15 and concurrent fibula fracture.

Surgical details including the frequency of staged external fixation (ex fix), time between injury and ex fix, time between ex fix and ORIF, time between injury and ORIF, operative time (in minutes) were obtained.

Early weightbearing was documented in cases when providers noted patients did not follow recommended weightbearing restrictions in the electronic medical record. Follow-up times were determined by evaluating the number of days between date of ORIF and the date of a patient’s last follow-up.

Primary outcomes were unplanned reoperation, infection requiring antibiotics, irrigation and debridement (I&D) in the operating room, nonunion, revision, and implant removal.

A comparison between demographics, injury characteristics, and outcomes in patients with psychiatric comorbidities and no psychiatric comorbidities was completed.

SPSS V28 was used for all statistical analysis. Fischer’s exact test and chi-squared test were used for categorical variables. Kolmogorov-Smirnov test for normality was conducted. For normally distributed variables, an independent-samples t-test was conducted. For non-normally distributed samples, a Mann-Whitney U test was used. The threshold for statistical significance was 0.05. When applicable, standard deviations were reported parenthetically following means in the same units.

RESULTS

There were 103 skeletally mature patients with pilon fractures (OTA types 43B/C) that met the inclusion/exclusion criteria of this study. Of these patients, 22 (21.4%) had at least one psychiatric comorbidity (PC) and 81 (78.6%) did not have psychiatric comorbidities (no PC). The prevalence of specific psychiatric diagnoses in the PC group was as follows: depression (41.9%), anxiety (25.8%), bipolar disorder (16.1%), schizophrenia (12.9%), and schizoaffective disorder (3.2%). There was a significantly higher percentage of female patients comprising the PC group relative to the no PC group (females: 59.1% vs 29.7%, p=0.003). There was also a higher rate of smoking (PC: 40.9% vs no PC: 16.0%, p=0.02) and illicit drug use (PC: 22.7% vs no PC 8.6%, p=0.08) in the PC group, though only the difference in smoking attained statistical significance. A comparison of all demographics can be found in Table 1.

The leading cause of pilon fracture in both groups was fall (PC: 63.6% vs no PC: 56.3%) and car accident (PC: 18.2% vs no PC: 17.5%). There was a higher incidence of comminuted fractures in the PC group (PC: 54.5% vs no PC: 32.1%, p=0.05). External fixator was not significantly different between groups (PC: 86.4% vs no PC: 72.8, p=0.19). There was no difference in the incidence of open tibia fractures or concurrent fibula fractures sustained by the two groups. Injury characteristics can be found in Table 2.

Operative time skewed longer on average in the PC group (241.3 minutes [SD: 84.2]) than the no PC group (217.2 minutes [SD: 102.6]); this difference was not

<table>
<thead>
<tr>
<th>N</th>
<th>PC</th>
<th>No PC</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>46.4 (9.5)</td>
<td>42.9 (13.5)</td>
<td>0.27</td>
</tr>
<tr>
<td>BMI</td>
<td>31.2 (8.4)</td>
<td>29.7 (7.2)</td>
<td>0.41</td>
</tr>
<tr>
<td>Sex (% F)</td>
<td>59.1</td>
<td>25.9</td>
<td>0.005</td>
</tr>
<tr>
<td>Smoking (%)</td>
<td>40.9</td>
<td>16</td>
<td>0.02</td>
</tr>
<tr>
<td>Illicit Drug Use (%)</td>
<td>22.7</td>
<td>8.6</td>
<td>0.08</td>
</tr>
<tr>
<td>DM (%)</td>
<td>14.3</td>
<td>7.6</td>
<td>0.39</td>
</tr>
<tr>
<td>CCI (%)</td>
<td></td>
<td></td>
<td>0.46</td>
</tr>
</tbody>
</table>

Table 1. A Comparison of Demographics Between Patients With Psychiatric Comorbidities (PC) and Patients With No Psychiatric Comorbidities (No PC)

Standard deviation reported in parenthesis after mean values. Abbreviations: Diabetes Mellitus (DM), Charlson Comorbidity Index (CCI)
Is Psychiatric Illness Associated with Worse Outcomes Following Pilon Fracture?

There was no statistical difference in bone graft use between groups (PC: 45.5% vs no PC: 35.8%, p=0.41).

In this dataset, 22.7% of PC patients were noncompliant with weightbearing restrictions relative to 7.5% of no PC patients (p=0.04). There was a mean follow-up of 83.6 weeks (SD: 59.2) in the PC group and 49.7 weeks (SD: 48.2) in the no PC group (p=0.2).

Table 2. Injury Characteristics Compared Between Patients With Psychiatric Comorbidities (PC) and Patients With No Psychiatric Comorbidities (No PC)

<table>
<thead>
<tr>
<th>Mechanism of Injury (%)</th>
<th>PC</th>
<th>No PC</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanism of Injury (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>63.6</td>
<td>56.3</td>
<td>0.66</td>
</tr>
<tr>
<td>Car accident</td>
<td>18.2</td>
<td>17.5</td>
<td></td>
</tr>
<tr>
<td>Motorcycle accident</td>
<td>9.1</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>Struck by car</td>
<td>9.1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Gunshot wound</td>
<td>0</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Assault</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Object dropped on leg</td>
<td>0</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Sports</td>
<td>0</td>
<td>11.3</td>
<td></td>
</tr>
<tr>
<td>Mean height of fall from height (in feet) [n=9, 24]</td>
<td>18.3 (15.1)</td>
<td>10.7 (7.7)</td>
<td>0.15</td>
</tr>
<tr>
<td>Fell in Suicide Attempt (%)</td>
<td>9.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AO Classification (%)</td>
<td></td>
<td></td>
<td>0.18</td>
</tr>
<tr>
<td>B1</td>
<td>9.1</td>
<td>13.6</td>
<td></td>
</tr>
<tr>
<td>B2</td>
<td>9.1</td>
<td>25.9</td>
<td></td>
</tr>
<tr>
<td>B3</td>
<td>9.1</td>
<td>12.3</td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>4.5</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>22.7</td>
<td>19.8</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>45.5</td>
<td>19.8</td>
<td></td>
</tr>
<tr>
<td>Open Fx (%)</td>
<td>22.7</td>
<td>28.4</td>
<td>0.41</td>
</tr>
<tr>
<td>Gustilo Classification (%)</td>
<td></td>
<td></td>
<td>0.37</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>18.2</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>IIIA</td>
<td>4.5</td>
<td>9.9</td>
<td></td>
</tr>
<tr>
<td>IIIIB</td>
<td>0</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>IIIIC</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Comminuted (%)</td>
<td>54.5</td>
<td>32.1</td>
<td>0.05</td>
</tr>
<tr>
<td>Fibula Fx (%)</td>
<td>72.7</td>
<td>64.2</td>
<td>0.46</td>
</tr>
<tr>
<td>Ex Fix (%)</td>
<td>86.4</td>
<td>72.8</td>
<td>0.19</td>
</tr>
</tbody>
</table>

...statistically significant (0.32%). There was no statistical difference in bone graft use between groups (PC: 45.5 vs no PC 35.8%, p=0.41).

In this dataset, 22.7% of PC patients were noncompliant with weightbearing restrictions relative to 7.5% of no PC patients (p=0.04). There was a mean follow-up of 83.6 weeks (SD: 59.2) in the PC group and 49.7 weeks (SD: 48.2) in the no PC group (p=0.2).

The PC group had more frequent complications, with differences in reoperation (PC: 54.5% vs no PC: 29.6%, p=0.03), infection (PC: 27.3% vs no PC: 9.9%, p=0.04), nonunion (PC: 27.3% vs no PC: 8.6%, p=0.03), and implant removal (PC: 45.5% vs no PC: 24.7%, p=0.05) achieving statistical significance. There was no significant difference in oral antibiotic use (PC: 13.6% vs. no PC: 6.2%, p=0.25) and revision rates (PC: 27.3% vs no PC: 16.3%), although these adverse events did occur more frequently in the PC group.

DISCUSSION

Patients with psychiatric comorbidities represented a significant proportion (20%) of all pilon fracture patients. The patients in the PC group had higher grade injury characteristics and poorer outcomes relative to patients without psychiatric comorbidities, though these differences did not always reach statistical significance.

There was a considerably higher percentage of female patients in the PC group. Amongst the top three most prevalent psychiatric conditions within our dataset, depressive and anxiety disorders are described by epidemiologic research as effecting a greater proportion of women, while bipolar disorder affects men and women at similar rates. Another potential explanation for the difference in sex between groups is that many falls from height in men were a result of construction or handy work. These work and hobby related injuries contributed to the incidence of pilon fractures in many male patients without psychiatric comorbidities. The combination of these factors may have driven the rate of female sex in the PC group higher relative to the no PC group.

Smoking is a known risk factor for complication following fracture fixation. The higher rate of active smokers in the psychiatric comorbidity group suggests that this patient population may benefit from additional attention regarding smoking cessation in the perioperative period.

Noncompliance with smoking was not documented in this study due to inconsistent reporting, but the sheer number of active smokers in the PC group at the time of injury suggests that this factor could have contributed to the higher rate of nonunions in these patients.

Illicit drug use can also be a risk factor for complication after fracture fixation. The pathophysiologic effects of drug use depend on the drug used and the method of use. There was a trend towards a higher rate of illicit substance use patients with psychiatric. More details would be necessary to better evaluate this factor’s effects on complication rates. Intravenous drug use, which was inconsistently reported but at least two PC patients had a reported history of, may have contributed to this group’s higher infection rate.
The higher rate of fracture comminution in the PC group may be attributable to higher energy mechanisms of injury experienced by PC patients.\textsuperscript{23,24} Falling was the most frequent cause of injury in both groups, albeit more frequently a cause of pilon fracture in the PC group. Patients with psychiatric comorbidities also skewed towards having more motorcycle/motor vehicle accidents and being hit by motor vehicles more frequently. On the whole, the PC group appeared to have higher energy mechanisms of injury, which may help explain their higher rate of fracture comminution.

The higher rate of weightbearing noncompliance in the PC group was associated with at least two cases of broken implants and consequent revision in the PC group. Assessment of a patient’s insight into their injury, plan for mobility in light of lessened or lost weightbearing of the affected limb, and the repercussions of early weightbearing may be useful in identifying patients needing additional counselling or support.\textsuperscript{25} Haptic feedback or electronic messaging reminders upon unpermitted weightbearing could also be helpful in reinforcing weightbearing restrictions.\textsuperscript{26,27} Additionally, in patients with treatment resistant psychiatric disease that may impede their capacity to consent to surgery or follow postoperative restrictions, methods of fracture fixation less reliant on weightbearing restrictions for success such as circular external fixation and arthrodesis could be explored to lower complication rates.\textsuperscript{25,28,29} An objective method of measuring weightbearing noncompliance, such as a pressure-sensitive film or sensor, would also likely provide more accurate rates of weightbearing noncompliance between patients with and without psychiatric comorbidities than those offered by this study.\textsuperscript{30}

Patients in the PC group had higher rates of complications than patients in the no PC group. Existing literature has shown higher rates of readmission, reoperation, and complicity in patients with psychiatric comorbidities that suffer pilon fractures at short-term follow-up.\textsuperscript{4} Our study also showed this trend, with reoperations occurring twice as frequently in patients with psychiatric illness at an average follow-up of one year after surgery. Taken together, the findings of our study and the study that precedes it suggest patients with psychiatric comorbidities have worse postoperative outcomes after pilon fracture ORIF.

This study is meant to emphasize that psychiatric disease is an important, potentially neglected determinant of orthopaedic outcomes after pilon fractures. As highlighted by Weinberg et al., patients with psychiatric comorbidities are less likely to receive their psychiatric medication and relevant follow-up instructions when managed by orthopaedic trauma services.\textsuperscript{9} Orthopaedic surgeons should be aware of the prevalence of psychiatric comorbidities in trauma patients and make plans of care that consider a patient’s psychiatric disease. Consulting an inpatient psychiatric team or a patient’s own psychiatric provider in the preoperative period may also prove efficacious in improving acute psychiatric management and long-term psychiatric follow-up.\textsuperscript{31,32} It is our hope that these collaborative efforts will, in turn, improve orthopaedic outcomes in this patient subset.

Given our study’s retrospective design, patient outcome reporting and follow-up was not standardized. To mitigate this, patients with incomplete data or lost to follow-up sooner than 24 weeks were excluded. The rate of psychiatric illness in our dataset should also be considered a minimum rather than a true rate of psychiatric comorbidities amongst all pilon fracture patients, given the potential for inconsistent reporting of patient psychiatric histories after orthopaedic trauma.\textsuperscript{31} We limited our analysis to only a handful of commonly encountered and consistently reported psychiatric diseases in clinical practice and grouped them together into a “psychiatric comorbidity” cohort. We also lacked the information necessary to distinguish between well managed and poorly managed psychiatric disease. Future studies may benefit from stratifying outcomes by psychiatric diagnosis and the addition of objective severity scores for a given psychiatric comorbidity.\textsuperscript{34}

In conclusion, a considerable proportion of patients with pilon fractures had psychiatric comorbidities, and we saw differences in the presentation and outcomes of these patients. Identification of modifiable and non-modifiable psychiatric conditions in patients presenting with severe pilon fractures is critical. It is important for physicians taking on surgical care of this injury pattern and it is important for the patient, family, or caregivers to understand the higher risk and complication profile associated with these comorbidities. Formal clinical pathways that prompt cross-departmental collaboration between orthopedic surgeons and mental health professionals is not only good medicine but warrants further study to potentially improve inpatient management and postoperative outcomes of these patients.

ACKNOWLEDGEMENT

This study was supported by an unrestricted grant from the Doren Family Foundation.

REFERENCES


ABSTRACT

Background: Femoral fragility fractures are one of the most common injuries managed by orthopedic surgeons. Malnutrition influences the poor outcomes observed in this population. Our purpose was to assess the annual trends of malnutrition diagnosis and determine risk factors for malnutrition and complications in patients 65 years and older presenting with femoral fragility fractures. We hypothesized that malnutrition would increase the risk of postoperative wound infection, wound dehiscence, non-union, and mortality.

Methods: The PearlDiver database was reviewed from 2010 to 2020. Patients ≥ 65-years-old with femur fractures treated with operative fixation were identified by CPT code. A preoperative diagnosis of malnourished state was defined by ICD-9 and ICD-10 codes and patients were divided into malnourished and non-malnourished cohorts. Patients were tracked for one year following operative fixation of a femoral fragility fracture for the occurrence of infection, wound dehiscence, nonunion and mortality. The rates of these complications were compared between malnourished and non-malnourished cohorts.

Results: There were 178,283 total femoral fragility fractures identified in patients aged 65-years or older. The overall prevalence of malnutrition diagnosis in this geriatric population was 12.8%. Documented malnutrition in femoral fragility fractures increased from 1.6% to 32.9% from 2010-2020 (P<0.0001). Compared to patients without malnutrition, patients with malnutrition are at increased risk of mortality (OR 1.31, 95% CI 1.258 – 1.3752, p < 0.0001), are more likely to develop a wound infection (OR 1.49; 95% CI 1.3416 – 1.7949; p < 0.0001), and more likely to develop non-union (1.89; 95% CI 1.6946 – 2.1095; p < 0.0001). Multiple demographic variables were associated with malnutrition diagnosis including higher age, higher Charlson Comorbidity Index, female sex, dementia, and institutionalization. Parkinson’s disease, feeding difficulty and institutionalization demographic variables had the highest risk of malnutrition.

Conclusion: The current study found that malnutrition diagnosis significantly increases the risk of adverse medical events in elderly adults with femoral fragility fractures. The rates of malnutrition increased steadily from 2010-2020. This trend is likely a result of increased awareness and testing for malnutrition, not reflecting an actual increased prevalence of malnutrition. Multiple expected demographic variables are associated with diagnosis of malnutrition.

Level of Evidence: III

Keywords: malnutrition, adverse medical event, femoral fragility fracture

INTRODUCTION

Musculoskeletal trauma in the elderly population is common with an estimated 250,000 patients presenting annually with hip fractures.1 The prevalence of malnutrition ranges from 24% to 88% depending on the population studied and how malnutrition is defined.2-Malnutrition is a potentially modifiable risk factor leading to increased rates of infection, delayed wound healing, hospital length of stay and mortality.3,5

Large database studies have been used to document the impact of malnutrition diagnosis on adverse medical events after orthopedic surgery. A study of 49,603 patients who underwent primary total hip and knee arthroplasty identified in the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database found a malnutrition rate of 4% defined as an albumin concentration < 3.5 g/dL and reported increased relative risks of surgical site infection, pneumonia, and renal insufficiency.6 Similarly, a systematic review and meta-analysis of the association of malnutrition and infection (periprosthetic and surgical
site) in > 250,000 patients after total joint arthroplasty reported increased risk of both prosthetic joint infections and surgical site infections among malnourished patients. Using the Nutritional Risk Screening tool to prospectively assess 1055 orthopedic and trauma patients 22% were found to be at risk for malnutrition. Patients at risk for malnutrition also had higher rates of adverse events and tended toward higher rates of local and systemic infections and decreased wound healing. To our knowledge malnutrition in the elderly population with femoral fragility fracture has not been investigated as a risk factor for adverse medical events in the PearlDiver Database.

Further investigation is needed to determine how the diagnosis of malnutrition impacts clinically important outcomes in the elderly femoral fragility fracture population. The goals of this study are to (1) Determine the prevalence of malnutrition in elderly patients with femoral fragility fractures, (2) Identify risk factors for malnutrition, and (3) Assess the impact of malnutrition diagnosis on postoperative complications in this population.

METHODS
All data was collected in the PearlDiver Database. This database is a vault of millions of Health Insurance Portability and Accountability Act compliant patient medical records with the ability to capture diagnostic, procedural and prescription data. Researchable coding includes International Classification of Diseases Ninth and Tenth Revisions (ICD-9 and ICD-10) for both diagnosis and procedure as well as Current Procedural Terminology (CPT) and National Drug Code (NDC).

The PearlDiver dataset was retrospectively queried from 2010 to the first quarter of 2020 to determine the incidence of femoral fragility fractures. Operative femur fractures were identified by CPT codes (OTA 31, 32, and 33). Patients were included with age 65-years-old or older with proximal, midshaft or distal femur fractures. Table 1 lists the CPT codes queried. Malnutrition diagnosis and postoperative variables including wound infection, wound dehiscence and non-union were identified by ICD-9 and ICD-10 codes. Patients were then separated into two cohorts, malnourished and non-malnourished, and were evaluated for one year following operative fixation of their femoral fragility fracture for the development of complications. Mortality rate is not a directly identifiable variable in the database. Survival was indirectly determined by their continued enrollment in the database at least 30 days after surgery.

Statistical Analysis
The frequencies (percentages) of malnutrition and complications including infection, wound dehiscence, nonunion and mortality were determined. Trend analysis to determine the prevalence of malnutrition over time was done utilizing Poisson regression. The relationships between the odds of complications and malnutrition were determined using logistic regression with and without adjustment for Charlson Comorbidity Index (CCI scores). We also explored the relationships between participant factors and odds of malnutrition with univariate logistic regression.

RESULTS
There were 178,283 total femur fractures identified. The overall prevalence of malnutrition in this geriatric population was 12.8% between 2010 and the first quarter of 2020. During this same period of time the prevalence of malnutrition diagnosis significantly increased from 1.6% to 32.9% (p < 0.001). (Figure 1). Demographic data was compared for the malnutrition and non-malnutrition cohorts. The malnourished cohort had a mean age of 78-years-old compared to the non-malnourished cohort which had a mean age of 75-years-old (p < 0.001) and the malnourished cohort was 73% female compared to 72% in the non-malnourished cohort among other significant variables (p = 0.0014).

Odds ratios (OR) for adverse medical events were determined. Compared to non-malnourished patients,

<table>
<thead>
<tr>
<th>CPT code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>27235</td>
<td>Percutaneous skeletal fixation of femoral fracture, proximal end, neck, in situ pinning of undisplaced or impacted fracture</td>
</tr>
<tr>
<td>27236</td>
<td>Open treatment of femoral fracture, proximal end, neck, internal fixation or prosthetic replacement</td>
</tr>
<tr>
<td>27244</td>
<td>Treatment of intertrochanteric, peritrochanteric, or subtrochanteric femoral fracture; with plate/screw type implant, with or without cerclage</td>
</tr>
<tr>
<td>27245</td>
<td>With intramedullary implant, with or without interlocking screws and/or cerclage</td>
</tr>
<tr>
<td>27506</td>
<td>Open treatment of femoral shaft fracture, with or without external fixation, with insertion of intramedullary implant, with or without cerclage and/or locking screws</td>
</tr>
<tr>
<td>27507</td>
<td>Open treatment of femoral shaft fracture with plate/screws, with or without cerclage</td>
</tr>
<tr>
<td>27511</td>
<td>Open treatment of femoral supracondylar or transcondylar fracture without intercondylar extension, includes internal fixation, when performed</td>
</tr>
<tr>
<td>27513</td>
<td>Open treatment of femoral supracondylar or transcondylar fracture with intercondylar extension, includes internal fixation, when performed</td>
</tr>
<tr>
<td>27514</td>
<td>Open treatment of closed or open femoral fracture, distal end, medial or lateral condyle, includes internal fixation, when performed</td>
</tr>
</tbody>
</table>
malnourished patients have an increased risk of mortality (non-continuous enrollment) (OR 1.31; 95% CI 1.2558 – 1.3752, p < 0.0001), are more likely to develop a wound infection (OR 1.49; 95% CI 1.252 – 1.7626; p < 0.0001), are more likely to have a wound dehiscence (OR 1.55; 95% CI 1.3416 – 1.7949; p < 0.0001), and are more likely to have a non-union (OR 1.89; 95% CI 1.6946 – 2.1095; p < 0.0001) (Table 2).

Potential risk factors for malnutrition were also evaluated including: age, sex, CCI, diabetes, obesity, dementia, depression, Parkinson’s disease, constipation, dysphagia, feeding difficulty, cognitive decline, institutionalization, tobacco use and alcohol use. Three factors were associated with a greater than two times risk for malnutrition and include Parkinson’s disease (OR 2.19; 95% CI 2.0486 – 2.3435; p < 0.001), feeding difficulty (OR 2.09; 95% CI 1.9192 – 2.0854; p < 0.0001) and institutionalization (OR 2.33; 95% CI 2.1678 – 2.5038; p < 0.0001) (Table 3).

**DISCUSSION**

This study was designed to determine the prevalence of malnutrition in elderly patients treated with operative fixation for femoral fragility fractures. We report an overall 12.8% rate of malnutrition with significant increase in diagnosis from 1.61% to 32.90% from 2010 to the first quarter of 2020. This is not an unexpected finding given the increased awareness of malnutrition diagnosis, readily available screening tools, and serum chemistries. However, this apparent increasing prevalence is likely related to the increased awareness of malnutrition and not an actual increase in prevalence in this patient population. The actual prevalence is likely closer to the results we found in 2020 as awareness and documentation increased. Rates of complications including mortality (non-continuous enrollment), wound infection, wound dehiscence and non-union were all significantly increased in malnourished patients treated operatively for femoral fragility fractures. Many risk factors for malnutrition were identified, including Parkinson’s disease, feeding difficulty and institutionalization as the greatest demographic risk factors for malnutrition.

The rates of malnutrition in the literature among patients undergoing musculoskeletal surgical procedures have a wide range. In 1982 Jensen et al. studied 129 patients undergoing orthopedic procedures and reported an average rate of 42% using anthropometric measurements (triceps skinfold, arm circumference) and biochemical testing (serum albumin <3.5 g/dl) as the definition for malnutrition. Subgroup analysis revealed a malnutrition rate of 28% among patients undergoing total hip arthroplasty and 59% among poly traumatized patients. A study of the ACS-NSQIP database from 2005-2013 identified 4,655 patients that underwent total shoulder arthroplasty finding a rate of 7.6%. A study of 327 patients from an urban U.S. level 1 trauma center with isolated hip fractures found the prevalence rate of malnutrition to be 17.5% when defined by an albumin level <3.5 g/dL. Similar to these studies we also report prevalence in our population. Unlike other studies, however, we also provide a trend of malnutrition over a 10-year period of time and report a significant increase over time.
from 1.6%-32.9%. The prevalence found in later years likely better reflects this population as awareness of the diagnosis has increased.

Increased complication and mortality rates have been previously described in the literature. In 2017 Chung et al. retrospectively studied 12,373 patients with hip fractures and found a 2-fold increased risk of postoperative complications and mortality. More recently in a study of 20,278 patients with hip fractures from the ACS-NSQIP database reported increased odds ratios for deep wound infection, any infection, reintubation, prolonged length of stay, readmission, reoperation, in-hospital mortality and 30-day mortality among malnourished patients. In this study malnutrition diagnosis was determined with an albumin level <3.5 g/dl. We report similar findings and reinforce the results of prior studies demonstrating increased rates of mortality and post-operative complications in malnourished surgical patients.

Many known risk factors exist for malnutrition in elderly patients. A systematic review of the literature based on longitudinal data from MEDLINE between 2000 and March 2015 found 15 significant risk factors for malnutrition in the older population (aged ≥65-years-old). We confirm many of the same risk factors in elderly adults with femoral fragility fractures including: age, sex, CCI, diabetes, obesity, dementia, depression, Parkinson’s disease, constipation, dysphagia, feeding difficulty, cognitive decline, institutionalization, tobacco use and alcohol use. With a predicted global increase in life expectancy between 2010 and 2050 we also expect an increase of older adults with malnutrition.

Increased mortality rates after hip fractures have been well studied and previously demonstrated. Diaphyseal and distal femur fractures have not been as extensively studied but a recent study of 11,799 femoral fractures found these fractures may have similar early mortality risks as hip fractures. We included all femoral fragility fractures as these patients have a similar prevalence of adverse medical event.

Our study adds to a growing body of literature about the significant impact malnutrition plays in surgical patients and specifically among elderly patients with femoral fragility fractures. It is important to recognize that malnutrition is a potentially modifiable risk factor and provides us an opportunity to improve the outcomes of this patient population.

**Limitations**

Limitations of this study should be acknowledged. First, the PearlDiver database contains over 4 billion patient records obtained from analysis of private insurance claims from Humana and United Healthcare, as well as government claims from Medicare. As a private analytics database it is not a random sample so data results and generalizations must be cautiously interpreted. Second, this is a retrospective study and the results are dependent on the completeness and accuracy of the data collected by PearlDiver. Furthermore, the results are dependent on diagnosis coding accuracy. Medical coding is very complex and the transition from ICD-9 to

<table>
<thead>
<tr>
<th>Malnutrition*</th>
<th>No Malnutrition*</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 78 (74-80)</td>
<td>75 (73-78)</td>
<td>1.0521</td>
<td>(1.0199-1.0853)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>CCI 4.34†</td>
<td>2.56†</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Female 16636</td>
<td>111380</td>
<td>1.0521</td>
<td>(1.0199-1.0853)</td>
<td>0.0014</td>
</tr>
<tr>
<td>Diabetes 11704</td>
<td>63836</td>
<td>1.5014</td>
<td>(1.4602-1.5438)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Obesity 4274</td>
<td>18264</td>
<td>1.7243</td>
<td>(1.6622-1.7887)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Dementia 7160</td>
<td>25651</td>
<td>1.7197</td>
<td>(1.6186-1.8268)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Tobacco 6059</td>
<td>26128</td>
<td>1.7816</td>
<td>(1.7251-1.84)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Alcohol 1792</td>
<td>6414</td>
<td>1.9734</td>
<td>(1.869-2.0835)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Depression 12202</td>
<td>60241</td>
<td>1.8042</td>
<td>(1.7546-1.8553)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Parkinson’s Disease 1168</td>
<td>3723</td>
<td>2.1911</td>
<td>(2.0486-2.3435)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Constipation 10406</td>
<td>50477</td>
<td>1.7333</td>
<td>(1.6853-1.7827)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Dysphagia 7938</td>
<td>37328</td>
<td>1.6798</td>
<td>(1.6308-1.7303)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cognitive decline 3124</td>
<td>11418</td>
<td>1.9935</td>
<td>(1.9110-2.0796)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Institutionalization 1027</td>
<td>3072</td>
<td>2.3298</td>
<td>(2.1678-2.5038)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Feeding difficulty 746</td>
<td>2471</td>
<td>2.0854</td>
<td>(1.9192-2.0854)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

*Values given are the number of patients. †Represents patient age. ‡Charlson Comorbidity Index.
ICD-10 on October 1, 2015 only increased that complexity. For example, ICD-9 includes one code for fracture non-union, however, ICD-10 includes over 200 codes for fracture non-union of the femur. Third, mortality cannot be directly measured in the PearlDiver database so continuing with insurance for 30 days post-operatively served as a surrogate. It is likely that patients discontinued their insurance within 30 days post-operatively for reasons other than death. Other studies have used these criteria for mortality in the PearlDiver database.

CONCLUSION

We found that malnutrition significantly increases the risk of adverse medical events in the elderly population with femoral fragility fractures. The rates of malnutrition increased steadily from 2010-2020, inferring an increased risk of malnutrition in 2020 compared to 2010, however, this trend is likely a result of increased awareness and testing for malnutrition and may not actually reflect increased rates of malnutrition. Diagnosis of malnutrition is associated with mortality (non-continuous enrollment), wound complications, and non-union. Significant risk factors for malnutrition in this study are Parkinson’s disease, feeding difficulty and institutionalization among others.

REFERENCES


ABSTRACT

Background: Changes in body composition, especially loss of lean mass, commonly occur in the orthopedic trauma population due to physical inactivity and inadequate nutrition. The purpose of this study was to assess inter-rater and intra-rater reliability of a portable bioelectrical impedance analysis (BIA) device to measure body composition in an orthopedic trauma population after operative fracture fixation. BIA uses a weak electric current to measure impedance (resistance) in the body and uses this to calculate the components of body composition using extensively studied formulas.

Methods: Twenty subjects were enrolled, up to 72 hours after operative fixation of musculoskeletal injuries and underwent body composition measurements by two independent raters. One measurement was obtained by each rater at the time of enrollment and again between 1-4 hours after the initial measurement. Reliability was assessed using intraclass correlation coefficients (ICC) and minimum detectable change (MDC) values were calculated from these results.

Results: Inter-rater reliability was excellent with ICC values for body fat mass (BFM), lean body mass (LBM), skeletal muscle mass (SMM), dry lean mass (DLM), and percent body fat (PBF) of 0.993, 0.984, 0.984, 0.979, and 0.986 respectively. Intra-rater reliability was also high for BFM, LBM, SMM, DLM, and PBF, at 0.994, 0.989, 0.990, 0.983, 0.987 (rater 1) and 0.994, 0.988, 0.989, 0.985, 0.989 (rater 2). MDC values were calculated to be 4.05 kg for BFM, 4.10 kg for LBM, 2.45 kg for SMM, 1.21 kg for DLM, and 4.83% for PBF.

Conclusion: Portable BIA devices are a versatile and attractive option that can reliably be used to assess body composition and changes in lean body mass in the orthopedic trauma population for both research and clinical endeavors.

Level of Evidence: III

Keywords: musculoskeletal trauma, lean body mass, body composition, bioelectrical impedance analysis, reliability

INTRODUCTION

Sarcopenia is the age-related decline in skeletal muscle mass and strength.1 Physical activity is important for maintaining bone density and muscle function. Bedrest and physical inactivity lead directly to loss of lean mass.2-4 Even short periods of inactivity5,6 can lead to substantial loss of muscle mass. Decreased function is required during the recovery phase after musculoskeletal trauma.7 Low lean body mass (LBM) after musculoskeletal trauma results in a higher rate of complications, poorer outcomes, and increased mortality.8,11

There is a current focus on nutritional interventions and early rehab programs to prevent loss of LBM after orthopedic trauma. Accurate and precise longitudinal measurements of body composition in these individuals is critical when assessing the efficacy of interventions targeted to maintain LBM in future clinical trials.12,13 There are many methods currently being used to assess body composition (whole-body DXA, CT, MRI, PET scan, air displacement plethysmography), but many of these methods are not suitable for clinical trials because they are indirect measures of LBM, require highly trained technicians, expose subjects to radiation, are expensive to use, and/or are not available at the bedside early after injury.14,15

The purpose of this study was to (1) Assess the inter-rater and intra-rater reliability of bioelectrical impedance (BIA) to measure body composition in patients after operative fracture fixation and (2) Quantify standard error of measurement (SEM) and minimum detectable change (MDC) in these same patients, using the portable, bedside, non-invasive InBodyS10 device (InBody USA, Cerritos, CA).16,17 Having a reliable BIA device for body composition measurement will allow for accurate
assessments of body composition for musculoskeletal trauma patients in the research setting.

METHODS

Subjects

Approval was obtained from our Institutional Review Board. Written informed consent was obtained from all participants. We enrolled 20 adult participants after operative fixation of pelvic or extremity fractures. Operative fixation included both temporary fracture fixation procedures, such as external fixation, as well as definitive fracture fixation with plates and screws or intramedullary nail. Participants with multiple injuries requiring multiple operations were eligible for enrollment after their first operative fixation procedure. The exclusion criteria were (1) BIA measurements not able to be completed within 72 hours of operative fixation, (2) BIA measurements not able to be obtained due to limits of patient positioning or splints/casts obstructing electrode placement, or (3) previous cardiac pacemaker implantation as this is contraindicated with BIA.

Measurement Technique

BIA body composition measurements were obtained in the supine position in accordance with the manufacturer’s recommendations; arms separated from the trunk and legs shoulder width apart without the thighs touching (Figure 1A).18 Body composition measurements using the InBody S10 device can be obtained using two different types of electrodes, known as touch type electrodes and adhesive type electrodes. To compare the reliability of the BIA device using both types of electrodes, 10 subjects were measured using the touch type electrodes and 10 subjects were measured using the adhesive type electrodes. The touch type electrodes were placed according to the manufacturer recommendations, with the finger clips placed on the first and third digits bilaterally and the ankle clips placed just posterior to the ankle malleoli bilaterally. Placement of the adhesive type electrodes was modified from the manufacturer recommendations to be better suited for orthopedic trauma patients who frequently have upper and/or lower extremity casts. For the upper extremity electrodes, the red electrode was placed over the head of the second metacarpal and the black electrode over the head of the fifth metacarpal. Similarly, for the lower extremity electrodes, the red electrode was placed over the head of the first metatarsal and the black electrode over the head of the fifth metatarsal (Figure 1B). Weight, height, age, and gender were recorded from the electronic health record to be entered into the device before obtaining the measurements.

Reliability

Body composition measurements were completed by two reviewers (B.K. and A.M.). Each subject was measured a total of four times, twice by each reviewer. The first measurement by each reviewer was obtained immediately following the informed consent and enrollment process. The electrodes were completely removed from the patient between measurements and the reviewers were blinded to results of the other reviewer. The second two measurements were obtained at least 1 hour after, but no more than 4 hours after, the first set of measurements. If the patient had any food or drink, took any medications, or participated in physical therapy between the two sets of measurements, this was recorded. All measurements were obtained in a single day and, thus, no follow-up was required.

Statistical Analysis

Inter-rater and intra-rater reliability of BIA body composition measurements were assessed using the intraclass correlation coefficient (ICC). Overall ICC values were calculated using all subjects, as well as ICC values for upper extremity and lower extremity injuries separately. The inter-rater reliability data was then used to calculate a Standard Error of Measurement (SEM). The SEM was then subsequently used to determine the Minimal Detectable Change with a 90% confidence interval (MDC90) and Minimal Detectable Change with a 95% confidence interval (MDC95) for the overall inter-rater reliability and the lower extremity inter-rater reliability data.

RESULTS

A total of 20 orthopedic trauma patients, aged 27-88 years, were enrolled from October 2021 to December 2021 and underwent BIA body composition measurements by two trained members of the research team. The demographics of the participating subjects as well as their associated injuries are listed in Table 1. During statistical analysis it was determined that height and weight was entered incorrectly for one subject, so results of only 19 subjects were used for statistical analysis.
BIA Outcomes

As can be seen from Table 1, the average BMI was 29.3, but broken down further one (5%) subject was underweight (BMI < 18.5), six (32%) subjects had a healthy BMI (18.5-24.9), three (16%) subjects had an overweight BMI (25-29.9), and nine (47%) subjects had an obese BMI (>30). Overall, BIA body composition measurements for Body Fat Mass (BFM), Lean Body Mass (LBM), Skeletal Muscle Mass (SMM), Dry Lean Mass (DLM), and Percent Body Fat (PBF) were 28.4 kg, 58.1 kg, 31.7 kg, 15.3 kg, and 30.9%, respectively. The values for BFM, LBM, SMM, DLM, and PBF in men were 21.8 kg, 63.1 kg, 34.6 kg, 16.6 kg, and 23.9% and for women were 42.9 kg, 47.2 kg, 25.2 kg, 12.5 kg, and 46.0%, respectively.

Reliability

Overall, the inter-rater and intra-rater reliability was excellent in all categories analyzed. The inter-rater reliability ICC values for BFM, LBM, SMM, DLM, and PBF were 0.993, 0.984, 0.984, 0.979, and 0.986 respectively. For intra-rater reliability, ICC values for rater 1 were 0.994, 0.989, 0.990, 0.983, 0.987 and for rater 2 were 0.994, 0.988, 0.989, 0.985, 0.989 for BFM, LBM, SMM, DLM, and PBF respectively (Table 2). Reliability remained excellent when the data was divided into lower extremity injuries (n=15) and upper extremity injuries (n=8). Inter-rater ICC values for injured lower limbs were 0.918, 0.987, and 0.985 for BFM, LBM, and PBF respectively. Similarly, for upper extremity injuries, inter-rater ICC values were 0.994, 0.995, and 0.993 for LBM, BFM, and PBF respectively. These values, along with the upper and lower extremity intra-rater reliability values are listed in Table 3.

Minimal Detectable Change

Inter-rater reliability data was used to calculate SEM and MDC values. Using the overall inter-rater reliability data, the MDC95 values were the following: 4.05 kg for BFM, 4.10 kg for LBM, 2.45 kg for SMM, 1.21 kg for DLM, and 4.83% for PBF. When the inter-rater reliability data from only lower extremity injuries was used, the following MDC95 values were obtained: 2.31 kg for LBM, 0.88 kg for BFM, and 37.66% for PBF. These values are listed in Table 4.

DISCUSSION

This study assessed the intra-rater and inter-rater reliability of a portable BIA device to measure body composition after operative fracture fixation and to determine the minimal detectable change in these same patients. Reliability values were excellent for both inter-rater and intra-rater reliability in this population with an average age of 59 years and an average BMI of 29.3. For

Table 1. Patient Demographics and BIA Measurements

<table>
<thead>
<tr>
<th></th>
<th>Total (n=19)</th>
<th>Male (n=13)</th>
<th>Female (n=6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>59.5 ± 17.6</td>
<td>57.3 ± 17.0</td>
<td>64.3 ± 18.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>172.4 ± 10.9</td>
<td>178.5 ± 7.3</td>
<td>159.4 ± 21.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>86.6 ± 20.5</td>
<td>85.0 ± 19.8</td>
<td>90.1 ± 21.6</td>
</tr>
<tr>
<td>BMI</td>
<td>29.3 ± 7.3</td>
<td>26.5 ± 5.4</td>
<td>35.2 ± 7.4</td>
</tr>
<tr>
<td>BFM (kg)</td>
<td>28.4 ± 17.1</td>
<td>21.8 ± 12.7</td>
<td>42.9 ± 16.6</td>
</tr>
<tr>
<td>LBM (kg)</td>
<td>58.1 ±12.0</td>
<td>63.1 ± 10.6</td>
<td>47.2 ± 6.1</td>
</tr>
<tr>
<td>SMM (kg)</td>
<td>31.7 ± 7.1</td>
<td>34.6 ± 6.2</td>
<td>25.2 ± 3.9</td>
</tr>
<tr>
<td>DLM (kg)</td>
<td>15.3 ± 3.1</td>
<td>16.6 ± 2.7</td>
<td>12.5 ± 1.6</td>
</tr>
<tr>
<td>PBF (%)</td>
<td>30.9 ± 14.5</td>
<td>23.9 ± 11.1</td>
<td>46.0 ± 7.9</td>
</tr>
</tbody>
</table>

Injuries:
- Upper Ext. Only: 1 (5%)
- Lower Ext. Only: 9 (47%)
- Upper + Lower Ext: 4 (21%)
- Pelvis Only: 1 (5%)
- Pelvis + Ext: 4 (21%)

BMI, Body Mass Index; BFM, Body Fat Mass; LBM, Lean Body Mass; SMM, Skeletal Muscle Mass; DLM, Dry Lean Mass; PBF, Percent Body Fat.

Table 2. Overall BIA Reliability Data Showing Inter-rater and Intra-rater ICC Values With 95% Confidence Intervals and Associated P-values

<table>
<thead>
<tr>
<th></th>
<th>Inter-rater (ICC 95% CI)</th>
<th>p-value</th>
<th>Intra-rater (ICC 95% CI)</th>
<th>p-value</th>
<th>Rater 1 ICC 95% CI</th>
<th>Rater 2 ICC 95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BFM</td>
<td>0.993 (0.981-0.997)</td>
<td>&lt;0.001</td>
<td>0.994 (0.986-0.998)</td>
<td>&lt;0.001</td>
<td>0.994 (0.986-0.998)</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LBM</td>
<td>0.984 (0.958-0.994)</td>
<td>&lt;0.001</td>
<td>0.989 (0.973-0.996)</td>
<td>&lt;0.001</td>
<td>0.988 (0.970-0.995)</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SMM</td>
<td>0.984 (0.960-0.994)</td>
<td>&lt;0.001</td>
<td>0.990 (0.975-0.996)</td>
<td>&lt;0.001</td>
<td>0.989 (0.972-0.996)</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DLM</td>
<td>0.979 (0.948-0.992)</td>
<td>&lt;0.001</td>
<td>0.983 (0.957-0.995)</td>
<td>&lt;0.001</td>
<td>0.985 (0.963-0.994)</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PBF</td>
<td>0.986 (0.964-0.995)</td>
<td>&lt;0.001</td>
<td>0.987 (0.969-0.995)</td>
<td>&lt;0.001</td>
<td>0.989 (0.973-0.996)</td>
<td></td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

BFM, Body Fat Mass; LBM, Lean Body Mass; SMM, Skeletal Muscle Mass; DLM, Dry Lean Mass; PBF, Percent Body Fat.
Schubert et al. conducted a reliability study of various laboratory methods to assess body composition in young adults, with BIA being one of the techniques assessed. This was a highly controlled study in which food intake, hydration, and physical activity were all limited prior to measurements. They calculated r values of 0.93, 0.98, and 0.94 for percent body fat, fat-free mass, and fat mass respectively. Vasold et al. completed a reliability study using three different low-cost BIA devices looking at fat-free mass. In this study, reliability for measures of fat-free mass ranged from 0.991-0.996 for all subjects, 0.974-0.985 when stratified for males, and 0.921-0.991 for females. The inter-rater and intra-rater ICC values in our study involving orthopedic trauma patients were comparable to the reliability values found in these other studies across various populations, with values often above 0.97. With confidence that measurements will be precise across periods of time and separate reviewers, BIA can be a powerful tool for body composition measurements in the research setting.

Bioelectric impedance is only one method in which body composition can be measured, so it is important to determine how reliable BIA is compared to other methods of measurement. Underwater weighing (UWW) was one of the first body composition measurements used due to its simplicity. In 1985, while testing two different tanks used for UWW, Williams et al. found percent body fat correlation coefficients of 0.989 and 0.981 for the two different tanks. Whole body DXA has long been the gold standard for body composition measurement, and Shiel et al. in their reliability study using DXA found ICC values of 0.996 for both whole body fat mass and whole-body lean mass. When the data was stratified regionally
to arms, trunk and legs, the ICC values were lower but were consistently above 0.96. Air displacement plethysmography (ADP) is another standard for body composition measurements, although it is not used as often as DXA. In a study of 283 women assessing ADP, Tucker et al. found an ICC value of 0.991. When they completed a third measurement and used the two closest values, the ICC improved to 0.998. Lastly, A-mode ultrasound is another method of body composition analysis that is being studied currently. Specifically in trauma subjects, Hendrickson et al. had ICC values of 0.96, 0.98, and 0.99 for percent body fat, fat mass, and fat free mass, respectively. In a comprehensive study of 32 healthy adult patients, Schubert et al. studied the reliability and validity of several of the most common body composition techniques in a single study. For UWW reliability values were 0.964, 0.993, and 0.968; for ADP were 0.973, 0.992, and 0.975; for DXA were 0.996, 0.994, and 0.997; and for BIA were 0.983, 0.997, and 0.986 for percent body fat, fat free mass, and fat mass, respectively. As can be seen, reliability of BIA in this study using orthopedic trauma patients is comparable to the other methods used to measure body composition, including those that are the gold standard. Due to its high reliability, and because it is portable and easy to use, BIA is a feasible option for body composition analysis in the trauma population. Most trauma patients are limited in their mobility due to their injuries, and thus a device that can be brought to the bedside for measurement is essential. BIA using the InBody S10 meets these requirements.

Finally, it is worth discussing the accuracy of BIA devices in predicting lean body mass (LBM). Despite many articles in the literature validating BIA against DXA and other reference standards, questions of BIA to accurately measure body composition are continuously raised. BIA measures LBM (or fat free mass) by determining the total body water content and then using the assumption that LBM is uniformly and constantly hydrated at a certain percentage. Of course this assumption can become inaccurate in certain populations and disease states, most notably elderly patients, obese patients, and patients with significant volume changes such as occurs in heart failure, liver disease, or kidney disease. It is also reasonable to assume that the hydration status of a patient around the time of BIA measurement can affect the values. In fact, Tinsley et al. found hydration status to be an independent variable predicting discrepancies between DXA and BIA measurements. This has led many to believe that BIA tends to either underpredict or overpredict LBM, depending on the circumstances. In a retrospective study of over 3600 measurements, Achamrah et al. found BIA underpredicted LBM by 0.8-2.5 kg, as compared to DXA as the gold standard, at BMI’s below 18.5 kg/m2, and overpredicted by 0.6-5.6 kg at BMI’s above 18.5 kg/m2. In contrast, Ling et al. found that BIA, as compared to DXA as the gold standard, slightly underpredicted at normal and overweight BMI’s but overpredicted at obese BMI’s in a healthy middle-age adult population. From this literature, it is clear that BIA has good validity for measuring LBM and does not predictably under or overpredict LBM, regardless of the population being studied. Importantly for orthopedic trauma patients, the measurement of LBM by BIA in the extremities appears to be quite accurate.

Limitations

There are several limitations of this study that are worth discussion. The first limitation of this study is the small population size and lack of ethnic diversity. Although we completed this project using 20 subjects, we felt this was an appropriate number for an initial reliability study using BIA technology in a specific orthopedic trauma fracture fixation population. This study was completed at a single Midwest academic center and thus diversity was limited to that of the general Midwest population. As portable BIA devices gain popularity in measuring body composition in the orthopedic population, reliability should be periodically reassessed as the population size and diversity of patients measured increases. Secondly, only a single BIA device was used in this study and no gold standard body composition device was used for validation. In future studies, it will be beneficial to assess whether reliability is different using different BIA devices, especially the portable options used in this study and the less portable options that are currently on the market. A portable device was preferred in this study as trauma patients are inherently less mobile given the nature of their injuries. Although BIA has been extensively validated against DXA and other techniques, it will need to be validated specifically in the...
orthopedic trauma population for future work. Third, all subjects enrolled were in the trauma population and we did not complete any measurements on a healthy population for comparison. As we did not compare to a healthy control population, we are unable to assess whether the trauma itself (with localized edema and fluid shifts) changes the measurements obtained by BIA devices. Relatedly, we excluded subjects who were unable to assume the general body positioning outlined in the InBodyS10 user manual, so we are unable to assess how large deviations from this body positioning affect the reliability of the measurements. If the reliability decreases with significant changes in body positioning, this may be one limitation to using BIA in the trauma population. Lastly, we only performed measurements on a single day for each patient, thus differences across longer periods of time cannot be assessed with this current study.

CONCLUSION

In conclusion, the results of this study show portable BIA to have a high inter-rater and intra-rater reliability for total and segmental muscle mass in an orthopedic trauma population after operative fixation. MDC values were calculated from this study to assist with powering and analyzing future research endeavors using this technology. Our findings are consistent with previous BIA reliability studies conducted on varying populations. Due to its portability, ease of use, low cost, lack of radiation exposure, and high reliability, BIA is an attractive option to assess LBM in orthopedic trauma patients in the clinical setting and in the research setting. Future research in this area should aim to assess the validity of BIA devices specifically in the orthopedic trauma population.

REFERENCES


ABSTRACT

Background: Several strategies exist to prevent venous thromboembolism (VTE) in operative pelvic and acetabular fractures, however literature lacks consensus on the optimal thromboprophylaxis. Even more debated, and perhaps controversial, is whether aspirin provides adequate thromboprophylaxis in the setting of these injuries. The primary objective was to evaluate the efficacy of aspirin in the prevention of venous thromboembolism (VTE) events, including deep vein thrombosis (DVT) and pulmonary embolism (PE) in operative pelvic and acetabular fractures compared to other anticoagulants.

Methods: A retrospective chart review of pelvic and acetabular fractures that underwent operative fixation was completed. The incidence of VTE and hematoma formation was evaluated and compared between patients who received aspirin versus enoxaparin or heparin. Multivariate analysis was performed to control for confounding demographic, comorbidity, and injury-related variables. The outcome measurements included development of DVT and/or PE and hematoma formation.

Results: Of patients with operative pelvic and acetabular fractures, 4.2% developed a DVT and 3.5% developed a PE, with 1.4% developing both. Of these patients 37.5% were treated with aspirin versus the 62.5% treated with heparin or enoxaparin. There was no significant difference in the incidence of DVT or PE between cohorts (p=0.498 and p=0.262). Aspirin trended toward significance as protective against post-operative hematoma (p=0.085).

Conclusion: This study suggests that aspirin is an acceptable method of VTE thromboprophylaxis with no inferior results to other common anticoagulants. As a chemoprophylactic agent, aspirin is an efficacious option in these complex injuries that shows no increase in the incidence in symptomatic VTE events.

Level of Evidence: III

Keywords: aspirin, pelvis, acetabulum, fracture, dvt/pe

INTRODUCTION

Pelvic-acetabular trauma injuries are complex, frequently require surgical intervention, and carry a high risk of complications. These can lead to poor patient outcomes and large economic health-care burdens. These fractures commonly occur with concomitant polytraumatic injuries and in the setting of significant medical comorbidities. Development of a venous thromboembolism (VTE) following surgical fixation of pelvic and acetabular fractures is a serious and sometimes life-threatening complication with significant economic implications. Previous studies have elucidated independent risk factors that predispose these patients to increased risk of pulmonary embolism (PE) and deep vein thrombosis (DVT) including age, associated injuries, injury severity, and time to surgery. One recent study in hip fracture patients demonstrated that VTE events were an independent reason for a 2-fold increase hospital length of stay and cost. Rates of VTE range from 10-30% and are even greater in patients who receive no chemoprophylactic treatment. Coupled with a small but significant rate of pulmonary embolism (PE) in pelvic and acetabular fractures, prevention strategies are critical.

Although VTE is a known complication, there is limited data and no consensus on optimal thromboprophylactic agents and algorithms following operative fixation of operative pelvic trauma. With high variability among different institutions, it is often debated if aspirin is an effective thromboprophylactic agent. Although a multitude of anticoagulants are used in the prevention of VTE, the associated risk of bleeding or hematoma development is another important consideration. Despite the extensive reports on the effectiveness of various anticoagulants in total joint arthroplasty literature, very little data exists regarding these thromboprophylactic medications.
in the setting of fracture patients, particularly pelvic and acetabular fractures. In fact, to the author’s knowledge no studies evaluating the efficacy of aspirin compared to enoxaparin or heparin in preventing symptomatic VTE in these complicated injuries is described in the literature.

The objective of this study is to evaluate the observed incidence of symptomatic VTE following operative fixation of pelvic and acetabular fractures in patients treated with aspirin compared to the short-acting injectable anticoagulants, enoxaparin and heparin. A secondary aim was to compare the rate of other complications associated with these chemoprophylactic agents. We anticipated that aspirin would be an efficacious VTE prophylaxis agent and have a lower rate of hematoma development compared to other agents.

METHODS

After institutional review board (IRB) approval, a retrospective chart review of patients who sustained pelvic ring and acetabular fractures treated with operative fixation was performed. Current Procedural Terminology (CPT) codes identified 163 pelvic or acetabular fractures managed operatively between 2015-2020 at our level 1 trauma center. Patients were included if they were ≥18 years of age, received aspirin, enoxaparin, or heparin as their primary anticoagulant, and had a minimum of 6 weeks post operative follow up. Nearly all post-operative VTE occur early within this timeframe.20,21 Patients were excluded if they were <18 years of age (4), had a pathologic fracture (2), had undergone previous operative fixation of pelvis or acetabulum (4), received warfarin or a newer oral anticoagulant (6), or lacked 6 week follow up (3).

Three fellowship-trained traumatologists treated all fractures. Surgical approach was dictated by fracture pattern and surgeon preference. The primary team determined treatment with aspirin, enoxaparin, or heparin. Patient demographics, medical comorbidities, and post-operative weight bearing status were accounted for across groups and normalized in a multivariate analysis.

The primary outcome measures were development of DVT or PE within a 6-week post-operative period. Hematoma development was considered a secondary outcome. Hematoma formation was defined by evidence on computed tomography (CT) and a drop in hemoglobin. Patients were treated with aspirin 81 milligrams (mg) twice a day, enoxaparin 40mg daily, or 5,000 units heparin twice a day. Mechanical prophylaxis of ambulation and sequential compressive devices (SCDs) were used in all patients. The rate of VTE and hematoma formation was compared between patients receiving aspirin and short-acting injectables, enoxaparin and heparin.

RESULTS

There were 144 pelvic and acetabular fractures that met inclusion criteria. Mean age was 42.2 ± 17.1 years. There were 95 males (66.0%) and 49 females (34.0%). There were 6 patients (4.2%) that developed DVT and 5 patients (3.5%) that developed PE. Two patients developed both (1.4%).

There were 54 patients treated with aspirin (37.5%) and 90 patients treated with heparin or enoxaparin (62.5%). On univariate analysis of complications, there was a significantly lower incidence of hematoma formation in the aspirin cohort (n=3, 5.6% vs. n=19, 21.1%, p =0.015) (Table 1). There were no differences in incidence of DVT, PE, or transfusion between cohorts. Similarly, there were no differences in the incidences of infection or mortality.

On univariate assessment of potential demographic and comorbidity confounders, the aspirin cohort was found to have a lower incidence of obesity (n=13, 24.1%
Aspirin in Pelvic and Acetabular Fractures

vs. n=40, 46%, p=0.009) (Table 2). On univariate analysis of potential injury and perioperative confounders, the aspirin cohort was found to have lower ISS (11.0±7.9 vs. 15.6±10.4, p=0.010), lower incidence of ICU stay (n=10, 22.7% vs. n=37, 51.4%, p=0.002), less weight bearing restrictions (p=0.001), and received more heterotopic ossification prophylaxis (p=0.031) (Table 3). Furthermore, there was no difference in rate of DVT or PE based on an anterior or posterior approach (Table 3).

On multivariate analysis of major complications, accounting for the confounding variables found on univariate analysis, there were no significant differences in the incidence of VTE between aspirin and enoxaparin/heparin cohorts (Table 4). However, aspirin trended on significance with less post-operative hematoma formation (adjusted odds ratio [aOR]: 0.687, 95% Confidence Interval [CI]: 0.015-1.315, [p=0.085]).

DISCUSSION

Several strategies exist to prevent venous thromboembolism (VTE) in operative pelvic and acetabular fractures, however the current literature lacks consensus on optimal thromboprophylaxis, particularly on the use of aspirin compared to other anticoagulant agents. This study suggests that there is no significant difference in the rate of VTE with aspirin compared to short-acting injectables enoxaparin and heparin and there is a trend towards a lower rate of hematoma associated with the use of aspirin.

Development of postoperative hematoma has been as-

Table 1. Univariate Analysis of Complications

<table>
<thead>
<tr>
<th>Complications</th>
<th>Enoxaparin/ Heparin</th>
<th>Aspirin</th>
<th>Relative Risk</th>
<th>95% Confidence Interval</th>
<th>Pvalue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Complications of Interest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep Vein Thrombosis</td>
<td>4 (4.4%)</td>
<td>2 (3.7%)</td>
<td>0.935</td>
<td>0.523-1.670</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Pulmonary Embolus</td>
<td>3 (3.3%)</td>
<td>2 (3.7%)</td>
<td>1.043</td>
<td>0.504-2.158</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Hematoma</td>
<td>19 (21.1%)</td>
<td>3 (5.6%)</td>
<td>0.674</td>
<td>0.539-0.843</td>
<td>0.015</td>
</tr>
<tr>
<td>Transfusion</td>
<td>17 (18.9%)</td>
<td>6 (11.1%)</td>
<td>0.816</td>
<td>0.615-1.083</td>
<td>0.217</td>
</tr>
<tr>
<td>Secondary Complications of Interest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infection</td>
<td>6 (6.7%)</td>
<td>3 (5.6%)</td>
<td>0.933</td>
<td>0.577-1.509</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Mortality</td>
<td>1 (1.1%)</td>
<td>2 (3.7%)</td>
<td>1.894</td>
<td>0.380-9.429</td>
<td>0.556</td>
</tr>
</tbody>
</table>

Table 2. Univariate Analysis of Demographics and Comorbidities

<table>
<thead>
<tr>
<th>Potential Confounder</th>
<th>Enoxaparin/ Heparin</th>
<th>Aspirin</th>
<th>Relative Risk</th>
<th>95% Confidence Interval</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>40.2±16.0</td>
<td>45.5±18.5</td>
<td>-</td>
<td>-</td>
<td>0.127</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>55 (61.1%)</td>
<td>40 (74.1%)</td>
<td>0.550</td>
<td>0.262-1.155</td>
<td>0.112</td>
</tr>
<tr>
<td>Female</td>
<td>35 (38.9%)</td>
<td>14 (25.9%)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking</td>
<td>30 (33.3%)</td>
<td>26 (48.1%)</td>
<td>1.273</td>
<td>0.959-1.688</td>
<td>0.077*</td>
</tr>
<tr>
<td>Obesity</td>
<td>40 (46.0%)</td>
<td>13 (24.1%)</td>
<td>0.708</td>
<td>0.552-0.907</td>
<td>0.009</td>
</tr>
<tr>
<td>Hypertension</td>
<td>24 (26.7%)</td>
<td>16 (29.6%)</td>
<td>1.058</td>
<td>0.790-1.416</td>
<td>0.701</td>
</tr>
<tr>
<td>Diabetes</td>
<td>8 (8.9%)</td>
<td>8 (14.8%)</td>
<td>1.281</td>
<td>0.772-2.127</td>
<td>0.273</td>
</tr>
<tr>
<td>Chronic Kidney Disease</td>
<td>1 (1.1%)</td>
<td>0 (0%)</td>
<td>-</td>
<td>-</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Coronary Artery Disease</td>
<td>2 (2.2%)</td>
<td>4 (7.4%)</td>
<td>1.913</td>
<td>0.613-5.973</td>
<td>0.197</td>
</tr>
<tr>
<td>Prior Deep Vein Thrombosis</td>
<td>0 (0%)</td>
<td>1 (1.9%)</td>
<td>-</td>
<td>-</td>
<td>0.375</td>
</tr>
</tbody>
</table>
associated with an increased rate of surgical site infection (SSI). Often patients suffering from pelvic trauma are polytraumatized patients and at high risk for complications. The reported rate of surgical site infections that occur following operative fixation of pelvic and acetabular fractures is 5-8%. The ability to limit infection and recognize factors that may be protective in these patients is critical since infection can greatly hinder the recovery of patients and add an unprecedented burden to the patient and the medical system.

Many patients with pelvic and acetabular fractures undergo a long stay in an ICU, are immobilized with weight bearing restrictions and have high ISS scores. Previous studies demonstrate that these factors are associated with increased development of VTE. In this study these variables, while noted to be lower in the aspirin cohort, were controlled for in the multivariate analysis to eliminate their confounding effect. Thus, there was no evidence to indicate that aspirin was inferior to enoxaparin or heparin. This study suggests that aspirin provides adequate VTE chemoprophylaxis following operative fixation of pelvic and acetabular fractures.

Table 3. Univariate Analysis of Injury and Perioperative Variables

<table>
<thead>
<tr>
<th>Potential Confounder</th>
<th>Enoxaparin/Heparin</th>
<th>Aspirin</th>
<th>Relative Risk</th>
<th>95% Confidence Interval</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concurrent Injuries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head Injury</td>
<td>5 (5.6%)</td>
<td>1 (1.9%)</td>
<td>0.739</td>
<td>0.505-1.082</td>
<td>0.410</td>
</tr>
<tr>
<td>Polytrauma</td>
<td>51 (56.7%)</td>
<td>24 (44.4%)</td>
<td>0.831</td>
<td>0.642-1.077</td>
<td>0.155</td>
</tr>
<tr>
<td>Injury Severity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abbreviated Injury Scale</td>
<td>2.8±0.8</td>
<td>2.6±0.7</td>
<td>-</td>
<td>-</td>
<td>0.083*</td>
</tr>
<tr>
<td>Injury Severity Scale</td>
<td>15.6±10.4</td>
<td>11.0±7.9</td>
<td>-</td>
<td>-</td>
<td>0.010</td>
</tr>
<tr>
<td>Ventilator</td>
<td>15 (20.8%)</td>
<td>3 (6.8%)</td>
<td>0.698</td>
<td>0.535-0.911</td>
<td>0.063*</td>
</tr>
<tr>
<td>Intensive Care Unit Stay</td>
<td>37 (51.4%)</td>
<td>10 (22.7%)</td>
<td>0.644</td>
<td>0.489-0.849</td>
<td>0.002</td>
</tr>
<tr>
<td>Perioperative Details</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay ≥48 Hours from Admission</td>
<td>60 (68.9%)</td>
<td>40 (74.1%)</td>
<td>1.097</td>
<td>0.842-1.429</td>
<td>0.508</td>
</tr>
<tr>
<td>Weight Bearing Status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>As Tolerated</td>
<td>5 (5.6%)</td>
<td>6 (11.1%)</td>
<td>-</td>
<td>-</td>
<td>0.001</td>
</tr>
<tr>
<td>Partial</td>
<td>43 (47.8%)</td>
<td>40 (74.1%)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Nonweight Bearing</td>
<td>13 (14.4%)</td>
<td>4 (7.4%)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Transfers Only</td>
<td>29 (32.2%)</td>
<td>4 (7.4%)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Heterotopic Ossification</td>
<td>Radiation</td>
<td>20 (22.2%)</td>
<td>21 (38.9%)</td>
<td>-</td>
<td>0.031</td>
</tr>
<tr>
<td>prophylaxis</td>
<td>Indomethacin</td>
<td>4 (4.4%)</td>
<td>5 (9.3%)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Surgical Approach</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>25 (27.8%)</td>
<td>12 (22.2%)</td>
<td>-</td>
<td>-</td>
<td>0.464</td>
</tr>
<tr>
<td>Posterior</td>
<td>35 (38.9%)</td>
<td>29 (53.7%)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Lateral</td>
<td>8 (8.9%)</td>
<td>4 (7.4%)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Percutaneous</td>
<td>17 (18.9%)</td>
<td>8 (14.8%)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Combined</td>
<td>5 (5.6%)</td>
<td>1 (1.9%)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Multivariate Analysis of Complications Based on Anticoagulation

<table>
<thead>
<tr>
<th>Complication</th>
<th>Adjusted OR</th>
<th>95% Confidence Interval</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVT</td>
<td>3.377</td>
<td>0.100-114.506</td>
<td>0.498</td>
</tr>
<tr>
<td>PE</td>
<td>10.174</td>
<td>0.177-585.710</td>
<td>0.262</td>
</tr>
<tr>
<td>Hematoma</td>
<td>0.139</td>
<td>0.015-1.315</td>
<td>0.085</td>
</tr>
<tr>
<td>Transfusion</td>
<td>0.687</td>
<td>0.146-3.234</td>
<td>0.635</td>
</tr>
</tbody>
</table>
Aspirin in Pelvic and Acetabular Fractures

the anterior approach would be a risk factor for VTE events due to mobilization and direct manipulation of great vessels that is often required. We theorized that there could be a potential risk that this could increase turbulence and thus increase the risk of a VTE event. However, this was not demonstrated in this study. Another recent study showed that this theoretical risk was not substantiated and that the rate of VTE was not increased in the anterior approach. Furthermore, this was a variable that was controlled for in the multivariate analysis. Regardless of approach aspirin appears to be an efficacious chemoprophylactic agent in patients with pelvic and acetabular fractures that undergo operative fixation.

Aspirin as an effective anticoagulation agent has been recognized in the total joint arthroplasty literature. This study suggests that it is also an effective thromboprophylactic medication in operative pelvic trauma and represents certain benefits for patients. The ease of administration compared to enoxaparin and heparin is a substantial consideration. Additionally, the relatively low cost of an over the counter medication is significant. These factors could potentially lead to increased patient compliance post-operatively.

This study is not without limitations. There are inherent limitations given the retrospective nature. Although it represents one of the larger cohorts of pelvic and acetabular fractures in the literature that reviews VTE prophylaxis, a larger population would be beneficial. With this small sample size that showed differences between groups such as less obesity, lower ISS, shorter ICU LOS and less restrictive weightbearing were analyzed using a multivariate regression model. However, a larger cohort examined prospectively would provide greater understanding of the optimal VTE prophylactic protocol. Furthermore, this study only examined aspirin compared to short-acting injectables, enoxaparin and heparin. However very few patients were excluded for receiving an alternative anticoagulation regimen for VTE prophylaxis, thus this may not be a significant limitation. While this study suggests that aspirin is not inferior to other anticoagulants, larger randomized controlled trials are necessary to further determine the optimal anticoagulation agent to reduce the risk of both VTE and postoperative hematoma formation in operative pelvic and acetabular fractures.

CONCLUSION

In this study, aspirin had an equivalent incidence of symptomatic VTE in operative pelvis and acetabular fractures compared to enoxaparin/heparin. This suggests that aspirin may provide an acceptable method of VTE thromboprophylaxis in operative pelvic trauma. In fact, as aspirin may reduce the incidence of post-operative hematoma, it may be potentially advantageous in reducing certain complications in patient recovery.

REFERENCES


ABSTRACT

Background: High energy, lower extremity trauma is associated with longstanding pain and functional limitations. The clinical decision to proceed with early amputation or limb salvage is often controversial. This study was designed to compare differences in complications, costs, and clinical outcomes of below knee amputation (BKA) performed early after injury or after attempted limb salvage in a hospital with standardized prosthetic care following amputation.

Methods: This is a retrospective comparative study of subjects who underwent BKA for a traumatic injury at a single level 1 trauma center and received standardized prosthetic care from a single manufacturer from 1999-2016 with minimum 2-year post-amputation follow up. Outcomes collected included demographics, surgical management, unplanned re-operations, and hospital and prosthetic cost data 2 years from time of injury.

Results: Overall, 79 subjects met criteria. Early amputation (EA) was defined by median duration between injury and amputation (6 weeks) with 41 subjects in the EA group and 38 subjects in the late amputation (LA) group. Subjects in the EA group were more likely to have open fractures, high energy mechanism, and less likely to have medical comorbidities. Post-amputation infection was common in both groups (17/41 (42%) vs 17/38 (45%), p=0.77). Subjects undergoing EA were more likely to require unplanned post-amputation revision, 22/41 (54%) versus 10/38 (27%), p=0.017. Hospital costs and prosthetics/orthotics costs from the time of injury to two years following amputation were comparable, with mean hospital EA costs $136,044 versus LA costs $125,065, p=0.38. Mean prosthetics/orthotics costs of EA subjects were $33,252 versus LA costs $37,684, p=0.59.

Conclusion: Unplanned post-amputation revision surgeries were more common when BKA was performed early after trauma. Otherwise, outcomes and cost were comparable when amputation was performed early versus late.

Level of Evidence: IV

Keywords: amputation, trauma, prosthesis, cost, below knee amputation

INTRODUCTION

High energy, lower extremity trauma has profound functional and socioeconomic impact on patients that orthopaedic trauma surgeons must consider when making the decision to recommend limb salvage or amputation. Careful documentation of relevant clinical outcomes and cost is critical to guide clinical decision making. Advances in surgical treatment such as microvascular tissue transfer with modern osteosynthesis techniques combined with custom dynamic orthoses after recovery have improved outcomes of limb salvage. However, historically, limb salvage is often considered a futile endeavor which can prolong suffering and disability before an eventual amputation.

Despite advancements in the field, limb salvage continues to have significant risk of functional limitations and pain necessitating late amputation. Late amputation has been associated with increased hospital admissions, longer hospital stay, higher cost, anxiety, and depression. Numerous studies have evaluated the use of algorithms to predict outcomes of limb salvage and amputation, but limitations of these algorithms are well documented. Overall, limb salvage carries a risk of late amputation, associated operative complications, and increased hospital costs.

Through collaboration with a prosthetics and orthotics group, this study aims to compare the long-term outcomes of individuals who undergo below knee amputation early versus late following failed limb salvage with standardized prosthetic care. The goal of this study was to document unplanned reoperations, complications, hospital readmissions, and hospital/orthotic/prosthetic cost, and clinical outcomes in adults who underwent
below-knee amputation following traumatic injury with standardized prosthetic care and compare outcomes between individuals that underwent early amputation versus late amputation.

METHODS

Our Internal Review Board approved this investigation. Consecutive individuals were identified who underwent below knee amputations after an acute traumatic injury at a Level 1 trauma center that received standardized orthotic and prosthetic care from a single manufacturer from 9/1/1999 - 9/1/2016. Potential subjects were excluded if they underwent below knee amputation for non-traumatic indications (neuropathy, infection, and vascular disease), if they received prosthetics care at another center, or if they had less than 2 years follow up (Figure 1). Demographics and outcomes data collected via chart review included: sex, age at injury and amputation, BMI, diabetic status, smoking status, and other medical comorbidities (Table 1). The following injury characteristics were documented: mechanism of injury, timing of amputation, open/closed fracture, and Gustilo and Anderson classification. There was a wide range in the duration of time between injury and amputation with a range of day of injury to 24 years. (Figure 2) The median duration of the time from injury to amputation was 37 days. For clinical relevance 42 days (6 weeks) from injury to amputation was chosen as the cutoff for late amputation in this investigation. Treatment characteristic variables collected included number of surgeries preceding amputation, number of unplanned orthopedic surgeries after amputation, total number of orthopedic surgeries related to the index injury. Clinical notes, hospital notes, and procedure notes were reviewed to determine if a revision was planned or unplanned. For example, repeat debridement of a contaminated wound with a wound vac in place would be considered a planned revision. Hospital cost data were collected from the billing department of our institution. Orthotics and prosthetics costs were collected from the single manufacturer for 2 years from the time of injury. All costs were corrected for inflation and converted to January 2019 dollars.

Characteristics were described in all patients as median (range) for continuous variables and frequencies (percentages) for categorical variables. Between group comparisons were made using the Wilcoxon Rank Sum test for continuous variables and Chi-square or Fisher's Exact tests, as appropriate. Lengths of stay and number of surgeries were compared using Poisson regression. A p-value of <0.05 was considered statistically significant and all analyses were made using SAS V9.4 (SAS Institute, Inc., Cary, NC).

RESULTS

Overall, 79 patients met inclusion criteria, with 41 patients undergoing early amputations, and 38 undergoing late amputations. There were significant differences between the timing of amputation in the two groups

| Table 1. Demographics Of Subjects in the Early and Late Amputation Group |
|-----------------------------|-----------------|-----------------|--------|
| Patient Demographics        | Early (n=41)    | Late (n=38)     | p-value |
| Age (mean) (years)          | 39.2            | 48.7            | 0.008  |
| BMI (kg/m²2) (mean ± Standard Deviation) | 27.8 ± 4.4      | 32.1 ± 5.8      | 0.003  |
| Sex (female)                | 4 (10%)         | 7 (18%)         | 0.27   |
| Smoking status              | 21 (51%)        | 16 (42%)        | 0.48   |
| Diabetes                    | 0 (0%)          | 6 (16%)         | 0.009  |
| Hypertension                | 6 (15%)         | 15 (40%)        | 0.010  |
| Hyperlipidemia              | 2 (5%)          | 9 (23%)         | 0.014  |
| Heart Disease               | 0 (0%)          | 6 (16%)         | 0.008  |

Highlight indicates statistical significance.
Early versus Late BKA after Trauma

(Figure 2). The median duration between injury and amputation was 3 days in the early group versus 432 days in the late amputation group. There were significant differences in demographics between the two groups (Table 1). Specifically, the early amputation group was younger, with a mean age of 39.2 ± 15.1 years versus 48.7 ± 14.2 years in the late group (p=0.008). The early amputation group had fewer medical comorbidities with significantly lower rates of diabetes, hypertension, hyperlipidemia, and coronary artery disease (all p < 0.05). Motor vehicles were the most common cause of injury in both groups (Table 2). There were significantly more falls in the late amputation group (3/41 [7%], vs. 19/38 [51%]) and significantly more power take off injuries in the early amputation group (8/41 [20%] and 1/38 [3%]), both p<0.05 (Table 2). Open injuries were significantly more common in the early amputation group. Furthermore, subjects in the early amputation group were significantly more likely to be admitted to the ICU and receive blood transfusion during their initial admission (p= 0.02 and p=0.0001, respectively).

Table 2. Incidence of Injury Mechanism and Injury Characteristics Between the Early and Late Amputation Groups. Motor Vehicle Collision (MVC), Gustilo and Anderson Classification (GA)

<table>
<thead>
<tr>
<th>Injury Characteristics</th>
<th>Early (n=41)</th>
<th>Late (n=38)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVC</td>
<td>22 (56%)</td>
<td>15 (40%)</td>
<td>0.10</td>
</tr>
<tr>
<td>Power Take-off</td>
<td>8 (20%)</td>
<td>1 (3%)</td>
<td>0.03</td>
</tr>
<tr>
<td>Fall</td>
<td>3 (7%)</td>
<td>19 (51%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Low Energy Fall</td>
<td>0 (0%)</td>
<td>8 (21%)</td>
<td>0.002</td>
</tr>
<tr>
<td>Moderate Energy Fall</td>
<td>1 (2%)</td>
<td>5 (13%)</td>
<td>0.10</td>
</tr>
<tr>
<td>High Energy Fall</td>
<td>1 (2%)</td>
<td>4 (11%)</td>
<td>0.19</td>
</tr>
<tr>
<td>Open Fracture</td>
<td>39 (98%)</td>
<td>19 (51%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>GA: I</td>
<td>0 (0%)</td>
<td>1 (7%)</td>
<td></td>
</tr>
<tr>
<td>GA: II</td>
<td>1 (3%)</td>
<td>3 (20%)</td>
<td></td>
</tr>
<tr>
<td>GA: IIIA</td>
<td>0 (0%)</td>
<td>1 (7%)</td>
<td></td>
</tr>
<tr>
<td>GA: IIIB</td>
<td>26 (70%)</td>
<td>9 (60%)</td>
<td></td>
</tr>
<tr>
<td>GA: IICC</td>
<td>12 (32%)</td>
<td>1 (7%)</td>
<td></td>
</tr>
</tbody>
</table>

Highlight indicates significance.
However, individuals in the early amputation group were more likely to undergo unplanned revision than those in the late amputation group (p =0.0168). Overall, subjects in the early amputation group underwent fewer total orthopedic procedures (median n=4 [1-11] vs. n=6 [1-13], p=0.0010) (Table 3). Post-amputation unplanned readmission was common in both early and late amputation groups (20/41 [49%] versus 12/38 [32%], p=0.14) (Table 4). Postoperative deep or superficial infection was common in both early and late groups (17/41 [42%] vs 17/38 [43%], p=0.87) (Table 4). Most infections were superficial in both groups and were treated with oral antibiotics. Deeper infections requiring operative irrigation and debridement were slightly less common in both groups, and osteomyelitis was the least common in both groups. There were no significant differences between depth of infection seen between the two groups.

Hospital billing data was available for all subjects who were treated after 2002. Overall hospital cost data was available for 57/79 (72%); 28/41 (68%) were from the early amputation group and 29/38 (76%) of patients were from the late amputation group. Total hospital associated costs were similar between the two groups, median $136,044 vs $125,065, p=0.38 (Table 5). As expected, the early amputation group had significantly higher costs associated with the initial admission, median $106,039 vs $34,345, p<0.0001 (Table 5). Prosthetics and orthotics costs were available for 67/79 (84%) of subjects; 33/41 (80%) from the early amputation group and 34/38 (90%) from the late amputation group. Median total orthotics and prosthetics costs from the time of injury to two years following amputation were not significantly different between the two groups with $33,252 vs. $37,684, p=0.59. However, subjects in the late amputation group had higher median pre-amputation orthotic and prosthetic costs compared to the early amputation group, $0 vs $490, p=0.001 (Table 6).

### DISCUSSION

Given the profound impact of below knee amputations on patient’s physical and mental well-being, it is important for to study the outcomes of early versus late amputation to guide clinical decision making.

---

**Table 3. Median Pre-Amputation, Unplanned Revision, and Total Orthopedic Surgery Count For Patients Who Underwent Early and Late Amputation**

<table>
<thead>
<tr>
<th>Surgical Count (n (min-max))</th>
<th>Early (n=41)</th>
<th>Late (n=38)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-amputation orthopedic procedures</td>
<td>1 (0-4)</td>
<td>3.5 (0-12)</td>
<td>WRS: &lt;0.0001</td>
</tr>
<tr>
<td>Post-amputation unplanned revision</td>
<td>1 (0-5)</td>
<td>0 (0-2)</td>
<td>WRS: 0.0168</td>
</tr>
<tr>
<td>Total number of orthopedic surgeries</td>
<td>4 (1-11)</td>
<td>6 (1-13)</td>
<td>WRS: 0.0099</td>
</tr>
</tbody>
</table>

Highlight indicates significance. (WRS=Wilcoxon Rank Sum Test)

---

**Table 4. Clinical Outcomes of Duration Till Weightbearing, Infection, Readmission, and Revision Surgery in Patients Who Underwent Early and Late Amputation**

<table>
<thead>
<tr>
<th>Clinical Outcomes</th>
<th>Early (n=41)</th>
<th>Late (n=38)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration Until Weightbearing (days) (mean (min-max))</td>
<td>142 (43-815)</td>
<td>107 (45-638)</td>
<td>0.64</td>
</tr>
<tr>
<td>Post-Operative Infection</td>
<td>17 (42%)</td>
<td>17 (43%)</td>
<td>0.87</td>
</tr>
<tr>
<td>Superficial Soft Tissue Infection</td>
<td>8 (47%)</td>
<td>8 (47%)</td>
<td>0.80</td>
</tr>
<tr>
<td>Deep Tissue Infection</td>
<td>7 (41%)</td>
<td>5 (29%)</td>
<td></td>
</tr>
<tr>
<td>Organ Space Infection</td>
<td>2 (12%)</td>
<td>4 (23%)</td>
<td></td>
</tr>
<tr>
<td>Hospital Readmission</td>
<td>20 (49%)</td>
<td>12 (32%)</td>
<td>0.14</td>
</tr>
<tr>
<td>Revision Surgery</td>
<td>22 (54%)</td>
<td>10 (27%)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Highlight indicates significance.

---

**Table 5. Median Hospital Costs Associated With Early and Late Amputation by Time From Injury to Amputation, Amputation Admission, Two-Years Following Amputation, and Total Costs From Time of Injury to Two-Year Follow-Up**

<table>
<thead>
<tr>
<th>Hospital Costs (median (min-max))</th>
<th>Early (n=28)</th>
<th>Late (n=29)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Amputation Costs</td>
<td>$0 ($0-$241,438)</td>
<td>$60,814 ($0-$421,849)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Amputation Admission</td>
<td>$106,039 ($80-$540,026)</td>
<td>$34,345 ($19,619-$136,242)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Costs to 2 years Postoperative</td>
<td>$4,128 ($0-$103,586)</td>
<td>$2,363 ($284-136,242)</td>
<td>0.99</td>
</tr>
<tr>
<td>Total Costs Injury to 2 years Postoperative</td>
<td>$136,044 ($32,889- $540,026)</td>
<td>$125,065 ($22,429- $526,483)</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Highlight indicates significance.
Orthopaedic trauma surgeons must use their clinical experience along with careful assessment of the injury severity, risk for complications, potential for meaningful functional recovery with manageable pain, and healing potential, to make an informed recommendation for limb salvage versus amputation. This study compared associated costs and clinical outcomes of below knee amputation performed early after injury and after failed limb salvage. There was a high rate of unplanned hospital readmissions and reoperations in both groups. Superficial surgical site infections were common after these complex injuries. Unplanned reoperations were more common when amputation was performed early (≤ 6 weeks after injury). Individuals that underwent late amputations were typically older and had lower energy mechanisms of injury. Post-amputation prosthetic costs and overall hospital costs were similar comparing early and late below knee amputation.

Previous studies have investigated outcomes of early versus late amputation after trauma, but there is a lack of consensus defining late amputation. In previous reports, definition of late amputation varies widely from 24 hours to 10+ months following an injury. Others define amputation within the initial hospitalization. Heterogeneity among these definitions makes inter-study comparison difficult. In this study we defined early versus late amputation based on the median duration between the time of injury and amputation. This numerical definition of early versus late amputation facilitates inter-study comparison and simplifies application of data, from varying study populations, into clinical decision making.

Overall, there were significant differences in demographics between the two groups. The late group tended to be older with and more commonly have medical comorbidities such as diabetes and hypertension. Previous studies have associated these medical comorbidities with fracture related complication including falls, malunion and non-union. Poor healing may mediate failed limb salvage and subsequent late amputation in a poor host. Finally, lower energy mechanisms of injury, such as ground level falls were significantly more common in the late amputation group. This is likely due to the fact that older patients with medical comorbidities are more likely to develop complications with limb salvage endeavors subsequently leading to late amputation.

Early amputation was associated with higher rates of unplanned revision compared to the late amputation group. Huh et al. studied outcomes of limb salvage, early amputation and late amputations in soldiers with combat related lower extremity injuries. They found significantly higher rates of revision in service members who underwent late amputation compared to early amputation; 3.18 surgeries, range (1-11) versus 1.85 surgeries, range (1-11), p=0.0002. In contrast, this study found unplanned revision rates were higher with early below knee amputation. The definition of late amputation varies between the two studies as Huh et al. studied combat related injuries, with blast or gunshot wounds being the most common mechanism of injury in their study. In contrast, our study focused on the civilian population; motor vehicle accidents were the most common cause of injury and ballistic type injuries were rare. The differences in injury mechanisms and associated energy levels may mediate the discrepant findings between these studies. Specifically, higher energy mechanism of injuries associated with combat are more likely to cause significant soft tissue damage which may predispose patients to infection and non-union. Furthermore, differences may be explained by the varying definition of revision surgery between studies. Huh et al. did not include operative irrigation and debridement as revision procedures. In contrast, unplanned irrigation and debridement for wound breakdown or infection was considered a revision surgery in this study.

In 2009 Harris et al. conducted a study as part of the Lower Extremity Assessment Project (LEAP) study and investigated complication rates following early and late amputation. In this study early amputation was defined as one occurring within the initial hospital admission and late amputations occurred within 6 months. Within the early amputation group, Harris et al. reported re-admission rates of 43/149 (29.8%). In comparison we

<table>
<thead>
<tr>
<th>Prosthetic Costs</th>
<th>Early (n=33)</th>
<th>Late (n=34)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Amputation Costs</td>
<td>$0 ($0 - $3,643)</td>
<td>$490 ($0 - $11,358)</td>
<td>0.001</td>
</tr>
<tr>
<td>Post-Amputation 2-year Follow-up</td>
<td>$33,252 ($14,078 - $70,646)</td>
<td>$34,463 ($8,027 - $74,401)</td>
<td>0.98</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$33,252 ($15,714 - $70,646)</td>
<td>$37,684 ($8,027 - $76,597)</td>
<td>0.59</td>
</tr>
</tbody>
</table>

Highlight indicates significance.
found a high rate of unplanned readmission (22/41) in the early group. Their study reported higher rates of infection among late amputations 17/25 (68%) versus early amputations 51/149 (34.2%). In comparison, this study found comparable rates of infection between the early and late group with infection rates of 17/41 (42%) versus 17/38 (43%) respectively. It is worth noting that when their definition for early versus late amputation was applied to our data sample there were 35 patients in the early amputation group and 16 patients in the late amputation group. There was no significant difference between rates of readmission or post-operative infection between the two groups. Discrepancies regarding injury type and severity may be mediating these differences. Specifically, Harris et al. only included a variety of severe injury types in their study such as open fractures Gustilo and Anderson type IIIB and IIIC as well as degloving injuries. In comparison, this study did not require open injury or severe soft tissue injuries for inclusion. Rather, patients were included in this study if they had a history of below knee amputation following a traumatic injury, regardless of open or closed injury. Overall, open injuries were significantly more common in the early group (39/41 vs 19/38, p< 0.0001 (Table 2). Since open injuries are known to result in higher rates of infection, it is possible that the lower prevalence of open injuries mediated lower infection rate seen in the late group between the two studies.

In this study early amputation was associated with higher amputation admission hospital costs. The majority (35/41) of the early amputations occurred within the initial injury admission. Often these patients had high energy injuries such as MVAs and power take off injuries. Often patients had numerous injuries outside of the musculoskeletal system and required hospitalization in the ICU. Longer hospital admission can account for cost discrepancy between the two groups for the amputation admission. While initial admission costs were greater in the early group, total costs at two years following amputation were equivalent between the two groups. A study conducted by MacKenzie et al. investigated costs associated with limb threatening injuries as part of the LEAP study. While the primary focus of their investigation was the cost of amputation versus limb salvage, the paper describes 149 patients who underwent primary amputation during initial hospitalization and 12 patients who underwent amputation 3 months after initial injury discharge. The average two-year cost of the 100 patients who underwent below-knee amputations was $86,244. When costs associated with delayed amputation, were excluded from the cost of amputation at any level they found costs were similar with an average of $90,406. When correcting for inflation the cost in 2019 US dollars is $144,295 and $143,271 respectively. In comparison we found a similar two-year hospital associated cost for early and late amputation ($136,044 vs $125,065, p=0.38). The median two-years orthotics and prosthetic costs in our study in early and late group were similar ($33,252 versus $37,684, p=0.59). There are noteworthy differences between the two studies. For example, MacKenzie et al. included other levels of amputation other than below knee amputation, where our study focused solely on below knee amputations. Finally, Mackenzie et al. had a smaller sample size of patients in the delayed amputation group. While it is difficult to directly compare the two studies, it is noteworthy that both studies found comparable costs between early and late amputation groups.

Limitations
This study included patients who underwent below knee amputation over 17 years at a single institution. Management of these injuries evolve over time and care may vary between surgeons. These differences were not accounted for. Traumatic lower extremity injuries resulting in amputation are relatively rare we have a relatively small sample size. Furthermore, while an objective cutoff was used to define early versus late amputation, the selection for the cutoff was arbitrarily set using the median duration between injury and amputation. There were significant differences in demographics and mechanism of injury between the two groups and our analysis does not attempt to compensate for these differences. Rather this study describes demographic and inciting injuries that may predispose a patient to have an early amputation or failed limb salvage with subsequent late amputation. While the study describes hospital, orthotic and prosthetics costs the study does not attempt to quantify the cost of associated with decreased productivity or time off work. Finally, as temporal relationships are more difficult to assess in retrospective studies, we cannot reach any conclusions regarding causation, but only association.

CONCLUSION
In this study compared clinical and hospital and orthotic cost related outcomes among adults sustaining traumatic injuries who underwent below knee amputation. This study utilized an objective timeline of median time to amputation to differentiate early and late amputation following failed limb salvage. Individuals who underwent early amputation were more likely to require unplanned revision surgery. Hospital and prosthetic costs up to 2 years were comparable between early and late below knee amputation. Future larger scale studies are needed to further evaluate treatment outcomes between early and late amputations. These characteristics should be taken into consideration when determining appropriate treatment for high energy lower extremity trauma.

94 The Iowa Orthopedic Journal
REFERENCES


THE RURALITY OF LOWER EXTREMITY FIREARM INJURIES

Matthew D. McIlrath, BS; Kirk Welsh, BS; Ignacio Garcia Fleury, MD; Qiang An, MS; Joseph A. Buckwalter V, MD, PhD

1Department of Orthopedics and Rehabilitation, University of Iowa Hospitals and Clinics, Iowa City, Iowa, USA

Corresponding Author: Joseph A. Buckwalter V, MD, PhD, joseph-v-buckwalter@uiowa.edu

Disclosures: The authors report no potential conflicts of interest related to this study.

Sources of Funding: American Foundation for Surgery of the Hand Grant.

ABSTRACT

Background: To highlight the unique spectrum of lower extremity firearm injuries seen at a rural, Midwestern level 1 trauma center to provide insight into prevalence, mechanism of injury, and identify modifiable factors that contribute to firearm injuries of the lower extremity. It is our belief that the creation of our database will help future trauma and firearm databases improve documentation and understand the relationship between anatomic location of injury and outcomes.

Methods: A retrospective review of lower extremity firearm injuries from a rural, Midwestern level 1 trauma center was collected from January 2011 to December 2019. Data acquired included injury description; demographics, injury mechanism/description/location, firearm used, toxicology, and information regarding hospitalization. Data was analyzed using Chi-squared analysis and Fisher’s exact test for categorical data and the Wilcoxon rank sum test for continuous data.

Results: 69 patients with lower extremity firearm injuries were identified. Average age was 30.14 years, 89.86% were males, and one fatality were identified. 47.83% (33) of these injuries were assaults, followed by unintentional injuries at 42.03% (29). Law enforcement–related and self-inflicted injuries contributed minimally. Handguns were the most common type of firearm, used in 72.5% of cases. Nearly 1/3 of the unintentional firearm injuries occurred during November or December, the active deer hunting months in the community of study.

Conclusion: The lower extremity is uniquely vulnerable to both assaults and unintentional injury in our rural environment, differing from what we have previously published regarding the upper extremity. Lower extremity gunshot wounds increased during the winter months, offering a correlation to deer hunting season. Our findings display that not all firearm injuries are created equal, and that there is a need to improve documentation of and additional study in order to optimally tailor firearm prevention measures based on the rurality-urbanicity spectrum.

Level of Evidence: III

Keywords: firearm, rural, trauma, unintentional, lower-extremity, gunshot

INTRODUCTION

In 2016, the American College of Surgeons (ACS) issued a consensus statement recommending addressing firearm injury prevention as both a trauma system and public health problem.1 This initiative aligns with research efforts at our institution to better understand and manage firearm injuries.2 Existing firearm injury data identifies two major shortcomings in data collection and analysis. First, much of the epidemiological research on firearm injuries has focused primarily on the urban landscape and person-to-person violence, with less attention focused on the rurality of firearm injuries, and secondly, documentation of firearm injuries including: demographics, injury details and outcomes is universally poor. Although one may expect firearm death rates in urban areas to dwarf those of rural areas, multiple studies demonstrate that population-adjusted mortality rates are nearly equivalent in both urban and rural settings.3,4 It is for this reason that we feel compelled to contribute to the underrepresented rural firearm literature, with the ultimate goal of tailoring policies and interventions to communities based on where they fell on a rurality-urbanicity spectrum.

Currently, both national and state databases lack identification of the anatomic location of firearm injury. This makes is very difficult to glean information pertaining specifically to upper extremity injuries, for example. With that, we decided to create two novel databases, the first of which would include all the upper extremity injuries which presented to our institution during an allotted time frame. From that database, we showed that the majority of these injuries are unintentional in nature, isolated to...
one extremity, and non-fatal incidences, most commonly occurring to white males.5

This study was designed to highlight the unique spectrum of lower extremity firearm injuries seen at a rural, Midwestern level 1 trauma center to provide insight into prevalence, mechanism of injury, and identify modifiable factors that contribute to firearm injuries of the lower extremity. It is our belief that the creation of our database will help future trauma and firearm databases improve documentation and understand the relationship between anatomic location of injury and outcomes.

**METHODS**

After Institutional Review Board approval, retrospective data was collected through electronic medical record review from a rural, Midwestern state. The study population included patients who sustained lower extremity firearm injuries from January 2011 through December 2019. Exclusion criteria included military members and incarcerated patients. All patients with firearm injuries were identified via a search of this hospital’s trauma registry and then filtered using the International Classification of Disease versions 9 and 10 (ICD-9,10) to isolate firearm-related injuries to the lower extremity.

Analysis of patient demographics including race, sex, age, date of birth, and date of injury was performed. Descriptive information pertaining to the injury, included mechanism of injury, type of firearm used, associations to seasonal hunting, and injury anatomical location. The Gustilo-Anderson (GA) classification system was utilized in classifying cases associated with fractures.

Treatment details including date of admission, discharge, and first operation, as well as length of stay, injury to operation time, and total number of surgeries, were identified. Additional variables identified include toxicology and re-operations. Statistical analysis was performed to compare subgroups within the data set. Chi-squared analysis and Fisher’s exact test were used for categorical data, while continuous data was assessed via the Wilcoxon rank sum test.

**RESULTS**

**Demographics**

Sixty-nine patients were identified with lower extremity firearm injuries from January 2011 through December 2019, one of which resulted in fatality. 89.86% (62) of the injuries occurred in male patients. Ages ranged from 10 to 72 years with a mean of 30.14 years. 55.07% (38) of patients were Caucasian, 31.88% (22) were African-American, and 13.05% (9) were of another race.

**Mechanism of Injury**

The mechanism of injury was unintentional in 42.03% (29) of the cases, assault in 47.83% (33) of cases, and other, described as self-inflicted or law enforcement-related, in 10.14% (7) cases (Table 1). Caucasian individuals accounted for 86.21% (25) of the unintentional firearm injuries. With a population contribution of approximately

<table>
<thead>
<tr>
<th>Table I. Variables Based on Mechanism of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Unintentional N=29 (42.03%)</td>
</tr>
<tr>
<td>Assault N=33 (47.83%)</td>
</tr>
<tr>
<td>Other N=7 (10.14%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sex</th>
<th>Unintentional</th>
<th>Assault</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>25 (86.21%)</td>
<td>31 (93.94%)</td>
<td>6 (85.71%)</td>
</tr>
<tr>
<td>Female</td>
<td>4 (13.79%)</td>
<td>2 (6.06%)</td>
<td>1 (14.29%)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>25 (86.21%)</td>
<td>9 (27.27%)</td>
<td>4 (57.14%)</td>
</tr>
<tr>
<td>Black</td>
<td>2 (6.90%)</td>
<td>17 (51.52%)</td>
<td>3 (42.86%)</td>
</tr>
<tr>
<td>Other</td>
<td>2 (6.90%)</td>
<td>7 (21.21%)</td>
<td>-</td>
</tr>
<tr>
<td>Firearm Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handgun</td>
<td>21 (72.41%)</td>
<td>5 (15.15%)</td>
<td>1 (14.29%)</td>
</tr>
<tr>
<td>Shotgun</td>
<td>5 (17.24%)</td>
<td>2 (6.06%)</td>
<td>-</td>
</tr>
<tr>
<td>Rifle</td>
<td>3 (10.35%)</td>
<td>2 (6.06%)</td>
<td>1 (14.29%)</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>24 (72.73%)</td>
<td>5 (71.42%)</td>
</tr>
<tr>
<td>Extent of Injury</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isolated Injury</td>
<td>29 (100%)</td>
<td>30 (90.91%)</td>
<td>7 (100%)</td>
</tr>
<tr>
<td>Non-Isolated injury</td>
<td>-</td>
<td>3 (9.09%)</td>
<td>-</td>
</tr>
<tr>
<td>Average Duration of Hospitalization (Days)</td>
<td>2.24</td>
<td>5.97</td>
<td>-</td>
</tr>
</tbody>
</table>
4.1% in this Midwestern state, African Americans were the victims of assault in 51.52% of the total assaults observed in this cohort.

Of the cases in which the firearm was identified, handguns were the culprit in 72.5% of cases, with shotguns and rifles contributing to 17.5% and 10% of cases, respectively. Handguns remain prevalent when focusing exclusively on the unintentional mechanism, being the cause of injury in 72.41% (21) of these cases. The firearm type was classified as “other” in cases of metallic ball projectile firearms (BB guns), pellet, or most frequently, unidentification of firearm type in the medical record. Lack of identification could be due to lack of the victim identifying the firearm type, or the physician failing to report the firearm type in the medical record. Importantly, 72.73% (24) of the assault cases lacked identification of firearm type, contributing to much of the “other” classifications.

**Description of Injury**

The firearm injuries were classified as either isolated, in which case the patient presented with a single lesion, or non-isolated, presentation with multiple lesions. 95.65% (66) of all presentations were isolated injuries in nature. As seen in Figure 2, 100% of the unintentional firearm injuries were isolated, while assaults were more frequently associated with non-isolated injuries. Additionally, on average, initial hospitalization following an assault was 5.97 days in duration while the unintentional injury average stay was 2.24 days (p=.0139)

**Seasonal Associations**

Of the 69 total presentations, 4 (5.80%) of them were identified as hunting accidents, all of which occurred as unintentional firearm injuries among Caucasian men. Of the confirmed hunting incidents, 3 (75%) of them were due to shotguns in December. Among the 29 unintentional firearm injuries, 9, or nearly 1/3 of them, occurred in November or December, the active deer hunting months in the community of study.

**DISCUSSION**

Our findings demonstrate that both assaults and unintentional injuries play a significant role in the lower extremity firearm injuries which present to our rural, level 1 trauma center. This varies from what we observe with upper extremity injuries, as a previous study done at our institution showed that 58.2% of those injuries occurred unintentionally, with only 34.6% of cases being assaults. This may indicate that the upper extremity is more prone to unintentional firearm injuries.

Although our lower extremity cohort was split fairly evenly among unintentional and assault mechanisms, we do know that the assault mechanism remains a bigger issue in more urban environments. A previous report from 2012 found that rates of unintentional firearm death in the United States generally increased with increasing rurality, quantified as 2.16 times higher after adjusted for confounders, in most rural counties when compared with most urban counties. It is for this reason that we see potential to mitigate many of the firearm injuries that we see with proper interventions and gun safety protocols. By optimizing unintentional firearm injury prevention, we not only prevent these anatomically isolated injuries, but, in addition, our hospital will better be able to accommodate the frequently more complex injuries, and longer hospitalizations, that assault cases demonstrate.

One avenue of mitigation may be to focus our attention to a cultural norm of our rural environment. While deer hunting puts food on the table for many of our populants, it also puts individuals in potentially vulnerable situations. Figure 3 demonstrates that the peak
Month of firearm injuries is shown to be in December, overlapping with deer hunting season. Guetschow et al. found that rates of firearm injuries in their rural setting also increased during the winter months, most frequently attributable to use of shotguns.\(^2\) Of note, long guns of high caliber are frequently used when hunting large animals including deer. We too identified shotguns as a key player during this time, with 3/7 total shotgun presentations we studied occurring in December. As we recognize that not all winter time injuries can be attributed to hunting accidents, we hypothesize that the fluctuating seasons of our Midwestern state offer winter time to clean/maintain firearms of all types, which is frequently the event preceding unintentional firearm injuries.

Being the only tertiary trauma center, our team of orthopedic surgeons handles cases from all over the state. This experience and raw number of cases provides means to begin strengthening our understanding/documentation of firearm injuries. We believe that our datasets can serve as a new standard of documentation based on anatomy, as this is one way in which we can begin to elucidate and understand the nuances of firearm injuries to the various extremities. With this database as a starting point, we plan to continue to break down firearm injuries by anatomy and additional metrics, as more understanding is needed to most effectively target gun policies and interventions.

Limitations of our study include a relatively small sample size, in part due to the isolated focus on lower extremity, but also due to lack of identification of every firearm injury that has presented to our institution due to lack of accurate ICD coding and proper documentation guidelines for this type of injury on the part of the providers. Additionally, the retrospective nature of our study potentially biases data analysis.

**CONCLUSION**

We found that firearm injuries in rural settings are primarily unintentional as compared to interpersonal violence seen in more urban environments. Interestingly, based on the available data, it appears that the upper extremity is more subject to unintentional injury, with the lower extremity being more frequently implicated in assaults. Additional study will need to be done in order to parse this out. We note an increase in rates of firearm injuries during the winter months, offering a correlation to the hunting season in our rural region. Rural and urban environments face different risk factors, and ubiquitous policy is likely not the most effective way to reduce firearm injuries. We took a lower extremity approach when creating our database in order to identify ways in which the lower extremity may be uniquely vulnerable compared to the upper extremity. With our findings, we aim to highlight that not all firearm wounds are created equal, and that there is a need to improve documentation to allow for further subset studies. We feel that these are the necessary steps in order to optimally address firearm prevention as a trauma and public health problem.

**REFERENCES**

Background: Rotational ankle fractures are common injuries associated with high rates of intra-articular injury. Traditional ankle fracture open reduction and internal fixation (ORIF) techniques provide limited capacity for evaluation of intra-articular pathology. Ankle arthroscopy represents a minimally invasive technique to directly visualize the articular cartilage and syndesmosis while aiding with reduction and allowing joint debridement, loose body removal, and treatment of chondral injuries. The purpose of this study was to evaluate temporal trends in concomitant ankle arthroscopy during ankle fracture ORIF surgery amongst early-career orthopaedic surgeons while examining the influence of subspecialty fellowship training on utilization.

Methods: The American Board of Orthopaedic Surgery (ABOS) Part II Oral Examination database was queried to identify all candidates performing at least one ankle fracture ORIF from examination years 2010 to 2019. All ORIF cases were examined to identify those that carried a concomitant CPT code for ankle arthroscopy. Concomitant ankle arthroscopy cases were categorized by candidates self-reported fellowship training status and examination year. Descriptive statistics were performed to report relevant data and linear regression analyses were utilized to assess temporal trends in concomitant ankle arthroscopy with ORIF for ankle fractures. Statistical significance was defined as p<0.05.

Results: During the study period, there were 36,113 cases of ankle fracture ORIF performed of which 388 cases (1.1%) were performed with concomitant ankle arthroscopy. Ankle fracture ORIF was most frequently performed by trauma fellowship trained ABOS Part II candidates (n=8,888; 24.6%), followed by sports medicine (n=7,493; 20.8%) and foot and ankle (n=6,563; 18.2%). Arthroscopy was most frequently utilized by foot and ankle fellowship trained surgeons (293/6,270 cases; 4.5%) followed by sports medicine (29/7,464 cases; 0.4%) and trauma (4/8,884 cases; 0.1%). With respect to arthroscopic cases, 293 cases (75.5%) were performed by foot and ankle fellowship trained surgeons, 29 (7.5%) sports medicine, and 4 (1.0%) trauma. Ankle arthroscopy utilization significantly increased from 3.65 cases per 1,000 ankle fractures in 2010 to 13.91 cases per 1,000 ankle fractures in 2019 (p=0.010). Specifically, foot and ankle fellowship trained surgeons demonstrated a significant increase in arthroscopy utilization during ankle fracture ORIF over time (p<0.001; OR: 1.101; CI: 1.054-1.151).

Conclusion: Ankle arthroscopy utilization during ankle fracture ORIF has increased over the past decade. Foot and ankle fellowship trained surgeons contribute most significantly to this trend.

Level of Evidence: IV
Keywords: ankle, fracture, arthroscopy, ABOS Part II, utilization

INTRODUCTION
Unstable rotational ankle fractures represent the fourth most common surgically managed fracture pattern and occur at a rate of 187 per 100,000 person-years. The standard of care for these injuries is open reduction and internal fixation (ORIF) with generally favorable outcomes reported; however, unsatisfactory results still occur. A 10-year follow-up study demonstrated good to excellent outcomes in only 52% of cases with other studies reporting high rates of stiffness and persistent pain after ORIF. Poor outcomes of appropriately managed
ankle fractures may be due to unrecognized chondral or ligamentous injury.

Previous studies have estimated the rate of associated cartilage injury following rotational ankle fractures to be as high as 63-79%, potentially contributing to poor postoperative outcomes. Standard ankle fracture ORIF techniques provide limited capacity to evaluate the articular surface. Ankle arthroscopy presents a minimally-invasive technique to directly visualize the articular cartilage and syndesmosis and allows for assistance in reduction, joint debridement, loose body removal, and treatment of appropriate chondral injuries. The current literature is scarce regarding the utilization and outcomes of arthroscopic-assisted ankle fracture fixation. However, a recent meta-analysis suggests the addition of ankle arthroscopy yields superior functional outcomes compared to traditional approaches using only open techniques.

Practice patterns of young orthopaedic surgeons are often reflective of national trends in terms of procedure utilization in the academic setting and volume over time. A current understanding of the utilization of arthroscopic-assisted ankle fracture fixation is warranted given the high rate of intra-articular injury and its impact on postoperative outcomes. Furthermore, the evaluation of early-career surgeons can determine the influence of fellowship training status on procedure selection and utilization.

Orthopaedic surgeons trained in sports medicine, foot and ankle, trauma, and other subspecialties perform arthroscopy at variable rates, and the influence of fellowship training on the treatment of ankle fractures is currently unknown. Identification of these trends and influences has implications for practice design as well as training of both residents and fellows. The purpose of this study was to evaluate temporal trends in ankle arthroscopy utilization during ankle fracture ORIF amongst early-career orthopaedic surgeons while examining the influence of subspecialty fellowship training on concomitant ankle arthroscopy utilization during ankle fracture ORIF.

**METHODS**

The American Board of Orthopaedic Surgery (ABOS) grants board certification pending satisfactory completion of both Part I (computer-based multiple choice) and Part II oral case based board examinations. Following 22 months of clinical practice, candidates for the ABOS Part II Oral Examination collect and submit all surgical cases from a six-month time period (35 case minimum). Information regarding these submitted cases is compiled in an electronic database maintained by the ABOS and is available for research purposes. Part II Oral Examination surgical case-specific information includes Current Procedural Terminology (CPT) codes, International Classification of Disease Ninth and Tenth Revisions (ICD-9, ICD-10) codes, year of surgery, and surgeon reported postoperative complications. Patient demographics including gender and age are also recorded. Patient reported outcome data is not collected in the ABOS Part II Oral Examination database. The current study was deemed exempt from Institutional Review Board (IRB) approval given the de-identified nature of the data.

The ABOS Part II Oral Examination database was queried to identify all candidates who performed at least one ankle fracture ORIF (Current Procedural Terminology [CPT] codes 27766, 27769, 27784, 27792, 27814, 27822, 27823, 27829, 27846, 27848) from examination years 2010 to 2019. All ORIF cases were examined to identify those that carried a concomitant CPT code for ankle arthroscopy (CPT codes 29891, 29892, 29894, 29895, 29897, 29898, 29899). Concomitant ankle arthroscopy cases were categorized by candidates self-reported fellowship training status and examination year. Fellowship training status was stratified as foot and ankle, sports medicine, trauma, multiple fellowships, and no fellowship.

**Statistical Analysis**

Descriptive statistics were performed to report relevant data and linear regression analyses were utilized to assess temporal trends in concomitant ankle arthroscopy utilization with ORIF. Odds ratios (OR) and 95% Wald Confidence Intervals (CI) were reported, where appropriate. Statistical significance was defined as p<0.05.

**RESULTS**

Over the study period, there were 36,113 cases of ankle fracture ORIF of which 388 cases (1.1%) were performed with concomitant ankle arthroscopy. Patients who underwent concomitant ankle arthroscopy were significantly younger (36.2±15.9 vs. 45.6±19.2 years, p<0.001) while there was no difference in patient sex between the two groups (49.0% vs. 46.7, male, p=0.373). Ankle fracture ORIF was most frequently performed by
trauma fellowship trained candidates (n=8,888; 24.6%), followed by sports medicine (n=7,493; 20.8%) and foot and ankle (n=6,563; 18.2%) (Table 1). Over the study period, the number of ankle fracture ORIF cases performed significantly increased for foot and ankle fellowship trained candidates (p=0.009). Conversely, ankle fracture ORIF cases decreased in the sports medicine group (p=0.040) and did not change in the Trauma group (p=0.354).

When considering only ankle fracture ORIF cases with concomitant arthroscopy, 293 cases (75.5%) were performed by foot and ankle fellowship trained surgeons, 29 (7.5%) sports medicine, and 4 (1.0%) trauma (Table 2). Ankle arthroscopy utilization significantly increased from 3.65 cases per 1,000 ankle fracture ORIF cases in 2010 to 13.91 cases per 1,000 ankle fracture ORIF cases in 2019 (p=0.010) (Figure 1). Over the study period, candidates that completed a foot and ankle fellowship performed more ankle arthroscopies during ankle fracture ORIF over time (p<0.001; OR: 1.101; CI: 1.054-1.151). No such trends were noted for candidates trained in sports medicine (p=0.409; OR: 1.055; CI: 0.929-1.198), trauma (p=0.908; OR: 0.979; CI: 0.686-1.398), multiple fellowships (p=0.908; OR: 1.035; CI: 0.934-1.147), no fellowship (p=0.911; OR: 1.014; CI: 0.794-1.295), and other (p=0.298; OR: 1.215; CI: 0.842-1.755). During ankle fracture ORIF, foot and ankle fellowship trained surgeons utilized concomitant ankle arthroscopy most frequently at 4.5%, while sports medicine and trauma fellowship trained surgeons only utilized concomitant ankle arthroscopy during 0.4% and 0.1% of ORIF cases, respectively (Table 3).

### DISCUSSION

Although the overall rate of concomitant ankle arthroscopy was low in the study cohort (1.1%), utilization of ankle arthroscopy during ankle fracture ORIF increased ten-fold over the study period among ABOS

<table>
<thead>
<tr>
<th>Year</th>
<th>Foot and Ankle</th>
<th>Sports Medicine</th>
<th>Trauma</th>
<th>No Fellowship</th>
<th>Multiple Fellowships</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>2011</td>
<td>12</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>2012</td>
<td>28</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>44</td>
</tr>
<tr>
<td>2013</td>
<td>24</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td>2014</td>
<td>23</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td>2015</td>
<td>38</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>53</td>
</tr>
<tr>
<td>2016</td>
<td>33</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>39</td>
</tr>
<tr>
<td>2017</td>
<td>30</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>41</td>
</tr>
<tr>
<td>2018</td>
<td>68</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>9</td>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>2019</td>
<td>35</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td>293</td>
<td>29</td>
<td>4</td>
<td>8</td>
<td>50</td>
<td>4</td>
<td>388</td>
</tr>
</tbody>
</table>

Figure 1: Temporal Trend in Concurrent Ankle Arthroscopy with Open Reduction Internal Fixation for Ankle Fractures.
Table 3. Proportion of Concomitant Ankle Arthroscopy During Open Reduction Internal Fixation Stratified by Fellowship Training

<table>
<thead>
<tr>
<th>Fellowship</th>
<th>Total Arthroscopy Cases (n)</th>
<th>Total ORIF Cases (n)</th>
<th>Rate of Concomitant Arthroscopy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot and Ankle</td>
<td>293</td>
<td>6,270</td>
<td>4.5%</td>
</tr>
<tr>
<td>Sports Medicine</td>
<td>29</td>
<td>7,464</td>
<td>0.4%</td>
</tr>
<tr>
<td>Trauma</td>
<td>4</td>
<td>8,884</td>
<td>0.1%</td>
</tr>
<tr>
<td>Multiple</td>
<td>50</td>
<td>2,432</td>
<td>2.0%</td>
</tr>
<tr>
<td>None</td>
<td>8</td>
<td>3,837</td>
<td>0.2%</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>6,838</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

Part II examinees. While ABOS Part II Oral Examination examinees that completed a fellowship in trauma performed the most ankle ORIF cases overall, they exhibited the lowest arthroscopy utilization rate of 0.1%. Trainees with fellowship experience in foot and ankle performed the most ankle ORIF cases with concomitant arthroscopy and were primarily responsible for the increased utilization of ankle arthroscopy observed over the study period.

Postoperative outcomes following traditional ankle fracture ORIF have generally been favorable. However, a significant number of patients experience a poor outcome even if anatomic reduction of the ankle fracture is achieved. Unrecognized articular cartilage injury has been implicated in cases of unsatisfactory postoperative results, as these injuries have been associated with the development of posttraumatic arthritis regardless of bony reduction. Lantz et al. demonstrated that patients with ankle fractures and concomitant cartilage injury at the time of ORIF experienced poorer results than patients without chondral pathology. Furthermore, Thomas et al. performed ankle arthroscopy in patients with persistent issues following ankle fracture ORIF and identified chondral lesions in 90% of cases. Previous studies have estimated the rate of associated cartilage injury from 63-79% in the setting of ankle fracture, leading many authors to advocate for direct visualization of the articular surface via arthroscopy at the time of ORIF.

Ankle arthroscopy also represents a potential therapeutic tool as it allows for assisted articular reduction, joint debridement, loose body removal, and treatment appropriate chondral injuries. A large database study of ankle fracture ORIF cases performed with concomitant arthroscopy found that 22.4% of all patients that underwent ankle arthroscopy at the time of ankle fracture ORIF had osteochondral lesions addressed with microfracture. Other studies in the literature have reported favorable outcomes following ankle fracture ORIF with concomitant ankle arthroscopy. Turhan et al. retrospectively compared 21 patients managed with ankle ORIF with concomitant arthroscopy to 26 patients with traditional ORIF alone and found superior Olerud-Molander scores in the arthroscopy group. Additionally, in a study by Takao et al., 62 patients with ankle fractures were randomized to either traditional ankle ORIF or ORIF with ankle arthroscopy. At a mean of 40-month follow-up, the arthroscopy group exhibited significantly improved American Orthopaedic Foot and Ankle Society (AOFAS) scores. Lastly, a meta-analysis of the existing literature demonstrated improved functional outcomes with the use of ankle arthroscopy prior to ankle fracture fixation compared to ORIF alone.

The current study of 36,113 cases of ankle fracture ORIF demonstrated an overall concomitant arthroscopy rate of 1.1% among ABOS Part II Oral Examination examinees over the past decade. Similarly, Ackerman et al. performed a study utilizing the PearlDiver Patient Record Database from 2005-2011 of 32,307 ankle fractures and found a 1.0% rate of concomitant ankle arthroscopy. Although the overall rate of concurrent ankle arthroscopy was low in the study cohort, ankle arthroscopy utilization during ankle fracture ORIF increased ten-fold over the study period. The previously mentioned study by Ackerman et al. also demonstrated a significant increase in the utilization of arthroscopy with ankle fracture ORIF from 2007-2011, although prior fellowship subspecialty training of the treating surgeons was not assessed.

The increased utilization of concomitant ankle arthroscopy in the current study was primarily due to ABOS Part II Oral Examination examinees with foot and ankle fellowship training experience. These candidates performed 75% of the concomitant ankle arthroscopies during ankle fracture ORIF observed in the ABOS Part II Oral Examination database. Furthermore, concomitant arthroscopic case volume for candidates with trauma and sports medicine fellowship training experiences, as well as those that had completed multiple fellowships or had received no subspecialty training, remained unchanged over time. ABOS Part II Oral Examination candidates with trauma fellowship training experience performed the most ankle fracture ORIF procedures yet had the lowest rate of concomitant ankle arthroscopy utilization at 0.1%. In contrast, examinees with foot and ankle fellowship training performed the third most ankle fracture ORIF cases with the highest rate of concomitant ankle arthroscopy utilization at 4.5%. A possible explanation for this discrepancy is decreased exposure to arthroscopic procedures in a trauma fellowship compared when compared with foot and ankle or...
sports medicine fellowship leading to decreased familiarity early in practice. Further work is needed to evaluate the effect of arthroscopic case exposure in training with arthroscopy case volume once in practice.

Limitations
The present study has multiple limitations. First, the study design is a retrospective review of prospectively collected data. Inherent to any database study, there is a risk of inaccurate coding or reporting of procedural data. Also, fellowship training status is self-reported within the ABOS Part II Oral Examination database by the candidates and is not cross-referenced with actual training certificates. The ABOS Part II Oral Examination database does not contain patient reported or functional outcomes. Additionally, the extent of exposure to ankle arthroscopy during residency and fellowship training for each individual candidate is unknown. Next, there is variability within a physician’s practice over time. The relatively short reporting interval of six months required by the ABOS may not consistently represent cases from select practices. This is particularly important to consider during the 6-month ABOS Part II Oral Examination board collection period, which is a monitored period of a surgeon’s practice where individual cases are individually scrutinized which may influence treatment decisions. Ankle fracture pattern and characteristics, including injury pattern or degree of comminution, are not included in the ABOS Part II Oral Examination database. Additionally, surgical indications are not recorded in the database. Lastly, the data represents a group of surgeons during a unique period of their careers. The knowledge that treatment decisions or postoperative complications are being evaluated may lead to case volumes not indicative of standard practice.

CONCLUSION
Ankle arthroscopy utilization during ankle fracture ORIF has increased over the past decade. Foot and ankle fellowship trained surgeons contribute most significantly to this trend.

REFERENCES

ABOS Part II: Trends in Ankle Arthroscopy


QUALITY OF LIFE IMPROVEMENT FOLLOWING RECONSTRUCTION OF MIDTARSAL CHARCOT FOOT DEFORMITY: A FIVE YEAR FOLLOW-UP

Patrick Cole McGregor, MD1; Madeline M. Lyons, MD1; Michael S. Pinzur, MD1

ABSTRACT
Background: There is increasing interest in reconstruction of diabetes-associated Charcot foot arthropathy with the goal of improving quality of life.

Methods: Twenty-four patients who completed the Short Musculoskeletal Function Assessment (SMFA) at baseline and one year following Charcot foot reconstruction were contacted and asked to complete the survey at five years following surgery.

Results: Fourteen of the 24 patients completed the SMFA preoperatively, one year following surgery and five years postoperatively. Two patients underwent below knee amputation in the interim. Improvement was noted in all domains measured by the SMFA, with a statistically significant improvement in difficulty with daily activities at five years.

Conclusion: Correction of non-plantigrade Charcot foot arthropathy results in clinically meaningful improvement in health-related quality of life at both one and five years postoperatively, including independence with daily activities. The improvement is maintained when reevaluated at five years. This supports the modern paradigm shift towards reconstruction of this deformity.

Level of Evidence: III
Keywords: charcot foot, diabetes, quality of life

INTRODUCTION
A three-year observational study performed by the American Orthopaedic Foot and Ankle Society (AOFAS) Charcot Study Group demonstrated that patients with diabetes-associated Charcot foot arthropathy reported a severe negative impact on their health-related quality of life (HRQOL). The reported impairment was not improved with the then accepted accommodative bracing. Several subsequent investigations concluded that bracing (i.e. Charcot Restraint Orthotic Walker, CROW) of the acquired deformity led to very unfavorable outcomes. This finding led to the current interest in surgical correction of the acquired deformity with the goal of eliminating accommodative bracing and allowing affected patients to walk with commercially available diabetic footwear. Most recently, reconstructive-minded surgeons in North America have strongly advocated for limb salvage procedures via surgical reconstruction of the acquired deformities.

Despite the encouraging outcomes reported in the literature, there is a paucity of data examining long-term outcomes of deformity correction in this population. Specifically, few authors have reported on HRQOL or patient reported outcome measures (PROMs) after surgical reconstruction. Data published in 2018 demonstrated a quantitative improvement in HRQOL correction of deformity associated with Charcot foot arthropathy is associated with improved function and quality of life at one-year follow-up using the well accepted Short Musculoskeletal Assessment Examination (SMFA). The goal of this investigation is to determine if these observed improvements are maintained over time.

METHODS
Following approval by the Institutional Review Board, 24 patients were identified that had previously completed the SMFA instrument prior to and one year after undergoing surgical reconstruction for diabetes-associated Charcot foot arthropathy. One patient who was not able to complete the one year follow-up survey died from unrelated medical comorbidities. Patients were contacted via mail and phone and asked to complete the SMFA at a period of five years following surgery. Informed consent was obtained. A minimum of four attempts were made to contact patients using contact information listed in the electronic medical record.

All of the patients were classified as having non-plantigrade midfoot deformities using the classification of either Schon or Brodsky. None of the patients had either clinical or radiographic abnormalities at the level of the tibiotalar joint. Surgical correction included correction of the deformity, resection of osteomyelitis...
when present, and maintenance of the correction for twelve weeks with a statically applied circular external fixator.\textsuperscript{9,15} Figure 1 shows preoperative radiographs and clinical photos as well as postoperative photographs of a representative patient.

The SMFA has been previously utilized with reported consistency in a similar patient population.\textsuperscript{15} The SMFA is a 2-part, 46-item, self-reported health status questionnaire that can be completed by most individuals in 10 minutes. It consists of 2 indices (dysfunction and bother index) and 4 subscales (daily activities, emotional status, arm and hand function, and mobility). The dysfunction index assesses patients' perceptions of their functional performance of various tasks on a scale of 1 (not at all difficult) to 5 (unable to do). The bother index allows patients to assess how much they are bothered by problems in broad functional areas (i.e. how much are you bothered by problems with feeling dependent on others?) on a scale of 1 (not at all bothered) to 5 (extremely bothered).\textsuperscript{13}

**Statistical Analysis**

The SMFA survey raw scores were calculated using the published scoring criteria. The response to items were summated to establish scores on the dysfunction and bother indices. The scores were then standardized to range from 0 to 100 with use of the published scoring formula. Poorer function is indicated by higher scores.\textsuperscript{13} Descriptive statistics were utilized to analyze the differences between the preoperative and five year data for the group.

A paired t test was used to estimate the mean change in each standardized SMFA index from baseline to follow-up. Because of the small sample sizes, all conclusions were confirmed using an exact version of the nonparametric Wilcoxon signed rank test.

**RESULTS**

Twenty-four patients had previously completed the SMFA survey both preoperatively and at one year following correction of Charcot foot arthropathy. One patient died in the first year due to unrelated medical comorbidities. Sixteen of the initial study patients (66.6%) were successfully contacted and completed the SMFA survey at five years postoperatively; two of the 16 had subsequently undergone amputation between one and five years postoperatively and were thus not included in this analysis. Eight patients were unable to be contacted despite multiple attempts. At the time of surgery, the average age of the initial study population was 59.7. The average hemoglobin A1c was 8.1 and the average body mass index (BMI) of the population was 37.4.

As a whole, the mean values for all variables measured in the SMFA were improved at five years when compared to the preoperative values (Table 1). On a cohort level, there was a 17-point decrease in the SMFA standardized functional index and a 3.6-point decrease in bother index between the preoperative and the five year postoperative values. Similarly, when looking at individual domains, there was a 8.7-point decrease in difficulty with daily activities, 4-point improvement in motion, and 5.7-point improvement in mobility. The arm/hand domain demonstrated minimal change, with a 1.7-point decrease at five years.

![Figure 1. Preoperative and postoperative clinical photos and radiographs of a patient that underwent surgical reconstruction of a non-plantigrade, midtarsal Charcot foot deformity.](Image)
A Wilcoxon Rank Test was performed to evaluate differences between the SMFA domains at baseline and five years. There was a statistically significant difference between the Daily Activity index at baseline and 5-year follow-up ($p = 0.037$, 95% confidence interval 0.7 to 16.6). All other domains assessed by the SMFA demonstrated improvement between the two time periods as listed in table 1, but did not reach significance due to the limited sample size (Table 2).

### DISCUSSION

Surgical reconstruction of the acquired deformity associated with diabetes-related Charcot foot arthropathy is now well accepted among reconstructive-minded Orthopaedic Foot and Ankle Surgeons. It appears that favorable clinical outcomes are achieved when patients are freed from encumbering accommodative orthoses and can safely walk with commercially available diabetic footwear.$^{6,15}$ We specifically chose patients with simple midfoot deformity as these are the patients that most commonly undergo corrective surgery and the most likely to achieve favorable clinical outcomes.$^{16}$

Our population demonstrated a clinically significant improvement in all domains of the SMFA between baseline preoperative and five year postoperative measurements. There was a statistically significant improvement in difficulty with daily activities. This domain asks patients to rate their difficulty with tasks such as shopping, driving, housework, yardwork, and leaving home independently. In the pursuit of improving the quality of life in patients with Charcot foot arthropathy, the ability to perform these tasks is of immense importance to independent living.

There are several limitations to this investigation. The most obvious is the small sample size. We also were not able to contact eight of the original 24 patients. Two of the patients had subsequently undergone an amputation between one and five years postoperatively and thus were not included in this analysis. A portion of our patients included in the initial study were out-of-state and ultimately were lost to follow up. We did not have any record of additional deaths in the study population, however this must be considered given the complexity of medical comorbidities in this population. Given the small sample size, we were able to observe improvements in all domains of the SMFA but only the measure of daily activity was statistically significant. Finally, the SMFA relies on patient-reported outcomes which can be subject to bias. Comparing these outcomes over three separate time points does help to mitigate the subjective nature of PROMs.

Despite the rise in acceptance of this reconstructive procedure, there is a limited amount of data on clinical outcomes in these patients. A systematic review of surgical reconstruction in Charcot neuroarthropathy evaluated 1116 feet that were reconstructed using a variety of techniques over a 15-year period. Of these patients, bone fusion was reported at 86.1% and 91% had returned to ambulation. Only six of the 42 studies representing 0.07% of patients included in the review utilized patient reported outcome measures (PROMs).$^{17}$ The results of this investigation add to the growing body of literature that supports a meaningful clinical improvement in this population following surgical reconstruction. More specifically, our results suggest that the reported improvement in HRQOL as assessed by the SMFA previously observed at one year postoperatively appears to be maintained over a period of five years.
The intent of the study is to evaluate whether the improvements noted at one year postoperatively were maintained at five years postoperatively. Our results suggest that these patients do experience a clinically meaningful improvement in their quality of life and independence after surgical reconstruction of a plantigrade foot. This information offers assistance in counseling this medically complex patient population on treatment options. Further investigation including more complex deformities involving the tibiotalar joint is warranted.

REFERENCES
EVALUATING THE ASSOCIATION BETWEEN ANESTHESIA TYPE AND POSTOPERATIVE COMPLICATIONS FOR PATIENTS RECEIVING TOTAL ANKLE ARTHROPLASTY

Frank R. Chen, MD; Theodore Quan, BS; Joseph E. Manzi, BS; Alex Gu, MD; Chapman Wei, BS; Sean Tabaei, MD; Marc Chodos, MD; Cary B. Chapman, MD; Kane O. Pryor, MD; Jiabin Liu, MD, PhD

ABSTRACT

Background: Total ankle arthroplasty (TAA) is performed for ankle arthritis and there has been interest investigating which anesthetic method is the best choice in order to optimize perioperative outcomes. In this study, we compared postoperative complications after TAA for patients receiving either 1) general anesthesia alone or 2) general anesthesia plus regional anesthesia.

Methods: Patients undergoing primary TAA from 2007 to 2018 were identified in a national database. Patients were stratified into 2 cohorts: general anesthesia and general anesthesia combined with regional anesthesia. In this analysis, 30-day wound, cardiac, pulmonary, renal, thromboembolic, and sepsis complications, as well mortality, postoperative transfusion, urinary tract infection, extended length of stay, and reoperation were assessed. Bivariate analyses and multivariable logistical regression were performed.

Results: Of 1,084 total patients undergoing TAA, 878 patients (81.0%) had general anesthesia and 206 (19.0%) had general anesthesia combined with regional anesthesia. Following adjustment, there were no increased risk of postoperative complications in the combined general and regional anesthesia group compared to those who only underwent general anesthesia.

Conclusion: Compared to general anesthesia alone, the addition of regional anesthesia to general anesthesia for TAA is not associated with increased risk of complications in the perioperative period.

Level of Evidence: III

Keywords: general anesthesia, regional anesthesia, total ankle arthroplasty, complications

INTRODUCTION

Total ankle arthroplasty (TAA) is a common treatment option for patients with posttraumatic arthritis, osteoarthritis, or inflammatory arthritis of the ankle. With the rise of better weight-bearing implants that have shown to be successful for use in ankle arthroplasty, TAA is becoming an increasingly common procedure for patients with ankle arthritis.1 The incidence of ankle osteoarthritis is about 1% of the world population and TAA rates are expected to rise.14 Given that TAA has emerged as an excellent treatment option for ankle arthritis and a significant proportion of the world population has ankle arthritis, there has been great interest in seeing how best to optimize outcomes for patients receiving TAA.

Regional anesthesia and general anesthesia can be used for TAA and both have their advantages and disadvantages. The most common regional anesthesia block given for TAA is a sciatic block in the popliteal fossa which can be approached from either lateral or posterior aspect of the popliteal fossa.5 Local anesthetic introduced into the popliteal space through either approach targets the sciatic nerve and provides adequate anesthetic for all downstream branches of the sciatic nerve, which covers the surgical area of a TAA. However, the saphenous nerve is not targeted with a sciatic popliteal block and anesthetic must also be introduced at the medial proximal tibia to cover the superficial region of the TAA surgical field. Relative contraindications to this regional anesthesia include bleeding disorders, hematoma or local infection at the injection site. On the other hand, general anesthesia has also been used for these procedures. An advantage of general anesthesia is that the patient has a protected airway whereas patients receiving regional anesthesia do not have a protected airway even though they are still sedated, which can be
dangerous if complications arise during surgery that necessitate emergency airway management. An advantage of regional anesthesia for TAA is that it has been proposed to improve pain, patient satisfaction, and reduce hospital costs after foot and ankle surgery compared to general anesthesia.6,7 Various previous studies have investigated anesthesia effects on perioperative outcomes related to TAA. In their randomized control trial, YaDeau et al. found that general anesthesia combined with regional anesthesia was associated with earlier readiness for discharge compared to neuraxial anesthesia combined with regional anesthesia. They also found that pain scores and side effects were the same for patients receiving lower extremity surgeries.8 Matsumoto et al. found that anesthesia time over 200 minutes was an independent risk factor that is associated with increased rates of adverse events after TAA.9 Borenstein et al. found that the combination of regional anesthesia saphenous/popliteal nerve blocks with opioids after surgery was associated with satisfactory patient experiences and no readmission for pain control for TAA.10 While all of these studies investigated perioperative outcomes for patients receiving TAA in different clinical contexts, none of these studies investigated if general anesthesia versus general anesthesia combined with regional anesthesia was associated with differences in perioperative outcomes within 1 month of surgery. While Matsumoto et al. found that longer anesthesia time was associated with increased complications, they did not stratify anesthesia type into general anesthesia, regional anesthesia or both.9 While Borenstein et al. found that regional anesthesia combined with postoperative opioids was associated with no adverse outcomes, they did not compare this to general anesthesia.10 To our knowledge, we are the first study to compare postoperative outcomes for patients receiving general anesthesia versus combined general anesthesia and regional anesthesia for TAA procedures. We hypothesized that the addition of regional anesthesia to general anesthesia would affect length-of-stay which could then affect postoperative complications in the perioperative period. In this study, a national database was used to study differences in perioperative outcomes for patients receiving general anesthesia versus combined general anesthesia and regional anesthesia for TAA.

METHODS
A retrospective cohort study of all patients who underwent primary TAA was performed. Data were collected through the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database, which is a national database that includes data from more than 700 participating institutions. This data is collected by trained clinical reviewers and it includes preoperative, demographic, comorbidity, and postoperative data.11,12 This database has been widely used in orthopedic surgery to track the clinical course of patients.14,15

Patient Selection
From the years 2007 to 2018, patients who underwent primary TAA were identified using Current Procedural Terminology (CPT) code 27702. Patients were excluded from this study if they had missing data, such as if their sex, race, and American Society of Anesthesiologists (ASA) classification were unknown. Patients were also excluded if they were classified as ASA grade V, or if they were <18-years-old. In this study, two subgroups were used to evaluate the impact of anesthesia type on complications following TAA: general anesthesia and general anesthesia combined with regional anesthesia.

Baseline Patient Characteristics
Patients’ baseline demographics data and clinical characteristics included age, sex, race, BMI, ASA classification, smoking status, and functional status. Patient comorbidities included chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), hypertension, dialysis, steroid use, bleeding disorder, diabetes, and dyspnea. Weight loss was defined as >10% loss of body weight in the last 6 months.

Postoperative Complications
The outcomes were classified into clinically relevant groups based on the type of complication. These groups included wound (superficial surgical site infection, deep surgical site infection, organ or space infections, and/or wound disruption), cardiac (cardiac arrest and/or myocardial infarction), pulmonary (pneumonia, reintubation, and/or failure to wean off ventilator for more than 48 hours), renal (renal failure and/or renal insufficiency), thromboembolic (deep vein thrombosis, pulmonary embolism, and/or stroke), and sepsis (sepsis and/or septic shock). Based on existing literature, major complications (cardiac arrest, pulmonary embolism, intubation, myocardial infarction, sepsis, septic shock, renal failure, and/or mortality) and minor complications (urinary tract infection, deep vein thrombosis, pneumonia, superficial surgical site infection, and/or deep surgical site infection) were categorized.16,17 Mortality, urinary tract infection, bleeding requiring transfusion, extended length of hospital stay, and reoperation were also recorded. Extended length of stay was defined as >3 days based on previous studies.18

Statistical Analysis
The Statistical Package for the Social Sciences (SPSS; Version 26; Armonk, NY) software was utilized in this
study to conduct bivariate and multivariate analyses. Using Pearson's Chi-squared test and analysis of variance where appropriate, data on patient demographics, comorbidities, and postoperative complications were analyzed with bivariate analysis. Demographics, clinical characteristics, and comorbidities were included in the multivariate analysis for p-values < 0.20.19 Postoperative complication variables with a p-value < 0.05 were selected for multivariate analyses. Multivariate analysis results were reported as odds ratios with 95% confidence intervals. A p-value of < 0.05 was the cut-off value for statistical significance in this study.

RESULTS

Demographics
In total, 1,084 primary TAA patients were included in the analysis after the exclusion criteria was applied. There were 878 patients (81.0%) in the general anesthesia group and 206 (19.0%) in the general anesthesia combined with regional anesthesia group. There were no differences in age, sex, race, ASA classification, BMI, smoking status, and functional status when comparing patients who underwent general anesthesia to those who had general anesthesia combined with regional anesthesia (Table 1).

Comorbidities
When compared to patients who underwent general anesthesia, those who had general anesthesia combined with regional anesthesia were more likely to use steroids (p=0.034) and have diabetes mellitus (p=0.032) (Table 1). Also, there was no significant difference in operative time between the two groups.

Complications
Following TAA, on bivariate analysis, compared to patients who underwent general anesthesia, patients who underwent combined general and regional anesthesia were more likely to develop postoperative complications within the first 30 days, such as cardiac problems (p=0.039), thromboembolic complications (p=0.035), and urinary tract infections (p=0.004) (Table 2).

Following adjustment for covariates on multivariate analysis, patients who had combined general and regional anesthesia did not have significantly increased risk of cardiac problems, thromboembolic complications or urinary tract infections compared to patients who only underwent general anesthesia (Table 3).

DISCUSSION
To our best knowledge, this is the first study to use the ACS-NSQIP database to assess the association of anesthesia types with regards to postoperative complications after TAA. After adjusting for preoperative comorbidities, we found that the combinatory use of general and regional anesthesia was not associated with increased risk of complications within 30 days following TAA in the NSQIP database.

No prior studies have compared the effects of general anesthesia versus general anesthesia combined with regional anesthesia on postoperative complications after TAA. While YaDeau et al. found that general anesthesia with regional anesthesia was associated with increased readiness for discharge compared to neuraxial and regional anesthesia for lower extremity surgery, they did not explore rates of postoperative complications within a 1-month window after TAA or examine general anesthesia alone.8 Borenstein et al. and Matsumoto et al. did not stratify by anesthesia type and compare general anesthesia against regional anesthesia for TAA procedures.9,10

To begin, patients who underwent combined general plus regional anesthesia did not show a significant difference in need for extended length of hospital stay (defined as greater than 3 days) following TAA compared to those in the general anesthesia only group. This was a major factor in our initial hypothesis that combined general and would cause longer hospital stays in the combined group, resulting in a higher rate of postoperative complications. The fact that the two groups did not show a difference in extended hospital stay may explain why there was no significant difference in the rate of complications.

It was also interesting that, in this cohort, more of the combined general and regional anesthesia patients tended to have diabetes mellitus and chronic steroid use. Diabetes mellitus can alter platelet function, cause vasculopathy, and is a known risk factor for increasing thromboembolic events, such as deep venous thromboembolism (DVT), in total joint arthroplasties.21,22 Diabetic neuropathy is also a known risk factor for postoperative urinary retention, leading to increased risks for UTI during orthopedic procedures.21,22 The current literature regarding the risk of chronic steroid use for thromboembolic events is conflicting. In vivo studies have shown that corticosteroid use promotes decreased platelet aggregation, while other in vivo studies have shown that corticosteroids promote production of hypercoagulable proteins.24 Retrospective surgical studies have also reported variable findings regarding whether chronic steroid use could promote thromboembolic events.24,26 Additionally, chronic steroid use can increase risk for UTI following total joint arthroplasties given its immunosuppressive effects on top of anesthetic effects of causing postoperative urinary retention.27 After adjustment for multivariate analysis, rates of thromboembolic events and UTI were not significantly different between groups. This may suggest that these complications were in fact due to comorbidities like diabetes mellitus and steroid...
Table 1. Demographics and Comorbidities Among Patients Undergoing Total Ankle Arthroplasty

<table>
<thead>
<tr>
<th>Demographics/Comorbidities</th>
<th>General Anesthesia</th>
<th>General + Regional Anesthesia</th>
<th>p-value: general + regional anesthesia vs general anesthesia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total patients, n</td>
<td>878</td>
<td>206</td>
<td></td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>418 (47.6)</td>
<td>101 (49.0)</td>
<td>0.713*</td>
</tr>
<tr>
<td>Male</td>
<td>460 (52.4)</td>
<td>105 (51.0)</td>
<td></td>
</tr>
<tr>
<td>Ethnicity, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>791 (90.1)</td>
<td>193 (93.7)</td>
<td>0.176*</td>
</tr>
<tr>
<td>Black or African American</td>
<td>29 (3.3)</td>
<td>9 (4.4)</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>43 (4.9)</td>
<td>4 (1.9)</td>
<td></td>
</tr>
<tr>
<td>American Indian or Alaska Native</td>
<td>1 (0.1)</td>
<td>0 (0.0)</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>12 (1.4)</td>
<td>0 (0.0)</td>
<td></td>
</tr>
<tr>
<td>Native Hawaiian or Pacific Islander</td>
<td>2 (0.2)</td>
<td>0 (0.0)</td>
<td></td>
</tr>
<tr>
<td>ASA, n (%)</td>
<td></td>
<td></td>
<td>0.892*</td>
</tr>
<tr>
<td>I</td>
<td>33 (3.8)</td>
<td>7 (3.4)</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>495 (56.4)</td>
<td>112 (54.4)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>341 (38.8)</td>
<td>84 (40.8)</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>9 (1.0)</td>
<td>3 (1.5)</td>
<td></td>
</tr>
<tr>
<td>Smoker, n (%)</td>
<td>81 (9.2)</td>
<td>18 (8.7)</td>
<td>0.827*</td>
</tr>
<tr>
<td>Functional status preoperative, n (%)</td>
<td></td>
<td></td>
<td>0.469*</td>
</tr>
<tr>
<td>Independent</td>
<td>865 (99.1)</td>
<td>199 (98.5)</td>
<td></td>
</tr>
<tr>
<td>Partially dependent</td>
<td>8 (0.9)</td>
<td>3 (1.5)</td>
<td></td>
</tr>
<tr>
<td>Mean age, yrs (SD)</td>
<td>63.92 (10.31)</td>
<td>63.70 (10.19)</td>
<td>0.782**</td>
</tr>
<tr>
<td>Mean BMI (SD)</td>
<td>31.37 (6.00)</td>
<td>31.31 (5.52)</td>
<td>0.904**</td>
</tr>
<tr>
<td>COPD, n (%)</td>
<td>23 (2.6)</td>
<td>6 (2.9)</td>
<td>0.815</td>
</tr>
<tr>
<td>CHF, n (%)</td>
<td>5 (0.6)</td>
<td>1 (0.5)</td>
<td>0.884</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>490 (55.8)</td>
<td>127 (61.7)</td>
<td>0.128</td>
</tr>
<tr>
<td>Dialysis, n (%)</td>
<td>3 (0.3)</td>
<td>0 (0.0)</td>
<td>0.401</td>
</tr>
<tr>
<td>Steroid use, n (%)</td>
<td>31 (3.5)</td>
<td>14 (6.8)</td>
<td>0.034</td>
</tr>
<tr>
<td>Bleeding disorder, n (%)</td>
<td>28 (3.2)</td>
<td>7 (3.4)</td>
<td>0.879</td>
</tr>
<tr>
<td>DM status, n (%)</td>
<td></td>
<td></td>
<td>0.032</td>
</tr>
<tr>
<td>No DM</td>
<td>778 (88.6)</td>
<td>169 (82.0)</td>
<td></td>
</tr>
<tr>
<td>Noninsulin-dependent DM</td>
<td>80 (9.1)</td>
<td>28 (13.6)</td>
<td></td>
</tr>
<tr>
<td>Insulin-dependent DM</td>
<td>20 (2.3)</td>
<td>9 (4.4)</td>
<td></td>
</tr>
<tr>
<td>Dyspnea, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No dyspnea</td>
<td>851 (96.9)</td>
<td>194 (94.2)</td>
<td>0.060</td>
</tr>
<tr>
<td>Moderate exertion</td>
<td>24 (2.7)</td>
<td>12 (5.8)</td>
<td></td>
</tr>
<tr>
<td>At rest</td>
<td>3 (0.3)</td>
<td>0 (0.0)</td>
<td></td>
</tr>
</tbody>
</table>

*Pearson’s chi-squared test  
**Analysis of variance  
Bolding equals significance p<0.05  
ASA, American Society of Anesthesiologists; SD, standard deviation; BMI, body mass index; COPD, chronic obstructive pulmonary disease; CHF, congestive heart failure; DM, diabetes mellitus.
Effects of Anesthesia Type After Total Ankle Arthroplasty

In sum, our data suggest that there is no difference in postoperative complications between using combined general anesthesia with regional anesthesia versus general anesthesia alone following TAA. As suggested previously, addition of regional anesthesia has been suggested to improve pain, patient satisfaction, and reduce hospital costs after foot and ankle surgery compared to general anesthesia.6,7 While Matsumoto et al. found that anesthesia time over 200 minutes was independently associated with increased rates of adverse events after TAA, our study showed no difference in operative time between groups.9 Although we do not have specific data on total anesthesia time of the patients in this study, our data does suggest that addition of regional anesthesia did not significantly increase total anesthesia time during TAA. Considering this data in combination, we argue this method of anesthesia should be considered for patients undergoing this procedure going forward.

There are several limitations of this study. As with any database study, the NSQIP database is subject to coding error. However, coding error is assumed to be equally distributed between both groups (general anesthesia and general plus regional anesthesia). Another limitation is that we only had 206 patients receiving general anesthesia plus regional anesthesia compared to 878 receiving general anesthesia alone. While we did not find that there were statistically significant differences in postoperative complications, future studies that have more patients should be performed as it would have more power. In addition, future studies may investigate longer-term pain and function scores related to general versus regional anesthesia and compare these differences to different 1-month perioperative outcomes we have captured in our study. Another limitation to this study was that we were not able to elucidate specifically which TAA systems were used in our patient population, as this information is not available in the NSQIP database. Nevertheless, it is important to identify which systems were used, therefore future studies should evaluate the different TAA systems in this patient population to provide more information on this topic.

Compared to general anesthesia alone, the addition of regional anesthesia to general anesthesia for total ankle arthroplasty is not associated with increased risk of postoperative complications.

### Table 2. Bivariate Analysis of Postoperative Complications of Patients Following Total Ankle Arthroplasty

<table>
<thead>
<tr>
<th>Complications</th>
<th>General Anesthesia</th>
<th>General + Regional Anesthesia</th>
<th>p-value: general + regional anesthesia vs general anesthesiaa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total patients, n</td>
<td>878</td>
<td>206</td>
<td></td>
</tr>
<tr>
<td>Any complication, n (%)</td>
<td>19 (2.2)</td>
<td>8 (3.9)</td>
<td>0.154</td>
</tr>
<tr>
<td>Major complication, n (%)**</td>
<td>5 (0.6)</td>
<td>3 (1.5)</td>
<td>0.181</td>
</tr>
<tr>
<td>Minor complication, n (%)††</td>
<td>9 (1.0)</td>
<td>5 (2.4)</td>
<td>0.109</td>
</tr>
<tr>
<td>Death, n (%)</td>
<td>3 (0.3)</td>
<td>0 (0.0)</td>
<td>0.401</td>
</tr>
<tr>
<td>Wound complication, n (%)</td>
<td>8 (0.9)</td>
<td>1 (0.5)</td>
<td>0.544</td>
</tr>
<tr>
<td>Cardiac complication, n (%)</td>
<td>0 (0.0)</td>
<td>1 (0.5)</td>
<td>0.039</td>
</tr>
<tr>
<td>Pulmonary complication, n (%)</td>
<td>2 (0.2)</td>
<td>1 (0.5)</td>
<td>0.113</td>
</tr>
<tr>
<td>Renal complication, n (%)</td>
<td>1 (0.1)</td>
<td>0 (0.0)</td>
<td>0.628</td>
</tr>
<tr>
<td>Thromboembolic complication, n (%)</td>
<td>1 (0.1)</td>
<td>2 (1.0)</td>
<td>0.035</td>
</tr>
<tr>
<td>Sepsis complication, n (%)</td>
<td>1 (0.1)</td>
<td>1 (0.5)</td>
<td>0.263</td>
</tr>
<tr>
<td>Urinary tract infection, n (%)</td>
<td>1 (0.1)</td>
<td>3 (1.5)</td>
<td>0.004</td>
</tr>
<tr>
<td>Postoperative transfusion, n (%)</td>
<td>5 (0.6)</td>
<td>0 (0.0)</td>
<td>0.278</td>
</tr>
<tr>
<td>Extended length of stay (&gt; 3 days), n (%)</td>
<td>54 (6.2)</td>
<td>12 (5.8)</td>
<td>0.861</td>
</tr>
<tr>
<td>Reoperation, n (%)</td>
<td>6 (0.7)</td>
<td>1 (0.5)</td>
<td>0.750</td>
</tr>
</tbody>
</table>

aPearson’s chi-squared test
**Includes cardiac arrest, pulmonary embolism, myocardial infarction, unplanned intubation, sepsis, septic shock, acute renal failure, or mortality.
††Includes urinary tract infection, pneumonia, deep venous thrombosis, superficial surgical site infection, or deep surgical site infection.

Bolding equals significance p<0.05

### Table 3. Multivariate Analysis of Postoperative Complications of Patients Following Total Ankle Arthroplasty

<table>
<thead>
<tr>
<th>Complications</th>
<th>p-value</th>
<th>Odds ratio (general + regional anesthesia/general anesthesia) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac complication</td>
<td>0.659</td>
<td>1.724 (0.153 to 19.370)</td>
</tr>
<tr>
<td>Thromboembolic complication</td>
<td>0.083</td>
<td>10.550 (0.736 to 151.289)</td>
</tr>
<tr>
<td>Urinary tract infection</td>
<td>0.051</td>
<td>9.940 (0.988 to 99.995)</td>
</tr>
</tbody>
</table>

Bolding equals significance p<0.05
CI, confidence interval.
REFERENCES


ACUTE TARSAL TUNNEL SYNDROME AFTER TOTAL ANKLE ARTHROPLASTY WITH VARUS DEFORMITY

Obianuju A. Obioha, MD; Daniel D. Bohl MD, MPH; Simon Lee, MD; Kamran S. Hamid MD, MPH

ABSTRACT

Background: A 54-year-old woman presented with varus ankle arthritis, which was corrected with total ankle arthroplasty (TAA). Immediately postoperatively, she was insensate throughout the plantar foot. After seven weeks, she underwent tarsal tunnel release, and the tibial nerve was found to be intact. Plantar sensation improved by one week after exploration with neurolysis and was completely intact at one year.

Conclusion: Loss of plantar sensation can occur following TAA for varus arthritic deformity. One potential cause is tibial nerve compression from tightening the laciniate ligament, resulting in acute tarsal tunnel syndrome. The condition can be remedied with early recognition and tarsal tunnel release.

Level of Evidence: V

Keywords: tarsal tunnel syndrome, total ankle arthroplasty, varus deformity, ankle arthritis, plantar numbness

INTRODUCTION

Tarsal tunnel syndrome (TTS) is an uncommon entrapment neuropathy resulting from compression of the tibial nerve or its branches in the fibro-osseous space posterior and inferior to the medial malleolus. Risk factors include both intrinsic causes (e.g., ganglion cysts, tenosynovitis, tumors) and extrinsic causes (e.g., systemic inflammatory diseases, trauma, anatomic abnormalities). Diagnosis can be difficult as symptoms can be vague or inconsistent across presentations. After failing conservative management, surgical treatment involves ligamentous release and/or removal of the space-occupying lesion.

Total ankle arthroplasty (TAA) is used to treat tibiotalar osteoarthritis and can concurrently correct for coronal plane deformity with or without the use of associated osteotomies. Previously reported neurological injuries following TAA usually involve the deep peroneal, superficial peroneal, or common peroneal nerves, but there have been few reports of tibial nerve complications. In particular, we are aware of only three publications describing acute tarsal tunnel syndrome following TAA.

The following describes a case of acute TTS following TAA performed for varus arthritic deformity. Associated literature is subsequently reviewed. The patient consented to publication of her case.

Case Report

A 54-year-old female presented for evaluation of progressively worsening left ankle pain. She reported a previous ankle injury that involved a misstep during ambulation, as well as an associated ankle arthroscopy and debridement a year later with little improvement. At presentation to our clinic 11 years after the initial injury, she had worsening ankle pain and a hindfoot varus deformity. She had ankle dorsiflexion to neutral, plantar flexion to 15 degrees, and limited inversion and eversion. She was neurovascularly intact with good strength throughout and had normal sensation in the tibial, sural, saphenous and superficial/deep peroneal nerve distributions. Radiographs and CT of the left ankle (Figs. 1 and 2, respectively) demonstrated end-stage tibiotalar arthritis with a 15° varus tibiotalar deformity and a relatively preserved subtalar joint.

The patient consented to a left TAA, Achilles tendon lengthening, and possible Malerba valgus-producing osteotomy. She ultimately underwent left TAA with intra-articular deformity correction and Achilles triple-hemi-section; the Malerba osteotomy was deferred secondary to neutral hindfoot correction via the ankle replacement (Fig. 3). No intraoperative complications were noted. At her one-week postoperative visit, she was noted to be insensate throughout the full distribution of the tibial nerve distal to the tibiotalar joint line. After extensive discussion, early operative intervention for this neurologic deficit was deferred in favor of watchful waiting. At her three-week postoperative visit,
her numbness was unchanged, and she was prescribed gabapentin and a short course of steroids, again choosing watchful waiting as part of a shared decision-making process. At her third postoperative visit, her numbness remained unchanged, with no sensation to light touch or painful stimuli. She also demonstrated toe clawing and diminished toe abduction strength at this point. Electromyography revealed left distal tibial neuropathy. At this point, operative intervention with tarsal tunnel release and possible nerve repair and/or grafting was offered to the patient, to which she consented.

The patient returned to the operating room with the assistance of a hand surgeon trained in microsurgery to be available for any requisite neurologic reconstruction. The tibial nerve was approached through an incision beginning 4 cm proximal to the medial malleolus and curving around the medial malleolus into the plantar-medial midfoot, stopping at the level of the talonavicular joint overlying the midportion of the abductor hallucis muscle. The proximal portion of the laciniate ligament (flexor retinaculum) was identified and opened into the sheath containing the tibial nerve. The nerve was identified and followed distally with release of the laciniate ligament, exposing its three distal branches within the tarsal tunnel. The medial plantar nerve was identified and traced distally around the malleolus, following beneath the abductor hallucis to the talonavicular joint level, with complete release of its fibro-osseous tunnel. The lateral plantar nerve was also traced distally and released, including the abductor hallucis deep fascia. Finally, the first branch of the lateral plantar nerve was identified and similarly released. The tibial nerve and its branches were noted to be in continuity, with no evidence of complete or partial transection; however, the

Figure 1A to 1D. Preoperative radiographs of the left ankle in AP (1A), oblique mortise (1B), lateral (1C), and Saltzman (1D) weightbearing views.

Figures 2A to 2D. Preoperative CT scan of the left ankle in coronal (2A), axial (2B), and sagittal (2C) planes, as well as 3D reconstruction (2D).
nerve did have a boggy, edematous appearance within the tarsal tunnel (Fig. 4). The tibial nerve was not taut and had satisfactory excursion, and the laciniate ligament was not repaired during closure.

One week after tarsal tunnel release, the patient demonstrated partial return of sensation in the plantar midfoot arch. Three weeks postoperatively, the patient had sensation plantarly from the heel to midfoot but was insensate at the plantar forefoot. Toe abdution remained weak. She started formal physical therapy and transitioned to weightbearing in a supportive shoe. Five months postoperatively, she reported normal heel and midfoot sensation but persistent lack of plantar forefoot sensation. At one-year postoperatively, the patient was sensate throughout the plantar aspect with only minor occasional subjective paresthesias in the forefoot. At that time, 5.07 monofilament testing was intact throughout. Her toe clawing had resolved, and toe abduction strength approached that of her contralateral side.

DISCUSSION

Complete loss of plantar sensation is an uncommon complication following TAA and suggests acute tibial nerve injury. Complete or partial transection of the nerve during tibiotalar joint preparation is a possibility and can be difficult to distinguish from severe neuropraxia. We were prepared to address transection with microsurgical reconstruction during the secondary procedure. However, no evidence of transection was found.

A compression neuropraxia is another potential cause of acute complete loss of plantar sensation. Compression of the tibial nerve can occur in the tarsal tunnel and is referred to as TTS. Few TTS cases have been described after TAA in the literature, but this phenomenon can occur when the procedure involves correction of varus or valgus deformity. The mechanism is increased pressure within the tarsal tunnel due to constraint by the laciniate ligament. However, complete plantar sensation loss is a rare manifestation of TTS. More commonly, patients complain chiefly of shooting pain along the tarsal tunnel and into the plantar foot, sometimes associated with burning, tingling, and other paresthesias.

The diagnosis of TTS in this case is supported by a number of factors. First, there is an anatomic and physiologic explanation: varus deformity correction lengthened the medial side of the ankle putting tension on its surrounding retinaculum. Moreover, improved ankle dorsiflexion with the change from stiff and varus to valgus may have put more tension on the nerve. Second, release of the tarsal tunnel appeared to create
space around a compressed nerve that appeared boggy and dysvascular. Third, tarsal tunnel release resulted in rapid improvement in plantar sensation and eventual complete deficit resolution.

Diagnosis of TTS following TAA can be challenging due to variability in inciting factors and clinical presentation. For example, Bejjanki et al. reported on a TAA patient who developed acute TTS secondary to a displaced posteromedial osteophyte. This patient presented with heel pain, medial foot hypersensitivity, and abductor hallucis muscle wasting. The decision to remove the osteophyte only occurred after she was also found to have significant abductor hallucis denervation on nerve conduction studies. Removal resulted in signs of improvement by six weeks postoperatively, but the authors noted a five-month delay between symptom onset and surgery. Similarly, Primadi conducted a retrospective study of 150 TAA patients and found that tibial nerve complications occurred in nine (6%). Three of these patients were found to have TTS—of note, all three underwent coronal plane deformity corrections (two valgus, one varus). The presentation in each case was partial plantar numbness and pain/paresthesias. Two patients did not develop symptoms until three and six months after TAA, respectively, while the third patient experienced symptoms within the first month. All patients underwent tarsal tunnel release, with one patient experiencing complete symptom resolution and two experiencing partial resolution.

Tarsal tunnel syndrome has also been reported following lateralizing calcaneal osteotomy (LCO) in the correction of hindfoot varus. Krause et al. reported on two such cases in patients with Charcot-Marie-Tooth. Both patients developed numbness in the medial and lateral plantar nerve distributions, and one underwent tarsal tunnel release, resulting in complete symptom resolution. Bruce et al. later demonstrated that LCO produced a significant reduction in tarsal tunnel size, providing some rationale for prophylactic tarsal tunnel release in patients planning for LCO. While VanValkenburg found a tibial nerve injury rate of 33.8% in their 80 LCO cases, they found no difference in this rate between patients with and without prophylactic tarsal tunnel release. Hence, the role of prophylactic tarsal tunnel release prior to LCO remains unclear.

In conclusion, coronal plane deformity correction as part of TAA can rarely result in acute TTS. While this typically manifests as tarsal tunnel pain radiating into the plantar foot, we present here a case in which it resulted in complete plantar numbness, presenting more similarly to a complete or partial tibial nerve transection. Physical exam can also show toe abduction weakness and clawing, and electromyography is a helpful confirmatory study. Definitive treatment involves release of the tibial nerve and its branches as they pass through and exit the tarsal tunnel into the plantar foot. Timely and complete release can result in resolution of both sensory and motor symptoms.

REFERENCES


ABSTRACT

Background: The direct anterior approach (DAA) for total hip arthroplasty (THA) has been popularized as a less invasive technique, however outcomes within the first year of practice after fellowship have not been investigated. The primary aim was to determine differences in complications and outcomes between DAA and posterior approach (PA) in the first year of practice. The secondary aim was to determine if there was a learning curve factor in DAA and PA after fellowship training.

Methods: THA cases performed by two surgeons during their first year of practice were reviewed. Overall, 181 THAs (91 DAA, 90 PA) in 168 patients, were performed. Intraoperative differences (blood loss, operative time), hospital stay, complications, reoperations, and revisions were compared.

Results: Overall surgical complications were similar between DAA and PA (11% vs. 9%, p=0.64), but complication profiles were different: dislocation (1% vs. 4%, p=0.17), intraoperative femoral fracture (2% vs. 1%, p=0.32), postoperative periprosthetic fractures (2% vs. 3%, p=0.64), neuropraxia (3% vs. 0%, p=0.08). There was no difference in rate of reoperation (1% vs. 3%, p=0.31). There was a difference in rate of revision at final follow-up (0% vs. 6%, p=0.02). DAA consisted of longer operative time (111 vs. 99 minutes; p<0.001), however was only significant in the first 50 cases (p<0.001), while the subsequent cases were similar (p=0.31). There was no difference in the first 50 cases compared to the subsequent cases for either approach regarding blood loss, complications, reoperations, or revisions.

Conclusion: DAA and PA for THA performed within the first year of practice exhibit similarly low complication rates, but complication profiles are different. In our series, PA did demonstrate a higher risk of revision at final follow-up. A learning curve is not unique to the DAA. Both DAA and PA THA exhibited a learning curve in the first 50 cases performed at the start of a surgeon’s practice.

Level of Evidence: III

Keywords: total hip arthroplasty, direct anterior approach, young orthopedic surgeon

INTRODUCTION

The direct anterior approach (DAA) for total hip arthroplasty (THA) is promoted as a less invasive, musclesparing approach to the hip with a true internervous plane. Previous studies report its benefits including soft tissue preservation, less postoperative pain, shorter hospital stay, improved gait mechanics, and faster recovery time.1-7 Early studies proposed that patients may benefit from improved early functional outcomes including a lower risk of dislocation;3,8 however, longer-term studies have suggested that patient reported outcomes (PROs) and rates of instability are equivalent between DAA and other approaches.3,9-14 The caveat to potential early perioperative benefits is the reported “learning curve” associated with the DAA.15 Recent literature has reported significantly longer surgical times, more intraoperative blood loss, increased risk of intraoperative femur fracture, and increased wound complication rates using the DAA during a surgeon’s early caseload, including the first 50 cases.15-21

Most residency graduates currently undergo specialized fellowship training, and the impact of formalized fellowship training on the learning curve associated with complicated arthroplasty procedures has not been previously studied.22-25 The purpose of this study was to compare complications, reoperations, and PROs between the DAA and the posterior approach (PA) in the first year of practice. The secondary aim was to determine if there was a learning curve factor in DAA and PA after fellowship training. We hypothesized that there would be no differences between the DAA and PA THA in the
first year of practice following arthroplasty fellowship regarding learning curve, operative data, complications, reoperations, and revisions.

METHODS
Following Institutional Review Board approval, a retrospective review was performed on patients who underwent primary THA by two joint arthroplasty fellowship-trained orthopedic surgeons at one academic institution between September 1, 2017, and August 30, 2018. This time interval was chosen due to this being the first year of orthopedic arthroplasty practice after fellowship training for both surgeons. Both surgeons were trained in the DAA and PA as fellows at academic institutions. Exclusion criteria included age less than 18 years, direct lateral, or anterolateral approaches and THA performed due to malignancy.

Two-hundred and fourteen primary DAA or PA THA procedures (91 DAA; 122 PA) in 196 total patients were performed during the study period. 32 THAs were excluded from analysis selection of PA due to significant comorbidities, leaving 91 DAA and 90 PA THAs in the final analysis (Figure 1). Fifteen patients underwent bilateral procedures (6 DAA; 9 PA) during the study period with 1 DAA and 2 PA under the same anesthetic. All other bilateral surgeries were performed during separate hospital admissions. Indications for THA included 139 primary osteoarthritis (67 DAA, 72 PA), 19 aseptic osteonecrosis (9 DAA, 10 PA), 12 fractures (9 DAA, 3 PA), 6 secondary to osteoarthritis due to previous fracture or rheumatologic disease (3 DAA, 3 PA), 5 secondary osteoarthritis due to dysplasia (3 DAA, 2 PA).

There was no difference in demographics or medical comorbidities between the two groups except for different in body mass index (BMI). The mean body mass index BMI for DAA was 27 kg/m² and for PA was 33 kg/m² (p<0.001). The number of patients at or above BMI 40 kg/m² (0% vs. 26%) were different for the two approaches (p<0.001, Table 1, Table 2). The average time for final follow-up was 11 months (range: 0 to 29 months), with no difference between DAA and PA for final follow-up (10 vs. 11 months; p=0.17).

Procedure
All DAA procedures were performed supine on a Hana® fracture table (Mizuho OSI, Union City, CA). All PA procedures were performed lateral decubitus on a Capello board. The implants used by the senior authors varied according to preference and availability, however all acetabular components were press-fit porous-coated, with or without screw fixation. There was a mix of press-fit and cemented stems depending on the patient’s age.
and bone quality. All patients received the same standardized postoperative care. Patients in the PA group received standard posterior hip precautions. The DAA patients were given no restrictions.

Data Collection

Demographic data including age, sex, BMI, American Society of Anesthesia (ASA) classification, Charlson Comorbidity Index, smoking status, and medical comorbidities were analyzed. Patient charts were reviewed for postoperative complications including: surgical site infection (SSI), periprosthetic joint infection (PJI), venous thromboembolism (VTE), length of hospital stay (LOS), discharge destination, emergency department (ED) visit within 30 days, and hospital readmission within 30 days. SSI was defined as infections that did not extend past the fascia and were managed with oral antibiotics, wound care, or superficial irrigation and debridement. PJI was defined using the Musculoskeletal Infection Society (MSIS) criteria. Operative reports were examined for surgical approach, anesthetic type, operative time, and intraoperative complications. Blood loss was determined with computed total blood loss per the OSTHEO study calculations outlined by Rosencher and colleagues. Patients undergoing bilateral THA under the same anesthetic (n=3) were excluded from blood loss analysis. Additionally, two more patients were excluded from this analysis due to lack of post-operative hematocrit as they discharged the same day.

Reoperation was considered a return to the operating room without removing/altering the bony prosthetic components. Revision was defined as removal of any prosthetic component at the bone interface.

Patient reported outcomes (PROs) were collected for all patients at least preop within 3 months (90 days) prior to surgery and follow-up at least 3 months postop (90 days). The Patient Reported Outcome Measurement Information System (PROMIS) global health scores for mental health (MH) and physical function (PF) were analyzed.

Learning Curve

The first 50 cases were compared to the subsequent procedures, as well as the first six months (9/1/17–2/28/18) to the last six months (3/1/18–8/30/18) within the specific approach. Additionally, the first 6 months (42 DAA and 39 PA cases) were compared to the subsequent cases (49 DAA and 51 PA) cases during the first year of practice.

Statistical Methods

An unpaired, unequal variance, two-tailed t-test was used to compare continuous variables. Fisher exact and Pearson Chi-Square tests were used to evaluate significant differences in categorical variables including complications between the groups. Stata (version 15.1;
130  The Iowa Orthopedic Journal

DAA - Direct Anterior Approach; PA - Posterior Approach; PRBC: Packed Red Blood Cells; UTI: Urinary Track Infection; DVT: Deep Vein Thrombosis; PE: Pulmonary Embolism; * indicates significance.

StataCorp, College Station, TX, USA) was used for all statistical analysis, with significance determined by a P value <0.05.

RESULTS

Operative details and hospital stay

Mean procedure time was significantly longer for DAA (111 vs. 99 minutes; p<0.001). There was no difference in the mean LOS (2.2 vs. 2.0 days, p=0.53) or patient disposition location; however, more DAA patients were discharged to a nursing facility (13% vs. 7%; p=0.15; Table 3) The average computed blood loss was 1183 mL (range: 126-3136 mL) with no difference between the approaches (p=0.06; Table 4).

Patient Reported Outcomes

There were a total of 44 (48.4%) DAA and 39 (43.3%) PA PRO were completed. The mean preoperative and postoperative PROMIS-PH scores were 40.3 (±7.7) and 46.3 (±8.2) for DAA and 38.6 (±7.3) and 45.0 (±10.3) for PA. Mean PROMIS-MH scores were 48.2 (±8.1) and 49.1 (±8.3) for DAA and 49.5 (±9.7) and 49.2 (±8.6) for PA. There was no difference between the groups when comparing the change of preoperative to postoperative scores (p=0.31, p=0.71).

Dislocations

Overall, 2.8% (n=5) primary THAs had a dislocation event. There was no significant difference in dislocation rate between the two approaches (1% DAA vs. 4% PA, p=0.17). One case in the DAA group (1.1%) dislocated, that was managed by closed reduction. Four dislocations occurred in the PA group (4.4%), of which two were successfully closed reduced and two eventually underwent revision due to recurrent instability. (Table 5)

Periprosthetic Fractures

Overall, an intraoperative femoral fracture occurred in 1.7% of THA procedures (2 DAA vs. 1 PA, p=0.48). All fractures were successfully managed with intraoperative cables and/or postoperative protected weight bearing.
There were five (2.8%) postoperative periprosthetic fractures (2 DAA vs. 3 PA, p=0.64). Postoperative periprosthetic fracture events are detailed in Table 6.

**Infection**

There was no difference in the rate of SSI between approaches (3 DAA vs. 3 PA; p=0.64). Two PA hips were diagnosed with acute PJI with MSIS major criteria (>2 positive intraoperative cultures (staphylococcus lugdunensis, morganella morganii). One PA hip was diagnosed with chronic PJI using MSIS major criteria (>2 positive tissue cultures of staphylococcus aureus), 18 months from primary procedure.

**Nerve Related Complications**

Three (3%) neurologic injuries occurred in the DAA group (2 lateral femoral cutaneous nerve dysesthesias, 1 partial femoral nerve neurapraxia; p=0.4) and none in the PA group. The three nerve injuries in the DAA approach remained present at final follow-up (Table 5).

**Medical Complications**

There was no difference between the two approaches in regard to readmission rates within 30 days of primary procedure (1.1% vs. 3.3%, p=0.30). A total of 3 (3.4%) PA patients had medical complications. None of the DAA cohort (0%) had medical complications (Table 3).

**Reoperations**

Overall, 4 hips (2.4%) required reoperation (Table 5). One (1.1%) DAA underwent reoperation due to Vancouver C periprosthetic fracture, requiring cable fixation and lateral locking plate (Table 6). As previously reported, three PA hips underwent reoperation for

---

**Table 6. Periprosthetic Femur Fracture**

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>BMI</th>
<th>Comorbidities</th>
<th>Time (post op)</th>
<th>MOI</th>
<th>Vancouver Classification</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>Female</td>
<td>13</td>
<td>Myotonic dystrophy, Osteopenia</td>
<td>2 weeks</td>
<td>Felt a “pop” and severe pain during abduction while getting out of bed</td>
<td>Vancouver A (Greater trochanter with 3 mm displacement)</td>
<td>Non-operative: TTWB, No active abduction</td>
</tr>
<tr>
<td>65</td>
<td>Female</td>
<td>22</td>
<td>DDH, Osteoarthritis of Lumbar Spine with fusion to Pelvis</td>
<td>4 weeks</td>
<td>TTWB due to intraoperative fracture treated by removing the stem, placing 2 proximal and one distal cerclage wires around the fracture to reduce it, and passing the stem through the reduced fracture. Placed NWB 2 weeks post op due to subsidence of stem. Sustained a ground level fall resulting in Vancouver C periprosthetic fracture.</td>
<td>Vancouver C</td>
<td>Reoperation: Retention of stem. Proximal femur lateral locking plate and cerclage wiring</td>
</tr>
<tr>
<td>89</td>
<td>Female</td>
<td>40</td>
<td>COPD, Right MCA stroke with contralateral weakness, Lumbar fusion</td>
<td>5 weeks</td>
<td>Ground level fall while getting out of bed</td>
<td>Vancouver A (Greater trochanter)</td>
<td>Non-operative: TTWB, No active abduction</td>
</tr>
<tr>
<td>52</td>
<td>Female</td>
<td>33</td>
<td>Crohn’s disease (long term corticosteroid use), chronic pain, chronic alcohol use disorder, anxiety, migraine, borderline personality</td>
<td>4 weeks</td>
<td>Relapse of her depression as well as her alcohol abuse, has had multiple falls. Admitted to psychiatric unit for suicidal attempt. Ground level fall directly on the ipsilateral hip in the shower. Radiographs demonstrated subsidence of her femoral component and medial fracture confirmed on CT scan</td>
<td>Vancouver B</td>
<td>Revision: New femoral stem with cerclage wiring</td>
</tr>
<tr>
<td>81</td>
<td>Female</td>
<td>27</td>
<td>Cervical Myelopathy, ataxia lumbar spinal stenosis, scoliosis and symptoms of neurogenic claudication, CKD</td>
<td>3 weeks</td>
<td>Missed hand grip of walker resulting in a ground level fall</td>
<td>Vancouver A (Medial Cortex above Lesser Trochanter)</td>
<td>Revision: New femoral stem with cerclage wiring</td>
</tr>
</tbody>
</table>

DAA: Direct Anterior Approach; PA: Posterior Approach; MOI: Mechanism of Injury; BMI: Body Mass Index; * indicates significance.
infection, with one case requiring superficial irrigation due to SSI, with no evidence of arthroscopy. Two cases underwent irrigation and debridement with polyethylene exchange due to acute PJI. There was no difference in rate of reoperation between the two groups at final follow-up (p=0.31) (Table 5).

Revisions

There were no revision procedures performed in the DAA cohort, compared to 5 (6%) in the PA cohort. Two revision cases were due to recurrent instability. Two revision cases were due to postoperative periprosthetic fractures. Both cases underwent successful revision of the femoral component to a fluted, tapered design. One revision was due to the previously mentioned chronic PJI that occurred 18 months after primary procedure. There was no difference in rate of reoperation between the two groups at final follow-up (p=0.31) (Table 5).

Learning Curve

The BMI was lower in the first 50 DAA cases when compared to the subsequent cases (p=0.02). Although the DAA consisted of longer operative time when compared to the PA, this was only significant in the first 50 cases (p<0.001), while the subsequent cases were similar (p=0.31).

There was a longer LOS when comparing the first 50 DAA cases to the subsequent cases (p=0.03). Age, blood loss, rate of complications, reoperations, and revisions did not change between the early cases to the subsequent cases. Additionally, there was no difference in complications, reoperations, and revisions when comparing the first months of practice to the subsequent cases in the first year. (Table 7)

DISCUSSION

This study took advantage of the unique opportunity to follow the practices of two new, fellowship trained surgeons. We investigated differences between the DAA and the PA during the first year of practice after completing a joint arthroplasty fellowship. We found no difference in blood loss, transfusion rate, LOS, complications, readmissions, reoperations, or PRO between the two approaches. The DAA did consist of longer procedure duration, while the PA had a higher incidence of revisions at final follow-up. This study also assessed the impact of learning curve by comparing the first 50 cases with subsequent cases and cases performed in the first 6 months versus the second 6 months. We found minimal evidence for DAA or PA learning curve except in operative time.

There continues to be conflicting evidence on the differences in blood loss, operative time, LOS, and institutional disposition between the DAA and conventional approaches, with several studies demonstrating higher surgical blood loss, longer procedure duration, and shorter LOS associated with the DAA approach. We found no difference in blood loss or transfusion

<table>
<thead>
<tr>
<th>Table 7. Direct Anterior Approach and Posterior Approach Learning Curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAA</td>
</tr>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>BMI</td>
</tr>
<tr>
<td>Computed Total Blood Loss (mL)</td>
</tr>
<tr>
<td>Duration (minutes)</td>
</tr>
<tr>
<td>Length of Stay (days)</td>
</tr>
<tr>
<td>Reoperations and Revisions</td>
</tr>
<tr>
<td>PA</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
</tr>
<tr>
<td>Computed Total Blood Loss (mL)</td>
</tr>
<tr>
<td>Duration (minutes)</td>
</tr>
<tr>
<td>Length of Stay (days)</td>
</tr>
<tr>
<td>Reoperations and Revisions</td>
</tr>
</tbody>
</table>

DAA - Direct Anterior Approach; PA - Posterior Approach; BMI - Body Mass Index (kg/m²) * indicates significance.
rate, LOS and non-institutional discharge between the approaches.

Intra-operative fractures of the proximal femur are often discussed in the DAA, with a reported incidence of 1.4-2.3%.\textsuperscript{31-33} Femoral fracture risk appears to be relatively higher in the DAA.\textsuperscript{34} While the current study demonstrated no statistical significant difference between the two approaches, the incidence of an intraoperative fracture was more common in the DAA compared to the PA, consistent with previous research.

Due to its intermuscular nature and preservation of the posterior soft tissue envelope, the DAA has been historically known to have a lower dislocation risk compared to the PA.\textsuperscript{8} More recent studies have reported similar dislocation rates in the DAA and PA without significant difference between the two approaches, citing the positive effects of modern techniques of posterior soft tissue repair, larger femoral head sizes, and increased offset stems in reducing dislocation rates.\textsuperscript{30,35-39}

While our results demonstrated no statistical difference in dislocation rates between the approaches, instability was more common in the PA patients. It is important to note the patient selection bias involved in the current study, as the DAA surgeon did reserve PA for heavier patients early in the learning curve, who may have been at risk for dislocation due to elevated BMI.

Transient neuropaxia of the LFCN has been reported to be as high as 81% of patients undergoing DAA THA\textsuperscript{40-43} and represents the most common complication using this approach.\textsuperscript{33}

However, most studies report significant improvement or resolution of sensory disturbance over time.\textsuperscript{40,41} In PA THA, the sciatic nerve is most at risk, with a reported 0.3-1.3% incidence of injury.\textsuperscript{44-47} In this study’s cohort, no PA cases sustained nerve injuries, while two DAA cases sustained neuropaxia to the LFCN and one case with reported partial femoral neuropathy.

In our study, there was no difference in reoperation rates between the two groups; however, five revisions were performed in the PA group while no DAA cases required revision during the study period. Revisions in the PA group were performed specifically for two periprosthetic fractures, two cases of recurrent instability, and one patient with PJI that occurred 18 months after primary procedure. Consistent with our findings, Gwan et al. reviewed 258,461 revision cases using the National Inpatient Sample database and demonstrated that persistent dislocation events are the most common etiology for revision THA.\textsuperscript{48} Sheth et al. examined a decade’s worth of data and compared DA, PA, direct lateral, and anterolateral approaches in regard to aseptic revision, revision for infection, and dislocation.\textsuperscript{49} They demonstrated no difference in adjusted risk for revision in any of the groups, however the anterolateral and DAA groups had a significantly lower risk of dislocation when compared to the PA. In contrast to our findings and the previously mentioned studies, Pincus et al. performed a large propensity-score matched analysis of 5,986 cases and suggested that the DAA is associated with both a higher risk of revision arthroplasty, deep infection requiring reoperation, and dislocation required closed or open reduction.\textsuperscript{50} However, this study matched the DAA cases (n=2,993) to a heterogeneous group that included only 22% PA cases (n=667) and 78% direct lateral cases (n=2326), providing confounding conclusions when comparing DAA to PA.

Learning Curve

The learning curve has been a significant interest when discussing advanced surgical approaches. Previous studies have investigated complication rates in surgeons changing approaches, resulting in a steep learning curve with reports of 20 to 300 cases.\textsuperscript{18,21,54-56} This in turn has many senior surgeons questioning the benefits of transition and incorporation of the DAA into their practice.\textsuperscript{57,58} However, there are no known studies investigating the learning curve and associated outcomes within the first year of practice after a dedicated arthroplasty fellowship.

In a comparison of DAA and PA used by surgeons early in their training, Spaans et al. evaluated two equal numbered groups of age- and comorbidity-matched patients across a year-long time period.\textsuperscript{18} Patients undergoing DAA THA experienced nearly twice the operative time and blood loss, in addition to a higher complication rate. The study did trend a decrease in operative time as surgeons gained experience, but this was not found to be statistically significant. We demonstrated similar findings, with a difference between DAA and PA operative time only being present when comparing the first 50 cases.

Limitations

Cases were reviewed from a single academic center, which limits the generalizability of the findings. Additionally, the specific approaches were performed by separate surgeons. This study’s cohort had mean BMI of 30, including 22 patients $\geq$40 kg/m\textsuperscript{2} in the PA cohort and 0 in the DAA patient cohort. While there continued to be a difference with exclusion of this subgroup, the significant proportion of obese patients in the PA group may have impacted the results of this study as it is known that morbid obesity is clearly associated with intraoperative differences (blood loss, operative...
time), hospital stay, complications, reoperations, and revisions. Additionally, the amount of PRO forms that patients completed were minimal, providing a lack of conclusions on PRO scores.

CONCLUSION
Both DAA and PA for THA have similarly low complication rates within the first year of practice following fellowship training. A learning curve is not unique to one approach. Femoral complications and nerve injuries are more common in DAA, while dislocation is more common in the PA.

REFERENCES


ABSTRACT

Background: Dual mobility (DM) bearings for total hip arthroplasty (THA) have been proposed to reduce the risk of instability in high-risk patients; however, their utility in primary THA remains relatively unexplored. No previous reports have described whether surgical approach influences outcomes associated with DM implant systems. This study aims to compare patient reported outcomes and post-operative groin pain between patients undergoing anterior approach versus posterior approach following primary THA with DM implants.

Methods: We retrospectively reviewed all patients who underwent primary THA and received a DM implant between 2011-2021. Patients were stratified into two cohorts based on surgical approach (anterior vs. posterior approach). Primary outcomes included the presence of substantial postoperative groin pain as well as readmission and revision rates. Demographic differences were assessed using chi-square and independent sample t-tests. Outcomes were compared using multilinear and logistic regressions.

Results: Of the 495 patients identified, 55 (11%) underwent THA via the anterior approach and 440 (89%) via the posterior approach. Surgical time (100.24 vs. 109.42 minutes, p=0.070), length of stay (2.19 vs. 2.67 days, p=0.072), discharge disposition (p=0.151), and significant postoperative groin pain (1.8% vs. 0.7%, p=0.966) did not statistically differ between the cohorts. 90-day readmission (9.1% vs. 7.7%, p=0.823) and revision rate (0.0% vs. 3.0%, p=0.993) did not significantly differ as well. Specifically, readmission (p=0.993) and revision (p=0.998) for instability did not significantly differ between the cohorts. We found no statistical difference in HOOS, JR (p=0.425), VR-12 PCS (p=0.718), and VR-12 MCS (p=0.257) delta score improvement from preoperative to 1-year follow-up between the two groups.

Conclusion: Comparable outcomes following implantation of DM constructs may be achievable irrespective of the surgical approach employed. The incidence of iliopsoas injections for groin pain did not significantly differ between anterior and posterior approaches. Future investigation is needed to determine whether surgical approach influences long-term outcomes in patients receiving DM implants.

Level of Evidence: III

Keywords: dual mobility, total hip arthroplasty, surgical approach, direct anterior approach, posterior approach, outcomes

INTRODUCTION

Postoperative dislocations represent a significant complication after total hip arthroplasty (THA). Approximately 0.2-7% of the patients experience instability following primary THA and 10-25% after revision THA.1 Previous reports suggest that the risk increases by approximately 1% every five years following the initial procedure.2,3 As a result, there have been many improvements in surgical techniques and implant designs in an effort to help prevent hip instability. Dual mobility (DM) bearings have demonstrated excellent short and midterm outcomes compared to standard bearing implants in reducing dislocation rates, especially in higher-risk patients.4 However, a recent meta-analysis found that DM articulations were not associated with lower overall revision rates compared to fixed bearing constructs.7 DM constructs comprise of two articulations: one between the femoral head and a large-diameter polyethylene (PE) outer head bearing and a second between the PE outer head bearing and the acetabular shell or acetabular liner, thus providing a greater range of motion and a greater jump distance before dislocation occurs.8 Although the use of these implants was initially limited due to concerns of excessive polyethylene wear, progressively improved designs have conferred excellent long-term results.10
However, controversy regarding the use of modular DM implants remains as French et al.9 found that modular DM implants can cause adverse reactions due to metal corrosion between the metal liner and the metal shell in up to 1.8% of cases, though it only occurred in 0.3% of cases on average.

The direct anterior approach (DAA) and posterior approach (PA) are two commonly used surgical techniques in THA. Previous studies have shown that pairing the DAA with DM bearings does not increase complications or worsen implant positioning21 and is a safe and effective strategy in increasing postoperative stability and reducing dislocations in patients undergoing THA.12-16 Similar studies employing the PA with DM implants show comparable results, such as increased postoperative stability and reduced dislocation rates.17-19 However, some studies have raised concerns about higher rates of postoperative groin pain following the use of DM implants via DAA, which may be attributed to the removal of the capsule and irritation of the iliopsoas muscle due to the use of larger implant heads.14,16

Although previous studies have described that both surgical approaches with DM implants have positively influenced patient outcomes in those with a high risk of instability, there is a paucity in the literature describing whether the surgical approach affects outcomes in patients receiving DM acetabular implants. In their systematic review of outcomes of DM components in THA, Darrith et al.20 proposed that further study was required to determine whether the surgical approach affects the outcomes and rates of dislocation after DM use in THA. Although the use of larger heads decreases the rate of dislocation, particularly in patients in whom a PA is used, their systematic review could not identify an independent effect of surgical approach without patient-level data, which provides the impetus for the present study.

Therefore, the purpose of this study is to evaluate outcomes between patients undergoing primary THA with DM implants via DAA versus PA. Outcomes of interest include the incidence of requiring iliopsoas injections for postoperative groin pain as well as readmission and revision rates. We hypothesize that the differences between surgical approaches will be negligible during the early postoperative period.

METHODS

We retrospectively queried all patients over the age of 18 who underwent primary THA with DM constructs between June 2011 and February 2021 at a single urban institution, which comprises a large academic center and a tertiary orthopedic specialty hospital. Patients were separated into two cohorts based on surgical approach: DAA vs. PA. Patients undergoing revision THA, as well as THA performed for non-elective or oncologic reasons were excluded from this analysis. Femoral stems were used at the discretion of the surgeon. Of the 30 surgeons who contributed at least one case to our analysis, 24 completed an additional year of fellowship training in adult reconstructive surgery. Of the 495 DM cases identified, 145 (30%) were skirted stainless steel (POLAR CUP; Smith and Nephew, Memphis, Tennessee), 40 (8%) were anatomic cobalt-chromium (Anatomic Dual Mobility [ADM]; Stryker Corporation, Mahwah, New Jersey), 210 (42%) were cylindrospheric (Modular Dual Mobility [MDM]; Stryker Corporation, Mahwah, New Jersey), and 100 (20%) were subhemispheric. Of the subhemispheric implants, 58 were manufactured from cobalt-chromium (CoCr) alloy (G7; Zimmer Biomet, Warsaw, Indiana), and the remaining 42 were manufactured from zirconium (OR30; Smith and Nephew, Memphis, Tennessee). The skirted stainless steel DM cup offers the option of screw fixation via a superior tab (not utilized in our study population); however, the anatomic cobalt-chromium implants lacked this capability thus both implants were only used without any screw fixation.

All patients included in this study participated in our institutional-wide comprehensive total joint pathway program, which encompasses uniform standardized protocols for all aspects of perioperative care. In addition, a standard institutional postoperative rehabilitation protocol, as well as a standard postoperative pain protocol was followed for all patients. Patient records and data were de-identified as part of our institutional quality improvement program; however, human-subjects review by our Institutional Review Board (IRB) was obtained prior to this study.

Data Collection

Patient demographic data including age, gender, race, body mass index (BMI; kg/m²), American Society of Anesthesiology (ASA) classification, Charlson Comorbidity Index (CCI), and smoking status were collected. In addition, clinical data including the length of stay (LOS; days), surgical time (minutes), discharge disposition, whether the patient required a postoperative iliopsoas injection to manage substantial groin pain, as well as 90-day all-cause readmissions and revisions were collected from our electronic patient medical record system (Epic Caboodle, version 15; Verona, WI) using Microsoft SQL Server Management Studio 2017 (Redmond, WA). Characteristics of the surgery, including the use of DM articulations, were gathered from the review of operative reports and implant logs. LOS was evaluated in days spent in the hospital following surgery and surgical time was derived from calculating the time difference between initial skin incision and skin closure. All patients were either discharged home with self-care or home services
or to an acute or subacute rehabilitation facility.

As part of our institutional standard of care, patients were registered for an electronic patient rehabilitation application (EPRA; Force Therapeutics, New York, NY) at the time of surgical scheduling by clinical care coordinators. The EPRA is a mobile and web-based technology that wirelessly delivers digital patient reported outcome (PROM) surveys to patients at pre-defined time intervals. This application was used to collect Hip dysfunction and Osteoarthritis Outcome Score for Joint Replacement (HOOS, JR) and Veterans RAND 12 Physical and Mental components (VR-12 PCS & VR-12 MCS) scores preoperatively, three months postoperatively, and one year postoperatively.

### Outcome Measures

The primary outcome evaluated included the incidence of requiring iliopsoas injections to treat considerable postoperative groin pain. Patients were deemed as having groin pain if they had an iliopsoas injection for anterior groin pain that was ordered at least 3-months but no more than 6-months postoperatively. Any patient who had a documented interventional radiology (IR) procedure coded as a “hip injection” was manually chart reviewed to determine if this was an iliopsoas injection; if documentation of an iliopsoas injection was present in the electronic medical record the patient was deemed as having groin pain.

Key secondary outcomes included 90-day all-cause readmission and revision rates, 90-day readmission and reoperation rates for dislocation, and PROMs, as assessed by the HOOS, JR, VR-12 PCS, and VR-12 MCS. Additional outcomes evaluated included perioperative data, such as surgical time, LOS, discharge disposition.

### Statistical Analysis

All data were organized and collected using Microsoft Excel software (Microsoft Corporation, Richmond, WA). A binary variable was created to identify patients who underwent THA via the DAA and PA. Demographic and clinical baseline characteristics of study participants were described as means with standard deviations (SD) for continuous variables and frequencies with percentages for categorical variables. Statistical differences in continuous and categorical variables were detected using independent samples t-tests and chi-squared ($\chi^2$) tests, respectively. Multivariate linear and logistic regressions were performed to control for potential confounding variables. These regression models were used to compare our primary and secondary outcomes measures between the two cohorts. A p-value of less than 0.05 was considered to be significant. All statistical analyses were performed using SPSS v25 (IBM Corporation, Armonk, New York).

### RESULTS

A total of 485 DM THA cases were included in this analysis. Of which, 55 (11%) underwent THA via the

---

**Table 1. Demographics of Included Patients Stratified by Approach**

<table>
<thead>
<tr>
<th></th>
<th>Anterior Approach (n=55)</th>
<th>Posterior Approach (n=440)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>61.20±12.12</td>
<td>63.50±12.62</td>
<td>0.202</td>
</tr>
<tr>
<td>Male- no. (%)</td>
<td>15 (27.3)</td>
<td>133 (30.2)</td>
<td>0.652</td>
</tr>
<tr>
<td>Race- no. (%)</td>
<td></td>
<td></td>
<td>0.563</td>
</tr>
<tr>
<td>White</td>
<td>42 (76.4)</td>
<td>297 (67.5)</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>5 (9.1)</td>
<td>58 (13.2)</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>1 (1.8)</td>
<td>6 (1.4)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>7 (12.7)</td>
<td>79 (18.0)</td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.68±5.93</td>
<td>29.05±6.71</td>
<td>0.168</td>
</tr>
<tr>
<td>ASA Class- no. (%)</td>
<td></td>
<td></td>
<td>0.620</td>
</tr>
<tr>
<td>I</td>
<td>4 (7.3)</td>
<td>37 (8.4)</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>33 (60.0)</td>
<td>257 (58.4)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>16 (29.1)</td>
<td>140 (31.8)</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>2 (3.6)</td>
<td>6 (1.4)</td>
<td></td>
</tr>
<tr>
<td>CCI</td>
<td>3.27±2.38</td>
<td>3.81±2.26</td>
<td>0.098</td>
</tr>
<tr>
<td>Smoking Status- no. (%)</td>
<td></td>
<td></td>
<td>0.204</td>
</tr>
<tr>
<td>Never</td>
<td>34 (61.8)</td>
<td>242 (55.0)</td>
<td></td>
</tr>
<tr>
<td>Former</td>
<td>20 (36.4)</td>
<td>161 (36.6)</td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>1 (1.8)</td>
<td>37 (8.4)</td>
<td></td>
</tr>
</tbody>
</table>

ASA, American Society of Anesthesiologists; BMI, body mass index; CCI, Charleston Comorbidity Index no., number.

---

**Table 2. Clinical Outcomes of Included Patients**

<table>
<thead>
<tr>
<th></th>
<th>Anterior Approach (n=55)</th>
<th>Posterior Approach (n=440)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical Time (min)</td>
<td>100.24±42.37</td>
<td>109.42±36.86</td>
<td>0.070</td>
</tr>
<tr>
<td>LOS (days)</td>
<td>2.19±2.52</td>
<td>2.67±2.16</td>
<td>0.072</td>
</tr>
<tr>
<td>Discharge Disposition- no. (%)</td>
<td></td>
<td></td>
<td>0.151</td>
</tr>
<tr>
<td>Home</td>
<td>47 (85.5)</td>
<td>346 (78.6)</td>
<td></td>
</tr>
<tr>
<td>Other Facility</td>
<td>8 (14.5)</td>
<td>94 (21.4)</td>
<td></td>
</tr>
<tr>
<td>Groin Pain- no. (%)</td>
<td>1 (1.8)</td>
<td>3 (0.7)</td>
<td>0.966</td>
</tr>
<tr>
<td>90-day Readmission- no. (%)</td>
<td></td>
<td></td>
<td>0.993</td>
</tr>
<tr>
<td>Dislocation</td>
<td>1 (1.8)</td>
<td>3 (0.7)</td>
<td>0.997</td>
</tr>
<tr>
<td>90-day Revision- no. (%)</td>
<td></td>
<td></td>
<td>0.998</td>
</tr>
</tbody>
</table>

LOS, hospital length of stay; min, minutes; no., number.
The incidence of iliopsoas injections to treat groin pain did not significantly differ between the DAA and PA cohorts (1.8% vs. 0.7%, p=0.966). Ninety-day all-cause readmission (9.1% vs. 7.7%, p=0.823) and revision (0.0% vs. 3.0%, p=0.997) rates did not differ between groups. The full clinical outcome comparison between the two groups is shown in Table 2.

**Primary Outcomes**

The incidence of iliopsoas injections to treat groin pain did not significantly differ between the DAA and PA cohorts (1.8% vs. 0.7%, p=0.966). Ninety-day all-cause readmission (9.1% vs. 7.7%, p=0.823) and revision (0.0% vs. 3.0%, p=0.997) rates did not differ between groups. The full clinical outcome comparison between the two groups is shown in Table 2.

**Secondary Outcomes**

Surgical time (p=0.070), LOS (p=0.072), and discharge disposition (p=0.151) were found to be statistically similar between patients who underwent DM THA via the DAA and PA (Table 2). Additionally, the 90-day readmission (1.8% vs. 0.7%, p=0.993) and revision (0.0% vs. 0.7%, p=0.998) rate due to dislocation did not statistically differ between both cohorts.

**DISCUSSION**

Previous studies have suggested that the implantation of DM implants with either DAA or PA has favorable results, such as reducing the risk of instability. However, no study to date has compared the difference in postoperative outcomes between these two surgical approaches in primary THA with DM bearings. Despite the success of these implants in high-risk patients, this study found no statistical differences in clinical or patient-reported outcomes between DAA and PA in primary THA performed using DM bearings. Furthermore, we found similar results regarding the use of iliopsoas injections for the management of substantial groin pain, readmission rates, and revision rates.

Overall, the literature remains inconclusive as to which surgical approach yields more favorable outcomes. A plethora of previous reports suggest no significant difference in patient outcomes between the DAA and PA, such as postoperative function and dislocation rates. However, some studies have found that the DAA may yield superior early results when compared to PA. Sheth et al. and Tsukada et al. reported that the DAA approach led to lower dislocation rates without increasing the risk of revision surgeries.

With regards to short-term outcomes, Martin et al. noted that DAA patients had a shorter LOS and earlier mobilization. In addition, Wang et al. found that the DAA provided better early functional recovery as as-
sessed by postoperative Harris Hip Scores (HHS) and lower Visual Analog Scale (VAS) pain scores. Jia et al.\textsuperscript{30} and Rodriguez et al.\textsuperscript{31} also recorded superior postoperative early function and pain relief in DAA patients. An earlier study performed at our institution found that DAA patients expressed higher satisfaction as assessed via the Forgotten Joint Score (FJS-12) 12 weeks postoperatively; however, controlling for surgeon volume nullified this difference.\textsuperscript{32} Notably, none of these studies stated if they included DM bearings. The integration of DM bearings may eliminate the variance seen in outcomes between the DAA and PA in primary THA.

Studies evaluating DM constructs via the DAA have shown promising results in decreasing dislocation rates, particularly in high-risk patients. For instance, Homma et al.\textsuperscript{15} and Ochi et al.\textsuperscript{12} found a reduction in dislocation rates in patients with displaced femoral neck fractures that underwent THA via DAA using DM bearings. Also, Jinnai et al.\textsuperscript{13} reported no dislocations, early postoperative functional recovery, and a low one-year mortality rate in their patient population following DM bearing implantation using the DAA. They hypothesized that the DAA and the increased range of motion provided by the DM bearings could have contributed to the early postoperative functional recovery and the low dislocation rates, respectively. However, notable complications of DM bearing use and the DAA include groin pain and perioperative femoral fracture. A retrospective study by Homma et al.\textsuperscript{14} using DM bearings for primary THA reported two cases of persistent postoperative groin pain in the group that received DM bearings via the DAA. The diagnosis of iliopsoas muscle impingement was determined based on pain with active flexion, hip flexion against resistance, and passive hyperextension. In another similar study, Batailler et al.\textsuperscript{16} compared the outcomes of 201 primary THA using a DM bearing via DAA to 101 performed via a posterolateral approach. They reported three cases of postoperative groin pain due to impingement in the DAA group. Although previous literature has associated postoperative groin pain with DM bearings in patients undergoing THA via the DAA, the present study found no significant difference in the rates of requiring iliopsoas injections for groin pain between the two approaches.

Previous studies have also shown beneficial results in patients that undergo THA via PA using DM bearings. Bouchet et al.\textsuperscript{18} and Tarasevicius et al.\textsuperscript{19} reported no dislocations in their study population when employing the PA in tandem with DM constructs. Furthermore, Guyen et al.\textsuperscript{17} reported maintaining hip stability in 51 (94%) of the 54 patients who received DM bearings with the PA. In addition, they reported no loosening or osteolysis in their patients on follow-up.

This study is not without limitations. The retrospective nature of the study may have introduced biases. Although we reviewed the patient demographics and demonstrated similarities regarding patient age, sex, and BMI, there is still the possibility of subtle differences in patient characteristics between the two groups not adequately captured by those criteria. Additionally, the use of DM implants was left to the operating surgeons’ discretion; therefore, we could not determine if its use was predetermined or carried out due to intraoperative instability. Thus, the incidence of these reasons may differ across groups; however, we attempted to minimize this confounding variable by controlling for demographic differences between the two cohorts. In addition, only 55 patients (11%) in this study underwent DAA THA compared to 440 (89%) who underwent PA THA; this could introduce sampling bias. It is important to note that in a recent polled survey of members attending the 2018 American Association of Hip and Knee Surgeons (AAHKS) annual meeting, the average utilization of the DAA use in THA was 56.2\%\textsuperscript{33}. Multiple implants were used in this study, which may have some confounding effects on our results. To further elucidate the effectiveness of each approach, prospective studies with longer follow-up are required. Notably, we did not examine component positioning, especially in regards to being related to groin pain, though this likely did not differ between the groups as evidenced by the similar outcomes observed between the two. Our analysis included THA patients from 2011-2021, and various institutional protocol changes over this period could have influenced our results. We may not have captured all revisions performed at outside institutions. While this raises the possibility that we underestimated the true revision rate, our findings coincide with those of previous studies, thus missed cases would likely not alter our findings. Lastly, all cases included in this study were from an orthopedic specialty hospital. As a result, our findings may not be generalizable to surgeons who have low DM bearing case volumes or are new to their respective surgical approach of choice.

CONCLUSION

This study demonstrates that patients undergoing an anterior-based surgical approach compared to a posterior approach did not yield differences in prevalence of iliopsoas injection for groin pain or PROMs when using DM constructs. In current practice, either approach may be used without significant difference in the incidence of postoperative groin pain as well as readmission and revision rates. Future investigation is necessary to determine whether surgical approach influences long-term outcomes in patients receiving DM implants.
REFERENCES


SURGICAL MANAGEMENT OF TIBIAL BONE LOSS IN REVISION TOTAL KNEE ARTHROPLASTY: CLINICAL OUTCOMES AND RADIOGRAPHIC ANALYSIS OF TANTALUM CONES, TITANIUM CONES AND TITANIUM SLEEVES

Emmanuel Gibon, MD, PhD; Terrie Vasilopoulos, PhD; Edvinas Sipavicius, BS; Justin T. Deen, MD; Hernan A. Prieto, MD; Chancellor F. Gray, MD; Hari K. Parvataneni, MD; Luis Pulido, MD

ABSTRACT

Background: The use of metaphyseal cones and sleeves has improved the ability to manage tibial bone loss in revision total knee arthroplasty (TKA). The purpose of this study was to compare the outcomes of three systems used for tibial metaphyseal reconstruction in revision TKA.

Methods: We performed a retrospective review of a consecutive series of 723 revision TKAs, including 145 (20%) knee revisions using tibial cones or sleeves. We compared porous tantalum (TM) cones, titanium (Ti) cones and titanium sleeves. The mean follow-up was 2.5 years.

Results: The rate of revision for any reason was similar among all groups. Revision-free survival rates were similar among all systems studied at a mean follow-up of 2.5 years (TM cones 93%, Ti cones 94%, titanium sleeves 89%). Ti cones had a lower complication rate (6%) compared to TM cones (24%) and sleeves (29%). TM cones (15%) and titanium sleeves (13%) had higher reoperation rates (for any cause) than Ti cones (2%). Radiographic loosening was higher for sleeves (11%) than TM and Ti cones (2%).

Conclusion: Metaphyseal reconstruction for tibial bone loss in revision TKA using tantalum cones, titanium cones and titanium sleeves showed successful and comparable early clinical outcomes at a mean follow-up of 2.5 years with higher rates of radiographic loosening for titanium sleeves.

Level of Evidence: III

Keywords: revision TKA, bone loss, cone, sleeve

INTRODUCTION

Metaphyseal tibia bone loss is commonly present during revision TKA. Establishing reliable fixation and support in the tibia is essential. Historically, the methods to treat severe tibia bone loss including impaction grafting and structural allograft were associated with poor results, with 5-year survivorship free of revision of 75% and 81%, and 10 year survivorship free of revision of 50% and 76%, respectively.

Modern techniques include the use of cones or sleeves in addition to cemented or cementless stems. These modern devices are designed to support the tibial baseplate through taper adapters or a cemented interface (Figure 1). Long-term robust fixation is ensured by biological fixation via ingrowth of metaphyseal bone around them. Titanium (Ti) tibia sleeves have been available since the early 2000s. Sleeves are specific to their manufacturer. Sleeves are cementless stepped porous coated implants allowing axial and rotational stability in the metaphysis. Studies have shown excellent survivorship. Watters et al. reported a survival rate of 98.5% at 5.3 years and Bloch et al., showed a survivorship of 97.8% at 10 years.

Titanium and tantalum trabecular metal (TM) tibial cones are alternative reconstruction methods. Porous tantalum has been used since 1997. The early clinical results using TM cones for revision TKA in the setting of large tibial bone loss were reported by Meneghini et al. In this early investigation, the authors demonstrated no loosening or migration at a mean follow-up of 3 years. Kamath et al. published the midterm results of TM cones with a revision-free survival greater than 95% at six years. Other studies corroborated these results. Highly porous taper Ti cones are more recently available, and as such, there is a paucity of literature analyzing their use. The potential advantage of these cones is a cannulated reaming technique that facilitates the preparation and insertion. The bone preparation for these second-generation metaphyseal cones is simplified, with a reamer system that matches the cone geometry better than traditional burring system used in first-generation cones. Faizan et al. investigated the mechanical stability of those Ti cones compared to traditional TM cones.
and their results showed similar mechanical stability. At a minimum 2-year follow up, Denehy et al. showed survivorship of 100% of Ti cones in revision TKA.16

The purpose of this study was to evaluate the clinical and radiographic outcomes of revision TKA comparing three different technologies used for tibial metaphyseal fixation including TM cones, Ti cones and Ti sleeves, with a minimum 1-year follow-up. We hypothesized that these three technologies would have similar clinical and radiographic outcomes.

METHODS

Between January 2014 and May 2019, we queried our electronic medical record system (EPIC, Verona, WI) and identified 723 consecutive patients having undergone revision TKA. Institutional Review Board approval was obtained. Patients younger than 18-years-old, who had surgery for oncologic reasons, or who had no tibial cones or sleeves were excluded. Of those 723, we identified 175 patients (24%) with a tibial cone or sleeve and had at least one year follow-up. Metaphyseal fixation with a cone or sleeves were for revision tibial bone loss. Among those 175 patients, 30 were lost to follow-up. Lost to follow-up patients had at least one year follow-up but were not seen in the past two years. All the remaining 145 patients (20%) were included and had complete clinical and radiographic evaluations at final follow-up. Of those 145 patients, 54 had porous tantalum cones (TM cone group), 53 had titanium cones (Ti cone group) and 38 had titanium sleeves (sleeve group).

All surgeries were performed by five fellowship-trained arthroplasty surgeons. The choice of the implants was at the discretion of the surgeon, based on his experience and preference. Sleeves were used by one surgeon only, initially in the series when there were limited cone options. Cones were mostly used by all surgeons later in the series. The surgical technique used for TM cones has been described by Meneghini et al.8 and is a broach only technique. For Ti cones, the technique has been described by Denehy et al.16 and consists of a ream only technique. For sleeves, we used the surgical technique described by Jones et al.3 and the technique is a ream and broach system. The sleeves used in the study were stepped, porous-coated, Ti metaphyseal sleeves (DePuy Synthes, Warsaw, IN). Sleeve preparation consisted of initial reaming of the tibial diaphysis until endosteal contact was achieved. Subsequently, sequential broaching was then performed with a metaphyseal broach and a trial stem until rotational and axial stability of the sleeve was obtained. We used size- and manufacturer-specific impactors to press-fit TM cones (Trabecular Metal™ cone, Zimmer, Warsaw, IN) and Ti cones. The latter included Tritanium™ cones (Stryker, Mahwah, NJ), and Optetrak Logic® cones (Exactech, Gainesville, FL). Any void between the cone and the host bone was filled with Demineralized Bone Matrix (DBM, Stryker, Mahwah, NJ). Tibial and femoral stems were cemented using antibiotic-free cement. The least constrained articulation option that provided stability was chosen.

We analyzed patients’ demographic data, comorbidities, reason for revision, number of previous TKA, intraoperative and postoperative data and clinical outcomes. Intraoperative data included the surgical time, level of constraint used, type of metaphyseal fixation, type of stem fixation, tibial fixation, and the occurrence of intraoperative fractures and associated procedures during knee revision. Postoperative data included surgical and medical complications such as aseptic loosening, fractures, deep joint infection, cardiovascular events, death, reoperations, and re-revisions. Functional outcomes were assessed with the Knee Injury and Osteoarthritis Outcome Score for joint replacement (KOOS JR) for each group.17

Preoperative x-rays were reviewed to classify preoperative bone loss, according to the Anderson Orthopaedic Research Institute (AORI) bone defect classification,18 and implant position in the coronal and sagittal plane. Postoperative x-rays obtained after surgery and at last follow-up were reviewed for implant position, alignment, radioluencies, as well as evidence of migration, fractures or bone resorption. Knee standing anteroposterior and lateral views were analyzed with the Knee Society Total Knee Arthroplasty Roentgenographic Evaluation and Scoring System (KSRESS) to assess radiographic loosening zones.19,20 Definite radiographic loosening was defined as a change of angle, vertical or horizontal implant migration exceeding 2 mm, or a continuous radiolucent line wider than 1 mm on both the AP and lateral radiographs. X-ray analysis was performed by the senior author and an adult reconstruction fellow.

Primary outcomes were defined as survivorship and clinical and radiographic analysis and secondary outcomes were defined as functional outcomes using the KOOS JR score.

Continuous measures were summarized as means ± standard deviations and categorical measures were
summarized with percentages. One-way ANOVA (for continuous measures), and chi-square tests (for categorical measures) were used to compare demographic and operative characteristics across groups. Kaplan-Meier curves were used to examine survivorship rates using time to revision for any reason, reoperation, and radiographic loosening as endpoints. Survivorship rates were compared using the Wilcoxon test. A p-value < 0.05 was deemed to be significant. Analyses were performed in JMP Pro 15 (SAS Institute Inc, Cary NC) and MedCalc version 19.4.0 (MedCalc Software Ltd, Ostend, Belgium).

RESULTS

The three study groups were homogenous with similar demographics (Table 1). The patients in the sleeve group had a longer mean follow-up of 41.1 ± 16.6 months compared to 29 ± 14.8 months in the TM cone group and 21.6 ± 9.7 months in the Ti cone group (p < 0.001). The three main reasons for revision were aseptic loosening, periprosthetic joint infection (PJI) and instability. In the Ti cone group, there were significantly (p = 0.02) more patients with a preoperative diagnosis of extensor mechanism rupture (13.2%) compared to the TM cone group (0%) and the sleeve group (7.9%). Other indications for revision were similar between groups. The proportion of patients with an ASA score of 3 was significantly (p = 0.025) higher in the Ti cone group (98.1%) than in the TM cone group (81.5%) and the sleeve group (81.6%).

The mean postoperative delta increase in KOOS-JR score was similar among groups, +20.7 (SD 20.4), +23.7 (SD 21.4) and +35.4 (SD 13.4) for the TM cone, Ti cone and sleeve group respectively (p = 0.29). Postoperatively, there were significantly (p = 0.025) more complications in the TM cone group (24.1%) and the sleeve group (29%) than in the Ti cone group (5.7%). In the TM cone group, there were significantly (p = 0.01) more intraoperative fractures (9.3%) than in the Ti cone group (0%) and the sleeve group (0%). The postoperative complications that occurred at any time during follow-up are summarized in Table 2. Given the occurrence of these complications, both the TM cone and the sleeve groups had significantly (p = 0.027) higher reoperation rates than the Ti cone group. However, the revision rate was not significantly different between groups.

Radiographically, preoperative tibial bone loss was similar between groups. The majority of our patients (115 patients, 79%) had severe (AORI IIA and greater) tibial defects. Postoperatively, there were more (p = 0.03) tibial radiolucent lines in the sleeve group (68.4%) than in the TM cone group (44.4%) and the Ti cone group (43.3%) (Table 3). Sleeves had more radiolucencies at the tip of the stem (AP zone 6 and Lateral zone

Table 1. Demographic and Operative Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>TM group</th>
<th>Ti group</th>
<th>Sleeve group</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>54</td>
<td>53</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Age, mean years ± SD</td>
<td>64.7 ± 10.1</td>
<td>68.7 ± 7.9</td>
<td>65.6 ± 7.5</td>
<td>0.25</td>
</tr>
<tr>
<td>Sex ratio, M/F (%)</td>
<td>38.9/61.1</td>
<td>37.7/62.3</td>
<td>47.4/52.6</td>
<td>0.62</td>
</tr>
<tr>
<td>BMI, mean ± SD (kg/m²)</td>
<td>34.7 ± 5.4</td>
<td>34.0 ± 6.9</td>
<td>35.0 ± 6.9</td>
<td>0.74</td>
</tr>
<tr>
<td>ASA score (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>13.0</td>
<td>2.0</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>81.5</td>
<td>98.1</td>
<td>81.6</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5.6</td>
<td>0</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>OR time, mean minutes ± SD</td>
<td>214.7 ± 49</td>
<td>201.6 ± 61.6</td>
<td>192.6 ± 59.6</td>
<td>0.17</td>
</tr>
<tr>
<td>Indication for revision (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aseptic loosening</td>
<td>54.7</td>
<td>35.9</td>
<td>52.6</td>
<td>0.11</td>
</tr>
<tr>
<td>PJI</td>
<td>28.3</td>
<td>43.3</td>
<td>21.1</td>
<td>0.06</td>
</tr>
<tr>
<td>Instability</td>
<td>11.3</td>
<td>30.2</td>
<td>21.1</td>
<td>0.05</td>
</tr>
<tr>
<td>Periprosthetic fracture</td>
<td>5.7</td>
<td>1.9</td>
<td>2.6</td>
<td>0.54</td>
</tr>
<tr>
<td>Osteolysis</td>
<td>7.6</td>
<td>15.1</td>
<td>7.9</td>
<td>0.37</td>
</tr>
<tr>
<td>Polyethylene wear</td>
<td>3.8</td>
<td>7.6</td>
<td>7.9</td>
<td>0.64</td>
</tr>
<tr>
<td>Malalignment</td>
<td>0</td>
<td>7.6</td>
<td>2.6</td>
<td>0.08</td>
</tr>
<tr>
<td>Extensor mechanism rupture</td>
<td>0</td>
<td>13.2</td>
<td>7.9</td>
<td>0.02</td>
</tr>
<tr>
<td>Stiffness</td>
<td>3.8</td>
<td>11.3</td>
<td>0</td>
<td>0.07</td>
</tr>
<tr>
<td>Patellar dysfunction</td>
<td>2.0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Number of previous TKA (%)</td>
<td></td>
<td></td>
<td></td>
<td>0.57</td>
</tr>
<tr>
<td>1</td>
<td>42.6</td>
<td>34.6</td>
<td>42.1</td>
<td></td>
</tr>
<tr>
<td>2+</td>
<td>57.4</td>
<td>65.4</td>
<td>57.9</td>
<td></td>
</tr>
<tr>
<td>Preoperative tibia stem fixation</td>
<td></td>
<td></td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Cemented</td>
<td>77.8</td>
<td>98.1</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>Hybrid</td>
<td>18.5</td>
<td>1.9</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>Uncemented</td>
<td>0</td>
<td>0</td>
<td>84.2</td>
<td></td>
</tr>
<tr>
<td>No stem</td>
<td>3.7</td>
<td>0</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>Tibia revised only (%)</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>0.35</td>
</tr>
<tr>
<td>Both components revised (%)</td>
<td>93</td>
<td>92</td>
<td>92</td>
<td>0.35</td>
</tr>
<tr>
<td>Level of constran (%)</td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>Hinge</td>
<td>28</td>
<td>49</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Non-hinge</td>
<td>72</td>
<td>51</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>Follow-up, mean (months) ± SD</td>
<td>29 ± 14.8</td>
<td>21.6 ± 9.7</td>
<td>41.1 ± 16.6</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>
3) and anteriorly below the tibial baseplate (Lateral zone 1). TM cones had more radiolucencies laterally below the baseplate (AP zone 3). Although there was a trend for more radiographic loosening in the sleeve group, it did not reach significance. The preoperative coronal and sagittal alignments were similar between groups. Postoperatively, the tibial slope was higher (p < 0.001) in the sleeve group (5.1° ± 2.5°) than in the TM cone group (4.1° ± 2.7°) and the Ti cone group (2.3° ± 1.9°).

Although the revision rate was lower in the Ti cone group, it did not reach a statistically significant difference. There was no significant difference in time to revision across groups (p = 0.95, Figure 2a). Revision-free survival rates were similar among all systems studied at 4 years (TM cones 93%, Ti cones 94%, titanium sleeves 89%). Time to radiographic loosening (p = 0.107, Figure 2b) and time to reoperation (p = 0.142, Figure 2c) were also not statistically significantly different across groups.

**DISCUSSION**

Our study is the first to compare these three technologies in a clinical setting. Our results demonstrated that TM cones, Ti cones and sleeves had all excellent mid-term revision-free survival rate. Our study also showed that Ti cones had less postoperative complications than TM cones and sleeve.

### Table 2. Clinical Outcomes. Complications in Detail: Some Patients Accumulated More Than One Complication

<table>
<thead>
<tr>
<th></th>
<th>TM group</th>
<th>Ti group</th>
<th>Sleeve group</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraoperative fracture (%)</td>
<td>5 (9.3)</td>
<td>0</td>
<td>0</td>
<td>0.01</td>
</tr>
<tr>
<td>Reoperation rate (%)</td>
<td>8 (14.8)</td>
<td>1 (1.9)</td>
<td>5 (13.2)</td>
<td>0.03</td>
</tr>
<tr>
<td>Revision rate (%)</td>
<td>4 (7.4)</td>
<td>3 (5.7)</td>
<td>4 (10.5)</td>
<td>0.69</td>
</tr>
<tr>
<td>Postoperative complications, total (%)</td>
<td>13 (24.1)</td>
<td>3 (5.7)</td>
<td>11 (29.0)</td>
<td>0.005</td>
</tr>
<tr>
<td>Hematoma (%)</td>
<td>2 (3.7)</td>
<td>0</td>
<td>2 (5.3)</td>
<td>0.28</td>
</tr>
<tr>
<td>Drainage (%)</td>
<td>2 (3.7)</td>
<td>0</td>
<td>3 (7.9)</td>
<td>0.13</td>
</tr>
<tr>
<td>SSI (%)</td>
<td>4 (7.4)</td>
<td>0</td>
<td>3 (7.9)</td>
<td>0.12</td>
</tr>
<tr>
<td>PJII (%)</td>
<td>4 (7.4)</td>
<td>0</td>
<td>3 (7.9)</td>
<td>0.12</td>
</tr>
<tr>
<td>Fracture (%)</td>
<td>5 (9.3)</td>
<td>0</td>
<td>0</td>
<td>0.01</td>
</tr>
<tr>
<td>Loosening (%)</td>
<td>2 (3.7)</td>
<td>1 (1.9)</td>
<td>4 (11)</td>
<td>0.29</td>
</tr>
<tr>
<td>Instability (%)</td>
<td>2 (3.7)</td>
<td>0</td>
<td>1 (2.6)</td>
<td>0.85</td>
</tr>
<tr>
<td>MI (%)</td>
<td>3 (5.5)</td>
<td>0</td>
<td>0</td>
<td>0.07</td>
</tr>
<tr>
<td>Death (%)</td>
<td>3 (5.5)</td>
<td>0</td>
<td>1 (2.6)</td>
<td>0.22</td>
</tr>
<tr>
<td>EMR (%)</td>
<td>0</td>
<td>1 (1.9)</td>
<td>0</td>
<td>0.42</td>
</tr>
<tr>
<td>PE (%)</td>
<td>0</td>
<td>0</td>
<td>1 (2.6)</td>
<td>0.24</td>
</tr>
</tbody>
</table>

SSI = surgical site infection; PJII = periprosthetic joint infection; MI = myocardial infarction; EMR = extensor mechanism rupture; PE = pulmonary embolism.

### Table 3. Radiographic Data

<table>
<thead>
<tr>
<th></th>
<th>TM group</th>
<th>Ti group</th>
<th>Sleeve group</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tibia AORI (%)</td>
<td></td>
<td></td>
<td></td>
<td>0.51</td>
</tr>
<tr>
<td>I</td>
<td>12</td>
<td>19.3</td>
<td>34.6</td>
<td></td>
</tr>
<tr>
<td>IIA</td>
<td>14.3</td>
<td>20.0</td>
<td>10.3</td>
<td></td>
</tr>
<tr>
<td>IIB</td>
<td>49.0</td>
<td>46.7</td>
<td>34.5</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>24.4</td>
<td>13.1</td>
<td>21.3</td>
<td></td>
</tr>
<tr>
<td>Preoperative tibia coronal alignment, mean ± SD</td>
<td>5.1 ± 7.5</td>
<td>4.8 ± 6.9</td>
<td>2.4 ± 6.4</td>
<td>0.23</td>
</tr>
<tr>
<td>Preoperative tibia slope, mean ± SD</td>
<td>5.4 ± 9.5</td>
<td>7.5 ± 6.4</td>
<td>7.0 ± 8.8</td>
<td>0.18</td>
</tr>
<tr>
<td>Postoperative tibia coronal alignment, mean ± SD</td>
<td>0.7 ± 2.0</td>
<td>0.7 ± 1.5</td>
<td>0.2 ± 1.9</td>
<td>0.44</td>
</tr>
<tr>
<td>Postoperative tibia slope, mean ± SD</td>
<td>4.1 ± 2.7</td>
<td>2.3 ± 1.9</td>
<td>5.1 ± 2.5</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Postoperative tibial lucency (%)</td>
<td>44.4</td>
<td>43.3</td>
<td>68.4</td>
<td>0.03</td>
</tr>
<tr>
<td>AP zone 1</td>
<td>29.6</td>
<td>20.8</td>
<td>42.1</td>
<td>0.09</td>
</tr>
<tr>
<td>AP zone 2</td>
<td>29.6</td>
<td>15.1</td>
<td>36.8</td>
<td>0.05</td>
</tr>
<tr>
<td>AP zone 3</td>
<td>37.0</td>
<td>11.3</td>
<td>26.3</td>
<td>0.008</td>
</tr>
<tr>
<td>AP zone 4</td>
<td>38.9</td>
<td>17.0</td>
<td>29.0</td>
<td>0.04</td>
</tr>
<tr>
<td>AP zone 5</td>
<td>3.7</td>
<td>1.9</td>
<td>13.2</td>
<td>0.09</td>
</tr>
<tr>
<td>AP zone 6</td>
<td>3.7</td>
<td>7.9</td>
<td>21.1</td>
<td>0.002</td>
</tr>
<tr>
<td>AP zone 7</td>
<td>0.0</td>
<td>1.9</td>
<td>5.3</td>
<td>0.19</td>
</tr>
<tr>
<td>Lat zone 1</td>
<td>13.0</td>
<td>9.4</td>
<td>29.0</td>
<td>0.03</td>
</tr>
<tr>
<td>Lat zone 2</td>
<td>11.1</td>
<td>9.4</td>
<td>18.4</td>
<td>0.41</td>
</tr>
<tr>
<td>Lat zone 3</td>
<td>5.6</td>
<td>1.9</td>
<td>26.3</td>
<td>0.001</td>
</tr>
<tr>
<td>Tibial loosening (%)</td>
<td>1.9</td>
<td>1.9</td>
<td>11.0</td>
<td>0.07</td>
</tr>
</tbody>
</table>

AP = antero-posterior; Lat = lateral.

In the revision setting, reliance on the epiphyseal bone alone has shown high rates of mechanical failure. Recently, a new concept of zonal fixation in revision TKA has emerged in which the authors demonstrated that solid fixation in at least two of the three zones should be obtained. The metaphysis, or zone 2, is critical, as studies have shown that failure to obtain fixation at this level leads to early failure. To achieve long-term fixation in zone 2, different methods have been used. Metaphyseal cementation with the hybrid stem fixation technique is one of them. Wood et al. showed a survival free of revision for aseptic loosening of 98% at 12 years using this technique. However, the majority of patients in this study had minimal tibial bone loss (AORI type I). Impaction bone grafting has shown poor survivorship with 50% at 10 years. Large structural bone allograft showed a revision rate free survival of
The use of cones and sleeves has revolutionized the management of tibial bone loss in revision TKA. Sleeves have been available for almost two decades. The main advantage of sleeves is their ability to fill capacious proximal tibias, achieve rotational and axial stability, and obtain alignment. On the other hand, metaphyseal cones come in different shapes and designs to accommodate defects. TM cones also offer the advantage of being customizable. Both TM cones and Ti cones allow surgeons to use different reconstruction systems independently of the cone manufacturer.

In the TM cone group, our results showed an overall complication rate of 24.1%. Most of these complications were not related to the cone itself. Previous studies have shown similar complications. Bohl et al. reported a complication rate of 39%, while Kamath et al. showed complication in 27%. Other studies showed complication rates ranging from 23% to 27%. Reoperation rates reported in previous studies ranged from 12.5% to 35%. Our reoperation rate was 14.8%. Our revision rate (7.4%) was similar to previously reported revision rates ranging from 0% to 17%. Between the two patients who experienced postoperative loosening, only one affected the tibial component (Figure 3). This low rate of loosening is similar to what has been reported. Bohl et al. showed a 4% rate of tibial subsidence and Kamath et al. reported only one aseptic loosening among their 66 cones. We observed a high rate of intraoperative fractures in this group. Moreover, intraoperative fractures were observed only in this group and did not originate from a single surgeon. We believe it is likely due to the nature of the bone preparation needed to fit the TM cone (free hand preparation with no milling or reaming). Our results showed that 44.4% of the tibial components in this group were associated with incomplete nonprogressive radiolucent lines. None of these radiolucent lines were around the tibial cone. Previous studies have shown radiolucent lines ranging between 15% and 23%. Bohl et al. reported that 56% of their TM cones were associated with radiolucent lines.

The clinical data using Ti cones is scarce since they were recently introduced. In a 2-year follow-up study, Denehy et al. reported a 24% revision rate. Tetreault et al. showed a 2.5% reoperation rate at 2-year follow-up and a survivorship free of revision for any reason
of 90%. Our reoperation rate (1.9%) and revision rate (5.7%) were similar to previously reported outcomes. In our Ti cone group, we had one aseptic loosening of the tibial component (Figure 4). Therefore, our rate of loosening was very low (1.9%). In their series, Denehy et al.\textsuperscript{16} reported no radiographic loosening. The rate of radiolucent lines in this group (43.3%) was similar to that in the TM group.

Sleeves, due to their longer-standing clinical presence, have much longer follow-up in our study. Studies have shown revision rates ranging from 1.6% to 22.1%.\textsuperscript{31-33} Survivorship, when available, showed excellent rates. Bloch et al.\textsuperscript{7} reported implant survivorship free of revision for any reason of 97.8% at 10 years. Chalmers et al.\textsuperscript{4} showed a 5-year survivorship free of revision for aseptic loosening of 99.5% for tibial sleeves. Conversely, Agarwal et al.\textsuperscript{31} in a minimum 7-year follow-up study reported a survivorship of 65% free of revision.

Our analysis showed that 68.4% of the tibial sleeves had radiolucent lines, which was significantly higher than in the TM and Ti cone groups. Wirries et al.\textsuperscript{5} reported a 51% incidence of postoperative radiolucent lines. Watters et al.\textsuperscript{4} observed 17% radiolucent lines beneath the tibial baseplate. In our sleeve group, 4 patients (11%) had evidence of failed osseointegration in the setting of aseptic loosening (Figure 5). Wirries et al.\textsuperscript{5} had 3 cases of aseptic loosening (6.4%), all including the tibial components. At a mean follow-up of 3 years, Chalmers et al.\textsuperscript{4} observed 0.8% of aseptic loosening of the tibial component. However, our sleeve group had more patients with AORI type III bone defects than in their study.

Our survivorship analysis showed excellent outcomes with a revision-free survival rate of 89%, 93% and 94% for sleeves, TM cones and Ti cones, respectively, at mid-term follow-up. This is consistent with previously published data. The drop at 48 months in figure 2a in the Ti cone group is explained by the fact that only three patients were available for analysis at that time and were therefore considered “at risk” statistically speaking. Although sleeves had significantly more radiolucent lines than the TM and Ti cone group, our survivorship analysis using radiographic loosening as the end point failed to show a significant difference.

Up to this date, cones and sleeves have only been compared in systematic reviews.\textsuperscript{34-36} Zanitaro et al.\textsuperscript{36} compared 927 cones and 1801 sleeves with a mean follow-up of 4.5 years. The authors showed excellent survivorship of more than 97% in both groups. Similarly, Roach et al.\textsuperscript{35} analyzed 1617 sleeves and 701 TM cones. Surprisingly, the reoperation rate was nearly double (19%) in the TM cone group compared to the sleeve group (10.7%). In their work, the authors showed a rate of 0.8% of aseptic loosening for the tibial sleeves and 0.5% for the tibial cones.

This study has some limitations. First, its retrospective design could have led to inaccurate reporting and loss of data. To mitigate this potential issue, we used a computerized database which captures all surgical cases, that helped us to gather accurate data. Second, the Ti cone group included two different cones: the Tritanium® (Stryker) and the Opetrak Logic® (Exactech) which were chosen depending on the surgeon’s preference. However, both of these cones are based on the exact same technology, which is a highly porous titanium surface. Third, we acknowledge that our cohorts were small but they match or exceed previously reported studies. Fourth, our bone loss assessment was based on the AORI classification, which is made from preoperative x-rays. We consider it was a uniform estimation of tibia.
bone loss in our retrospective study among the groups. Mulhall et al.\textsuperscript{37} demonstrated a good agreement between preoperative and intraoperative AORI classification for the tibia. Fourth, sleeves were used by only by one surgeon in our database, which may make the results less generalizable. Finally, the follow-up in the sleeve group was significantly longer than in the TM and Ti cone group, which might have accounted for the higher rate of radiographic loosening in the sleeve group.

**CONCLUSION**

Our study demonstrates that TM cones, Ti cones and sleeves are reliable options to manage severe bone loss in revision TKA with comparable survivorship at mid-term follow-up. However, highly porous Ti cones showed lower reoperation rates as well as lower intra and postoperative complication among groups. Nonprogressive radiolucent lines are often observed, especially below the tibial baseplate. Larger cohorts with longer follow-up are necessary to assess construct durability in the long-term.

**REFERENCES**


ABSTRACT

Background: The purpose of this study was to perform a systematic review and meta-analysis on the association between operative time and periprosthetic joint infection (PJI) after primary total hip arthroplasty (THA) and total knee arthroplasty (TKA).

Methods: PubMed, Embase, and Cochrane CENTRAL databases were searched for relevant articles dating 2000-2020. Relationship of operative time and PJI rate in primary total joint arthroplasty (TJA) was evaluated by pooled odds ratios (OR) and 95% confidence intervals.

Results: Six studies were identified for meta-analysis. TJA lasting greater than 120 minutes had greater odds of PJI (OR, 1.63 [1.00-2.66], p=0.048). Similarly, there were greater odds of PJI for TJA procedures lasting greater than 90 minutes (OR, 1.65 [1.27-2.14]; p<0.001). Separate analyses of TKA (OR, 2.01 [0.76-5.30]) and THA (OR, 1.06 [0.80-1.39]) demonstrated no difference in rates of PJI in cases of operative time ≥120 minutes versus cases <120 minutes (p>0.05 for all). Using any surgical site infection (SSI) as an endpoint, both TJA (OR, 1.47 [1.18-1.83], p<0.001) and TKA (OR, 1.50 [1.08-2.08]; p=0.016) procedures lasting more versus less than 120 minutes demonstrated significantly higher odds of SSI.

Conclusion: Following TJA, rates of SSI and PJI are significantly greater in procedures ≥120 minutes in duration relative to those <120 minutes. When analyzing TKA separately, higher rates of SSI were observed in procedures ≥120 minutes in duration relative to those <120 minutes. Rates of PJI in TKA or THA procedures alone were not significantly impacted by operative time.

Level of Evidence: V

Keywords: total knee arthroplasty, total hip arthroplasty, operative time, infection, wound complication, periprosthetic joint infection, duration, surgical site infection

INTRODUCTION

Periprosthetic joint infection (PJI) is a severe complication of total joint arthroplasty (TJA) procedures for both the healthcare team and patient. As the annual volume of total knee and total hip arthroplasty procedures increases, so does the prevalence of revision arthroplasty secondary to surgical site infections (SSI) and PJI. Operative time has previously been evaluated as a potential independent risk factor for development of postoperative SSI and/or PJI. While many studies have suggested that longer operative times may increase the risk of postoperative SSI and PJI, other studies have not demonstrated increased risk of SSI and PJI in cases with longer operative times. In light of these competing results, establishment of specific duration thresholds and/or time increments that may place patients at increased risk for infectious complications is needed. The purpose of this study was to perform a systematic review and meta-analysis to assess potential associations qualitatively and quantitatively between specific thresholds of operative time, SSI, and PJI following primary TJA.

METHODS

Search strategies were developed with the assistance of a health sciences librarian with expertise in conducting systematic searches. The strategies were developed by the authors and a health sciences librarian by gathering, evaluating, and testing search terms. Comprehensive search strategies, including searching by index and keyword methods, were devised for the following databases: PubMed, Embase (Elsevier platform), and Cochrane CENTRAL (Wiley). To maximize sensitivity, no pre-established database filters were used other than an English language filter. Searches were finalized in October 2019 and then updated in October 2020 to identify results published during the systematic review process. The full PubMed search strategy, as detailed below in Table 1, was adapted for use with the other electronic
Table 1. Final PubMed Search October 2019

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>#4</td>
<td>“Editorial”[Publication Type] OR “Comment”[Publication Type] OR “Letter”[Publication Type] OR “Review”[Publication Type]</td>
</tr>
</tbody>
</table>

Limited to English[lang]=1433

Limited to English[lang]=1433

After removal of duplicates, a total of 2,577 records were obtained. Titles and abstracts of all obtained records were screened by three independent reviewers (N.M.S., C.N.C., N.A.B.) to assess if the relationship between operative time and infection were evaluated. The three reviewers compared screening results and reached an agreement on which records to include for full-text analysis. Inclusion of articles into qualitative synthesis was based upon the following criteria: (1) relationship between infection and operative time was evaluated in primary THA and/or TKA procedures, (2) any wound complication, PJI, or SSI was defined as an endpoint, (3) operative time was reported in a manner sufficient for analyzing effect on infection rate. An additional inclusion criterion for quantitative synthesis was: (4) provision of sufficient data for calculating pooled odds ratios (OR) with a 95% confidence interval.\(^2\) Non-primary THA/TKA procedures, editorials, commentaries, letters, reviews, and non-English language studies were excluded from analysis. To avoid overlapping data, only one study utilizing the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was included;\(^7\) all other studies utilizing ACS-NSQIP were excluded. The selected study by Duchman et al.\(^7\) was included as it classified operative time in a manner that best matched our specific-increment analysis. Exclusion of full-text articles were recorded and are shown in Figure 1.

One-hundred sixty-eight full-text articles were reviewed for inclusion. These studies were then evaluated independently by three reviewers, and important characteristics were recorded for quality assessment. The characteristics included: author, title, year published, years of study, institution, country, study design, methods of controlling for confounders, controls (gender, body mass index (BMI), American Society of Anesthesiologists (ASA) classification, length of stay, operative time, etc.), number of THA, TKA, and TJ A procedures in each respective cohort, minimum follow-up, mean follow-up, definition of operative time, mean operative time, distribution of operative time intervals (if any) and definition/criteria of wound complications, SSI and/or PJI.

After reviewer consultation, data from seventeen studies were extracted for qualitative synthesis and six studies for quantitative synthesis, detailed in Table 2. Definitions of operative time varied across studies; for the purpose of the present study, existing studies were placed into one of two categories of operative time: (1) skin incision to wound closure, and (2) total anesthesia time. All studies included in the quantitative analysis defined operative time as skin incision to wound closure. There was significant heterogeneity in definitions of wound complications between studies. To compensate for this, we defined an SSI as any reported description of surgical site infection, including PJI. If studies specifically reported PJI, an additional analysis with only PJI as an endpoint was performed. Follow-up time ranged from two weeks to four years post operation across studies; given this variability, we were unable to control for an average follow-up time in our analysis, and no study exclusions were made based on the study follow-up period. Distribution of operative time categories varied significantly between studies. For the present study, we established the following paired categories of operative time for use in qualitative and quantitative analysis: (1) $<90$ minutes or $\geq 90$ minutes and (2) $<120$ minutes or $\geq 120$ minutes.

Six unique analyses were performed: two utilized SSI as a primary endpoint, while four utilized PJI as the primary endpoint. Odds ratios for SSI and PJI were determined for operative time in each paired category.
Primary THA and TKA were evaluated in a pooled cohort and then analyzed separately as unique procedures. Analysis of THA alone with SSI as a primary endpoint could not be completed since enough studies with pertinent data, using our parameters, could not be found. Similarly, this was the case when evaluating TKA or THA alone using 90-minute cutoffs with PJI as a primary endpoint. Heterogeneity was tested using the Q and I² statistics and could not be ruled out. As a result, inverse-variance weighted random-effects models were used to evaluate the pooled odds ratios using RStudio version 4.0.2 (RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA).

RESULTS

A total of 81,373 THA and 149,319 TKA were evaluated from the six included studies, for a total of 230,692 primary TJA procedures. In a pooled cohort of THA and TKA, there was a 1.7 times higher likelihood of PJI in cases ≥ 90 minutes relative to those < 90 minutes in duration (OR=1.7 [95% CI 1.3-2.1]; p<0.001) [Table 3]. Using this cohort, there was also a 1.7 times higher likelihood of PJI in cases ≥120 minutes relative to cases < 120 minutes in duration (OR=1.7 [95% CI 1.0-2.7]; p=0.048) [Table 4].

Using SSI as the primary endpoint in a pooled cohort of THA and TKA, there was 1.5 times greater odds of SSI in cases 120 minutes in duration versus cases < 120 minutes in duration (OR=1.7 [95% CI 1.0-2.7]; p<0.001) [Table 5]. In a cohort of TKA alone, there was also 1.5 times greater odds of SSI in primary TKA ≥ 120 minutes in duration versus primary TKA < 120 minutes in duration (OR=1.5 [95% CI 1.1-2.1]; p=0.016) [Table 6]. Evaluating TKA alone, there was no increased odds of PJI in primary TKA ≥ 120 minutes in duration versus primary TKA < 120 minutes in duration (OR 2.0 [95% CI 0.8-5.3]; p=0.160) [Table 7]. Similarly, when evaluating THA alone, there was no increased odds of PJI in...
primary THA ≥ 120 minutes in duration versus primary THA < 120 minutes in duration (OR=1.1 [95% CI 0.8-1.4]; p=0.691) [Table 8].

Qualitatively, a study by Dicks et al.6 examined relationships between operative time and SSI, assessing THA and TKA separately. Operative time was recorded in two distinct methods: surgeon-median operative duration (the analysis we used for our meta-analysis due to increment categorization) and total operative duration. When analyzing 25,531 THAs, total operative durations exceeding the 75th percentile (>105 minutes) had a 1.11 times higher risk for SSI than durations in 25th-75th percentile (61-105 minutes) (RR 1.11; [95% CI, 1.03–1.21]; p=0.01).6 However, when analyzing surgeon-median operative duration in THAs, there was no significant increase in risk for SSI in cases >75th percentile (>104 minutes) in surgeon-median operative duration to cases in the 25th-75th percentile (71-104 minutes) (RR 1.10 [95% CI, 0.81– 1.50]; p=0.55).6 Similarly, Badawy et al.5 included 28,262 primary TKA procedures. There was not a significantly higher risk of infection in the >110-minute group when compared to the <75-minute group (HR = 1.8 [95% CI 1.3-2.5], p=0.001).5

**DISCUSSION**

The purpose of our meta-analysis was to assess the impact of increased operative time on subsequent infection rates in primary TJA. The results from our analyses indicate that for TJA procedures lasting greater than 120 minutes, there are significantly higher odds of PJI [Table 4] and SSI [Table 5] than in cases lasting less than 120 minutes. Similarly, operative time greater than 120 minutes in TKA procedures significantly affected SSI rates [Table 6], and TJA procedures exceeding 90 minutes were associated with higher PJI rates [Table 3].

Agodi et al.9 evaluated risk factors for infection in THA and TKA procedures. Study data demonstrated that longer operative times were a predictor of SSI in total joint procedures, similarly to the conclusions drawn from our study. This study also expanded their data to THA procedures, finding operative time as the single independent risk factor (RR: 4.54; 1.06-19.48).9 Unfortunately, we did not have enough data to quantitatively analyze THA SSI data independently.
In a study by Wang et al., PJI and SSI rates were independently associated with increased operative time in TJA procedures. Data from this study was used in our meta-analysis on PJI rates, but the totality of literature review could not be accounted for due to low power in our study. They found that for every 20-minute increase in operative time there was a 25% increased risk for PJI.8 Also, there was a two times higher risk for developing SSI for patients exceeding an operation length of 90 minutes (OR 2.10 [95% CI 1.16-3.803], p=0.014).8 Duchman et al. ran a multivariate logistic regression using 99,444 patients to identify potential complications of increased operative times in TJA procedures. The notable variable studied for our purposes was any wound complication, including PJI. Operative time >120 minutes was found to be an independent risk factor for wound complication in TJA (OR 1.440, 95% CI 1.210-1.713).7 Additionally, they found that procedures >120 minutes had twice the incidence of wound complication than procedures ≤120 minutes.7

Both TJA [Table 5] and TKA [Table 6] procedures showed a significant effect of operative time greater than 120 minutes on SSI rate. As seen in Namba et al., procedure times taking less than 120 minutes were associated with lower rates of deep SSI compared to cases longer than 210 minutes. They also found that for every 15-minute increase in operative time there was a 9% higher deep surgical site infection risk (p<0.001; 95% CI: 0.04-0.13).12 Both findings were in accordance with our quantitative analysis results.

In our subgroup analysis of TKA [Table 7] and THA [Table 8] there was no significant effect of increased operative time on PJI rate. Similarly, in a study by Aggarwal et al. there was no significant effect of operative duration greater than 120 minutes on PJI rates (p=0.840) following primary THA. In contrast to our findings, the study by Ong et al. found PJI rates to rise significantly with increasing operative time (p<0.001). This relationship showed a 78% increase in PJI risk for patients undergoing surgeries lasting longer than 210 minutes compared to those less than 120 minutes (OR 1.78, 95% CI: 1.40-2.26).13 However, Ong et al. did not include cases lasting 120-210 minutes in their analysis, which could significantly impact the study findings. A separate study by Ong et al. also studied the relationship between risk of revision in TKA and THA procedures and operative time. Analysis demonstrated increased rates of all-cause revision with increased operative time following both TKA and THA. Anis et al. supports the findings established by Ong et al. They found operative time to be an independent risk factor for both PJI (adjusted OR 1.01 [95% CI 1.01-1.012], p<0.001) and SSI (adjusted OR 1.01 [95% CI 1.004-1.01], p<0.001), with every 15-minute

<table>
<thead>
<tr>
<th>Study</th>
<th>Author</th>
<th>Year</th>
<th>PJI ≥90</th>
<th>no PJI ≥90</th>
<th>PJI &lt;90</th>
<th>no PJI &lt;90</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Badaway</td>
<td>2017</td>
<td>209</td>
<td>16135</td>
<td>102</td>
<td>11816</td>
</tr>
<tr>
<td>2</td>
<td>Wang</td>
<td>2019</td>
<td>32</td>
<td>2284</td>
<td>105</td>
<td>14921</td>
</tr>
</tbody>
</table>

OR: 1.65 (95%CI: 1.27 - 2.14); p-value: 0.0002

<table>
<thead>
<tr>
<th>Study</th>
<th>Author</th>
<th>Year</th>
<th>SSI ≥120</th>
<th>no SSI ≥120</th>
<th>SSI &lt;120</th>
<th>no SSI &lt;120</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anis</td>
<td>2018</td>
<td>111</td>
<td>2800</td>
<td>199</td>
<td>8730</td>
</tr>
<tr>
<td>2</td>
<td>Dicks</td>
<td>2015</td>
<td>43</td>
<td>3402</td>
<td>390</td>
<td>38352</td>
</tr>
</tbody>
</table>

OR: 1.50 (95%CI: 1.08 - 2.08); p-value: 0.0159

<table>
<thead>
<tr>
<th>Study</th>
<th>Author</th>
<th>Year</th>
<th>PJI ≥120</th>
<th>no PJI ≥120</th>
<th>PJI &lt;120</th>
<th>no PJI &lt;120</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anis</td>
<td>2018</td>
<td>11</td>
<td>1261</td>
<td>39</td>
<td>4775</td>
</tr>
<tr>
<td>2</td>
<td>Dicks</td>
<td>2015</td>
<td>94</td>
<td>7012</td>
<td>679</td>
<td>59933</td>
</tr>
<tr>
<td>4</td>
<td>Duchman</td>
<td>2016</td>
<td>32</td>
<td>17259</td>
<td>151</td>
<td>81982</td>
</tr>
</tbody>
</table>

OR: 1.63 (95%CI: 1.00 - 2.66); p-value: 0.0488

<table>
<thead>
<tr>
<th>Study</th>
<th>Author</th>
<th>Year</th>
<th>SSI ≥120</th>
<th>no SSI ≥120</th>
<th>SSI &lt;120</th>
<th>no SSI &lt;120</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anis</td>
<td>2018</td>
<td>111</td>
<td>2800</td>
<td>199</td>
<td>8730</td>
</tr>
<tr>
<td>2</td>
<td>Dicks</td>
<td>2015</td>
<td>43</td>
<td>3402</td>
<td>390</td>
<td>38352</td>
</tr>
</tbody>
</table>

OR: 1.47 (95%CI: 1.18 - 1.83); p-value: 0.0005

Table 3. TJA PJI Results – 90 Minutes

Table 4. TJA PJI Results – 120 Minutes

Table 5. TJA SSI Results

Table 6. TKA SSI Results

Table 7. TKA PJI Results

Table 8. THA PJI Results
increase in time corresponding to higher infection rates.\textsuperscript{4} When using the 120-minute parameter, patients with surgeries greater than 121 minutes were 5 times more likely to develop PJI and 3 times more likely to develop SSI compared to procedures under 85 minutes.\textsuperscript{4}

The low statistical power in our study may cause the discrepancies seen in our conclusion on THA and TKA compared to Anis et al.\textsuperscript{4} and Ong et al.\textsuperscript{13} The inclusion of more studies and patients could drive our data in the other direction, therefore aligning with conclusions set out by the previous studies. The difficulty associated with finding enough data to fit specific operative time increments is clearly a limitation in this portion of our quantitative analysis. Another limitation is that every meta-analysis is dependent upon the data in each study. All these studies are limited by their retrospective nature. Additionally, due to the variation in which data was reported we were unable to include a significant amount of existing data in the literature. The presence of confounding variables that could impact infection rates seen in cases of longer duration is likely, including obesity, overall case complexity (i.e., conversion arthroplasty), and intraoperative complications.

In conclusion, the rates of PJI and SSI in primary TJA procedures are significantly greater when exceeding a 120-minute threshold. Furthermore, a pooled cohort of THA and TKA demonstrated risk at a 90-minute threshold for PJI. Individual analysis of THA and TKA on SSI rates proved to be significant past the 120-minute point, however PJI results, due to limited data, were not significant. Findings from our quantitative results and qualitative review were relatively consistent, however additional analysis should be completed to compare specific operative time thresholds as more data with similar increment reports are made.

REFERENCES


ABSTRACT

Background: While muscle atrophy is a function of normal aging, loss of muscle in the setting of hip and knee osteoarthritis (OA) has been observed using radiographic studies. There is limited data available regarding changes in extremity composition using bioimpedance (BIA). The purpose of this study was to assess the changes in extremity composition in patients with isolated, unilateral hip or knee OA using BIA.

Methods: Patients presenting to our institution’s adult reconstruction clinic from February 2020 to April 2021 were retrospectively reviewed to identify those with isolated, unilateral hip and knee OA. The InBody 770 Body Composition Analyzer (InBody USA, Cerritos, California) was used to perform a complete body composition assessment, per protocol. Lean extremity mass (LEM), fat mass (FM), intracellular water (ICW), extremity body water (EBW = ICW + extracellular water (ECW)) and phase angle (PA) were determined. Differences between the affected (OA) and unaffected (no OA) extremities were compared using t-tests.

Results: 38 patients had isolated hip OA. The mean age was 60.8 (±11.7) years, mean BMI was 31.7 (±6.8) kg/m², and 39.5% were female. LEM, FM, EBW, and PA were significantly decreased in the hip OA extremity (LEM: 20.0 vs. 20.4 kg, p=0.0008, FM: 8.8 vs. 8.9 kg, p=0.0049, EBW: 15.7 vs 16.0, p=0.0011, ICW: 9.5 vs. 9.7 L, p=0.0004, PA: 4.5 vs 4.9º, p<0.0001). There were 25 patients with isolated knee OA. Mean age was 62.8 (±11.3) years, mean BMI was 33.6 (±6.9) kg/m², and 52.0% were female. FM and PA were significantly lower in the knee OA extremity (11.3 vs 11.4 kg, p=0.00291, 4.5 vs 4.9º, p=0.0001). There were no significant differences in LEM, EBW, and ICW between the knee OA extremity and the unaffected extremity.

Conclusion: Patients with isolated, unilateral hip OA had decreased LEM, FM, EBW, and ICW in the affected extremity. Both unilateral hip and knee OA was associated with decreased PA, suggestive of greater underlying dysfunction in muscle or cellular performance. Further study is needed to better define when these abnormalities develop, how they progress over time, and the impact of targeted interventions in reversing these changes.

Level of Evidence: III

Keywords: osteoarthritis, hip, knee, body composition, phase angle

INTRODUCTION

Changes in body composition, such as a decrease in muscle mass and an increase in adipose mass, occur as a function of normal aging. In some, these changes may be pathologic. The term “sarcopenia” was coined to describe a pathologic change in muscle mass, function, and performance. Interest in sarcopenia has been increasing as it has been identified as a potentially modifiable risk factor for complications after orthopaedic surgical procedures, including total joint arthroplasty.1–6

Previous studies have identified changes in muscle mass in association with hip and knee osteoarthritis (OA) using radiographic modalities, such as magnetic resonance imaging (MRI), though overall data is limited.7-11 The process or etiology involved in the setting of OA and the development of muscular deficits is unclear. One hypothesis is painful, end-stage OA may result in reduced levels of physical activity, altered gait patterns, and abnormal muscle recruitment, leading to muscle atrophy.12 Alternatively, other propose loss of muscle mass and strength has been proposed as a preceding factor contributing to progression of OA and worsening pain.13,14

As interest in sarcopenia and assessment of extremity composition increases, it is essential to be able to readily identify these patients and better understand the relationship between OA and changes in extremity composition. While radiological modalities may be utilized, they may be time-consuming, expensive, expose patients to ionizing radiation, and impractical for longitudinal assessments.15 Bioimpedance (BIA) is a previously validated...
method to assess body or extremity composition using electrical conductivity.\textsuperscript{16,17} Given that it can be performed rapidly, does not require specialized interpretation, and does not use ionizing radiation, it is an ideal instrument for longitudinal assessments. There is limited data on use of BIA for assessment of extremity composition in hip and knee OA. Therefore, the purpose of this study was to use BIA to determine segmental extremity muscle, fat, and water composition analyses to determine the changes in body composition in patients with isolated, unilateral hip or knee osteoarthritis.

**METHODS**

This study was approved by our Institutional Review Board. Eligible patients were ≥18 years of age and presenting to our institution’s adult reconstruction clinic for care of hip or knee OA between February 2020 and April 2021. New patients underwent comprehensive body composition testing per protocol using the InBody 770 Body Composition Analyzer (InBody USA, Cerritos, California), which is a six-frequency BIA testing device capable of providing segmental extremity muscle, fat, and water composition analysis. Testing was not performed on patients unable to stand for approximately one minute to complete BIA testing, had a medical contraindication to BIA testing, including the presence of a cardiac pacemaker.

Retrospective chart review was performed to identify those presenting with isolated, lower extremity osteoarthritis. This was defined as a chief complaint pertaining to a unilateral hip or knee joint. Patients were excluded if there was a documented complaint in another hip or knee joint, they were receiving targeted treatment in another major lower extremity joint (i.e. corticosteroid injections), there was preexisting neurologic injury, or presence of internal orthopaedic hardware (i.e joint replacement prosthesis, internal fixation device).

Segmental body composition data was reviewed for both the affected and unaffected lower extremity. Lean extremity mass (LEM), fat mass (FM), extremity body water (EBW), intracellular water (ICW), and phase angle (PA) were determined. LEM is the mass of all body components, less fat. EBW is the sum of ICW and extracellular water (ECW) for a single extremity. PA is a quantitative assessment of the ratio of ICW and ECW, cellular membrane integrity, and may correlate with presence of lymphedema or sarcopenia.\textsuperscript{18,19} Differences in body composition parameters between the affected (OA) and unaffected (no OA) extremities were determined and compared using t-tests. Hip and knee OA patients were analyzed separately. Significance was set at p-value <0.05 and analyses were performed using SAS statistical software version 9.4 (SAS Institute, Cary, NC, USA).

**RESULTS**

A total of 38 patients with isolated, unilateral hip OA were identified. Mean age was 60.8 (±11.7) years, mean body mass index (BMI) was 31.7 (±6.8) kg/m\textsuperscript{2}, and 39.5% were female. Table 1 contains extremity composition data for both the affected and unaffected extremities. LEM was significantly lower in the hip OA extremity (20.0 vs. 20.4 kg, p=0.0008). FM was also significantly lower in the hip OA extremity (8.8 vs. 8.9 kg, p=0.0049). Compared to the unaffected extremity, EBW (15.7 vs 16.0, p=0.0011) and ICW (9.5 vs 9.7 kg, p=0.0004) were both significantly decreased in the hip OA extremity. Phase angle was lower in the affected extremity (4.5 vs 4.9º, p<0.0001).

25 patients with isolated, unilateral knee OA were identified. Mean age was 62.8 (±11.3) years, mean BMI was 33.6 (±6.9) kg/m\textsuperscript{2}, and 52.0% were female. Extremity composition for each lower extremity is provided in Table 2. There were no significant differences in LEM between the knee OA extremity and the unaffected extremity. FM was significantly lower in the knee OA extremity (11.3 vs 11.4 kg, p=0.0291). EBW and ICW did not differ between the knee OA and unaffected extremities, however phase angle was significantly lower in the knee OA extremity (4.5 vs 4.9º, p=0.0001).

**DISCUSSION**

Global rates of end-stage hip and knee OA are high, as evidenced by increasing demand for TJA and continued projections for future growth.\textsuperscript{20} Historically, BMI has been used as a method of risk stratification. However, BMI has a limited capacity to provide detailed assessment of an individual's body composition, as it is only a weight:height ratio, and it is controversial as to whether decreasing BMI is possible or conveys a meaningful

<table>
<thead>
<tr>
<th>Table 1. Isolated Unilateral Hip OA Extremity Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIP OA EXTREMITY</td>
</tr>
<tr>
<td>LEM – KG (SD)</td>
</tr>
<tr>
<td>FM – KG (SD)</td>
</tr>
<tr>
<td>ICW – L (SD)</td>
</tr>
<tr>
<td>EBW – L (SD)</td>
</tr>
<tr>
<td>PA – ° (SD)</td>
</tr>
</tbody>
</table>
Does Unilateral Hip or Knee Osteoarthritis Lead to Changes in Extremity Composition

Interest in a more detailed assessment of body composition has increased as a potential method of risk stratification and optimization. This current study demonstrated that isolated, unilateral hip OA was associated with decreased LEM, FM, EBW, and ICW, while isolated, unilateral knee OA was associated with slightly decreased FM, but not significant changes in LEM, EBW, or ICW. Both hip and knee OA were associated with decreased phase angle, suggestive of altered water homeostasis and cellular integrity. Magnitude of changes in muscle or fat mass were small in magnitude, though larger changes occurred in PA.

Zacharias et al. found decreased gluteal muscle volume and increased fatty infiltration as assessed using computed tomography in patients with unilateral hip osteoarthritis. In addition to reduced muscle volume, hip OA has been associated with decreased muscle strength in the gluteus maximus, adductors, hamstrings, and quadriceps. A meta-analysis on the impact of hip OA on muscle size reported changes may vary between muscles or based on stage of OA. This current study did not find differences in LEM based on the presence of unilateral knee OA, though that has previously been reported. Lower limb skeletal muscle index has previously been found to correlate with knee osteoarthritis. Conversely, increased cross-sectional area of the vastus medialis has been associated with reduced pain in patients with knee OA. The mechanism by which muscle changes in the setting of OA occur is not well-defined; studies have found increased inflammatory markers and increased muscle fibrosis in the setting of OA. Others have postulated reduction in activity due to painful OA may be a major contributor to loss of muscle. PA was found to be significantly lower in the affected extremity in the setting of isolated unilateral hip and knee OA. PA has previously been shown to have a correlation with muscle strength, with lower PA being associated with lower muscle strength, in both hip and knee OA. Low PA has also been associated with frailty and sarcopenia. Outcome data specific to orthopaedics is limited, however it has been associated with mortality and other complications in other surgical disciplines. Similar to muscle atrophy, whether PA begins before or after progression of late-stage OA and whether it is predictive of postoperative complications requires further study. Additionally, it is also not clear what threshold at which a change in PA conveys a clinically significant risk for complications.

Limitations of this study are assessment of a small sample size from a single institution. Determination of unilateral, isolated OA was made based on chart review, with absence of documented complains of other joint pain, focused treatment, or prior joint replacement qualifying as isolated disease. Given patients were not directly questioned regarding OA-like symptoms in other joints, it is possible OA symptoms in other joints were unreported. Body composition analysis was assessed at a single time point and radiographic OA severity or duration of symptoms prior to presentation and potential correlation with adverse changes in extremity composition were not assessed. Future investigations should focus on longitudinal assessments to quantify temporal course of changes in extremity composition. It is unclear whether changes in composition occur as a result of OA and resultant disuse or if muscle changes occur first and contribute to development of symptomatic OA. Additionally, the impact of targeted interventions, such as nutritional supplementation, resistance training, or mechanical compression, to prevent or reverse changes muscle and improve lymphedema should be studied.

CONCLUSION

Isolated unilateral hip OA was associated with adverse changes in extremity composition in both hip and knee OA. These changes were associated with decreased phase angle, suggestive of greater underlying dysfunction in muscle or cellular performance. Further study is needed to better define when these abnormalities develop, how they progress over time, and the impact of targeted interventions.

REFERENCES


PERIOPERATIVE OPIOID COUNSELING REDUCES OPIOID USE FOLLOWING PRIMARY TOTAL JOINT ARTHROPLASTY

Christopher N. Carender, MD1; Christopher A. Anthony, MD2; Edward O. Rojas, MD3; Nicolas O. Noiseux, MD1; Nicholas A. Bedard, MD1; Timothy S. Brown, MD3

ABSTRACT

Background: Preoperative counseling may reduce postoperative opioid requirements; however, there is a paucity of randomized controlled trials (RCTs) demonstrating efficacy. The purpose of this study was to perform an interventional, telehealth-based RCT evaluating the effect of perioperative counseling on quantity and duration of opioid consumption following primary total joint arthroplasty (TJA).

Methods: Participants were randomized into three groups: 1. Control group, no perioperative counseling; 2. Intervention group, preoperative educational video; 3. Intervention group, preoperative educational video and postoperative acceptance and commitment therapy (ACT). Opioid consumption was evaluated daily for 14 days and at 6 weeks postoperatively. Best-case and worse-case intention to treat analyses were performed to account for non-responses. Bonferroni corrections were applied.

Results: 183 participants were analyzed (63 in Group 1, 55 in Group 2, and 65 in Group 3). At 2 weeks postoperatively, there was no difference in opioid consumption between Groups 1, 2, and 3 (p>0.05 for all). At 6 weeks postoperatively, Groups 2 and 3 had consumed significantly less opioids than Group 1 (p=0.04, p<0.001) (Table 1). Group 3 participants were less likely to obtain an opioid refill relative to Group 1 participants (p=0.04). Participants in groups 2 and 3 ceased opioid consumption a median of 6 days and 2 days sooner than Group 1, respectively (p<0.001, p=0.03) (Table 2).

Conclusion: Perioperative opioid counseling significantly decreases the quantity and duration of opioid consumption at 6 weeks following primary TJA.

Level of Evidence: I

Keywords: opioid, total hip arthroplasty, total knee arthroplasty, counseling

INTRODUCTION

As frequent providers of narcotic prescriptions, orthopedic surgeons are at the epicenter of the opioid epidemic in the United States. Primary total joint arthroplasty (TJA) is one of the most common orthopedic procedures performed in the United States, with projections estimated to exceed 1 million cases annually by the year 2025. Patients undergoing primary TJA receive some of the greatest quantities of prescription opioids postoperatively relative to patients undergoing other major orthopedic procedures. Taken together, primary TJA patients represent a cohort in which small-scale changes in opioid consumption have the potential to make a large impact on the opioid epidemic.

Recent interventions aimed at patient counseling regarding opioid use in the perioperative period have been successful in reducing quantity and duration of postoperative opioid consumption after upper extremity surgery. Previous interventions have utilized in-person counseling by the treating surgeon, or staging showings of a pre-recorded video to patients during the preoperative work-up. However, as the COVID-19 epidemic continues, additional in-person interaction is becoming less practical and exploring novel strategies for patient communication in the perioperative period is necessary. Perioperative text-messaging has been demonstrated to be an effective tool in communicating with patients undergoing total joint arthroplasty. The purpose of this study was to examine the efficacy of perioperative patient counseling on reducing the quantity and duration of opioid consumption following primary TJA.

METHODS

Trial Design

The study was a single-center, non-blinded randomized controlled trial (RCT) designed in compliance with Consolidated Standards of Reporting Trials (CONSORT) Group guidelines. The trial was approved by the University of Iowa Hospitals and Clinics Human Subjects
Research Institutional Review Board (IRB 201805715) prior to study initiation. Written consent was obtained from all patients prior to study enrollment.

Recruitment and Enrollment
Prospective participants were identified at the time of their indication for primary total knee arthroplasty (TKA) or total hip arthroplasty (THA) between March 2019 and February 2020. Inclusion criteria were patients ≥18 years and ≤80 years of age, undergoing primary THA or TKA, English language proficiency, with a text-messaging compatible mobile phone. Exclusion criteria were patients younger than 18 years or older than 80 years of age, patients undergoing aseptic or septic revision THA or TKA, patients undergoing additional procedures during the study period, and those without text-messaging compatible mobile phones. Prospective participants deemed eligible for enrollment were approached following their clinic visit by a study coordinator. Enrollment in the study was strictly voluntary. After a thorough discussion of study policy and the risks and benefits of study enrollment, written informed consent for participation was obtained.

Power Analysis and Randomization
Prior to study initiation, an a priori power analysis was conducted based off of retrospective opioid consumption data collected from our institution and published previously. To detect at least a 30% reduction in quantity of opioid consumption (measured in morphine milliequivalents [MME]), 48 patients would be needed in each study group.

As part of the primary TJA care pathway at our institution, all patients undergoing primary TJA are required to attend the Total Joint Patient Education Class lead by orthopedic nurses. Once patients were enrolled in the study, they were randomized according to the date of their preoperative patient education class; randomization in this fashion was necessary as one of our interventions included showing an educational video on perioperative opioid use to all class participants. Patients were randomized into one of three study groups: Group 1 (“Control”), no perioperative counseling; Group 2 (“Video Only”), intervention group, viewing of a pre-recorded video during preoperative patient education class; Group 3 (“Video + ACT”), intervention group, viewing of a pre-recorded video during preoperative patient education class and administration of acceptance and commitment (ACT) therapy via an automated text-messaging robot (Figure 1).

Interventions
All study participants underwent surgery with one of four fellowship trained adult reconstruction surgeons. Surgical approach and component selection were entirely at the discretion of the staff surgeon. Postoperatively, participants followed a standardized clinical pathway respective to their surgery (TKA vs THA). Opioids were prescribed as part of a multimodal pain management pathway in accordance with existing practice standards previously described by Holte et al.

Study participants in the Video Only and Video + ACT groups screened a pre-recorded video during their preop-
Perioperative Opioid Counseling Reduces Opioid Use Following Primary Total Joint Arthroplasty

A preliminary patient education class. The video was developed by fellowship trained adult reconstruction surgeons within the practice and consisted of approximately 3 minutes of narration over slides aimed at illustrating correct use, alternatives, and dangers of opioid pain medications. Participants in the Video + ACT group also received ACT via text messages beginning on postoperative day 1 for a total of 14 days. Administration of ACT via text messaging to patients following orthopedic surgery has previously been validated by Anthony et al. Content of text messages may be found in the Appendix, Table A1.

Study Outcomes and Data Collection

Primary study endpoints were quantity of opioid consumption (measured in MME) at 14 days postoperatively and 6 weeks postoperatively, as well as duration of opioid consumption, measured in days. Secondary study endpoints included the total number of opioid refills obtained in each group at 6 weeks postoperatively, change in Patient-Reported Outcomes Measurement Information System (PROMIS) Pain Intensity Scale v1.0 scores from preoperatively to 6 weeks postoperatively, as well as mean Visual Analog Scale (VAS) pain scores per 24-hour period measured on postoperative day 1 to postoperative day 14.

Quantity of opioid consumption and mean VAS pain scores of all study participants was measured using an automated text-messaging robot through the first 14 days postoperatively. Each day, the robot would query participants regarding their mean VAS pain score over the preceding 24 hours (Figure 2). Following this, the robot would query the participant regarding how many tablets of opioid pain medication they had consumed in the past 24 hours (Figure 2). Responses were saved on a secure, Health Insurance Portability and Accountability Act (HIPAA)-compliant server. Opioid consumption measured in tablet counts was manually converted into MME. Total quantity of opioid consumption at 6 weeks postoperatively was the sum of opioids consumed in the first 14 days plus any opioids obtained by the participant through refills. The total number of opioid refills obtained per participant in the 6-week postoperative period was also recorded.

Participants were considered to have ceased opioid at the time any of the following conditions was met: (1) participants reported consuming zero opioid tablets for the remainder of the first 14 days postoperatively and did not receive a subsequent opioid refill; (2) participants ceased responding to opioid consumption queries and the participant’s existing opioid prescription ran out

Table 1. Demographic Data, by Study Group

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (n, % female)</td>
<td>1. Control</td>
<td>2. Video Only</td>
</tr>
<tr>
<td></td>
<td>39 (62%)</td>
<td>32 (58%)</td>
</tr>
<tr>
<td>Surgery (n, % THA)</td>
<td>26 (41%)</td>
<td>21 (38%)</td>
</tr>
<tr>
<td>Age (mean ± SD; years)</td>
<td>59 ± 11</td>
<td>59 ± 11</td>
</tr>
<tr>
<td></td>
<td>1v2: 0.98</td>
<td>2v3: 0.65</td>
</tr>
<tr>
<td>Prolonged Opioid Use &gt; 60 mo. (n, %)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Opioid Use Within 3 mo. of Index Surgery (n, %)</td>
<td>0 (14%)</td>
<td>4 (7%)</td>
</tr>
</tbody>
</table>

SD – standard deviation.
(based on frequency and quantity prescribed, assuming participant taking opioid as frequently as possible allowed be prescription), and the participant did not receive a subsequent opioid refill; (3) once all refill prescriptions ran out (based on frequency and quantity prescribed, assuming participant taking opioid as frequently as possible allowed by each respective prescription).

PROMIS Pain Intensity Scales v1.0 were administered in person by the study administrator at the time the participants were enrolled into the study as well as at the participant's 6-week postoperative follow-up visit.

Demographic data collected included participant sex, age, a history of prolonged opioid use (defined as opioid use for longer than 6 months at any time point prior to their index surgery), and a history of any opioid use within 3 months of index surgery. Surgical data included type of surgery performed (primary TKA vs. primary THA).

### Query Response Rates and Statistical Analysis

The overall participant response rate to all queries posed by the automated text-messaging robot was 66%.

Response rates were not significantly different between study groups (Control, 66%; Video Only; 68%; Video + ACT, 63%; p>0.05 for all). To account for non-responses, differences in quantity of opioid consumption between groups was performed using intention to treat analyses using “best-case” and “worst-case” scenarios. In the best-case scenario, the absence of a response to a query regarding the quantity of opioid tablets consumed in the past 24 hours was recorded as the participant taking zero MME for that 24-hour period. In the worst-case scenario, the absence of a response to a query regarding the quantity of opioid tablets consumed in the past 24 hours was recorded as the participant taking the maximum amount of MME allowed by their respective prescriptions. For both best-case and worst-case scenarios, participants were considered to consume the entirety of any refill prescriptions that were written.

Quantity of opioid consumption between groups was evaluated for normality by Shapiro-Wilk tests and was found to be a non-normal distribution; non-parametric testing was used. Demographic variables were compared between groups using Chi-square and one-way analysis of variance (ANOVA). * denotes statistical significance.

### Table 2. Quantity of Opioid Consumption at 2 Weeks Postoperatively, Best-Case Scenario

<table>
<thead>
<tr>
<th>Value</th>
<th>Group 1: Control</th>
<th>Group 2: Video Only</th>
<th>Group 3: Video + ACT</th>
<th>p-value 1v2</th>
<th>p-value 1v3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>192</td>
<td>113</td>
<td>90</td>
<td>0.28</td>
<td>0.56</td>
</tr>
<tr>
<td>IQR</td>
<td>60-308</td>
<td>8-308</td>
<td>15-248</td>
<td>0.04*</td>
<td>0.15</td>
</tr>
<tr>
<td>Min</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.47</td>
<td>0.56</td>
</tr>
<tr>
<td>Max</td>
<td>690</td>
<td>623</td>
<td>694</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Median, interquartile range (IQR), minimum (min), and maximum (max) values are reported in morphine miliequivalents (MME). * denotes statistical significance.

![Figure 3](image1.png)

**Figure 3.** Quantity of opioid consumption at 2 weeks postoperatively, best-case scenario.

Box and whisker plot of quantity of opioid consumption at 2 weeks postoperatively in the best-case scenario, organized by study group. BCS – best-case scenario; MME – morphine miliequivalents.

![Figure 4](image2.png)

**Figure 4.** Quantity of opioid consumption at 2 weeks postoperatively, worst-case scenario.

Box and whisker plot of quantity of opioid consumption at 2 weeks postoperatively in the worst-case scenario, organized by study group. WCS – worst-case scenario; MME – morphine miliequivalents.
of variance (ANOVA) testing. Bonferroni corrections were applied to all p-values given the presence of multiple comparisons for respective each study variable. Analyses were completed using SAS statistical software v9.4 (SAS Institute, Inc., Cary, NC, USA).

RESULTS

Eight-hundred and seventeen patients were assessed for study eligibility (Figure 1); 374 did not meet inclusion criteria and were excluded, while 213 patients declined to participate. 230 participants underwent randomization to one of three study groups: 85 to the Control group, 67 to the Video Only group, and 78 to the Video + ACT group. During the study, a hardware failure occurred with one of our servers, resulting in data loss for 47 patients in total (Figure 1); these patients were excluded from analysis. A total of 183 participants underwent analysis.

There was no difference in sex, surgery type, age, prevalence of prolonged opioid use, of prevalence of opioid use within 3 months of index surgery between the three study groups (p>0.05 for all) (Table 1).

At 2 weeks postoperatively, in the best-case scenario, there was no difference in quantity of opioid consumption between all study groups (Table 2, Figure 3). Similarly, at 2 weeks postoperatively in the worst-case scenario, no difference in quantity of opioid consumption was observed between all study groups (Table 3, Figure 4).

At 6 weeks postoperatively, in the best case-scenario, the Video Only and Video + ACT groups consumed a significantly lower quantity of opioids relative to the Control group (p=0.04, p<0.001, respectively) (Table 4, Figure 5). There was no difference in quantity of consumption between the Video Only and Video + ACT groups. In the worst-case scenario at 6 weeks postoperatively, the Video + ACT group consumed a significantly lower quantity of opioids relative to the Control group (p=0.04) (Table 5, Figure 6). There was no difference in quantity of consumption between the Video Only and Control groups or the Video Only and Video + ACT groups.

Participants in the Video Only and Video + ACT groups consumed opioids for a median of 8 days and 12 days, respectively; median duration of consumption in the Control group was 14 days. Duration of opioid consumption was significantly shorter in participants in the Video Only and Video + ACT groups relative to participants in the Control group (p<0.001, p=0.03) (Table 6, Figure 7). There was no difference in duration of opioid consumption between Video Only and Video + ACT groups (p=0.38).

A total of 28 participants (44%) in the Control group obtained an opioid refill compared to 16 participants (29%) in the Video Only group and 18 participants (27%) in the Video + ACT group. Participants in the Video + ACT group were significantly less likely to obtain an opioid refill relative to the Control group (Odds Ratio 0.48 [95% Confidence Interval 0.23-0.99]; p=0.04) (Table 7). There was a statistically significant trend towards a decreasing likelihood of obtaining any opioid refill from

<table>
<thead>
<tr>
<th>Value</th>
<th>Group</th>
<th>p-value</th>
<th>p-value (corrected)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Control</td>
<td>2. Video Only</td>
<td>Video + ACT</td>
</tr>
<tr>
<td>Median</td>
<td>330</td>
<td>195</td>
<td>98</td>
</tr>
<tr>
<td>IQR</td>
<td>143-578</td>
<td>15-465</td>
<td>15-268</td>
</tr>
<tr>
<td>Min</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Max</td>
<td>2025</td>
<td>1300</td>
<td>773</td>
</tr>
</tbody>
</table>

Median, interquartile range (IQR), minimum (min), and maximum (max) values are reported in morphine milliequivalents (MME). * denotes statistical significance.

Table 4. Quantity of Opioid Consumption at 6 Weeks Postoperatively, Best-Case Scenario
DISCUSSION

Patients undergoing primary TKA and THA receive a large fraction of the opioid prescribed by orthopedic surgeons in the United States. As such, they are frequently a target group for potential interventions aimed at curbing prescription and consumption of opioid pain medications. Changes in practitioner prescribing practices have proven effective in decreasing the amount of opioid pain medication available to patients after primary TJA without adverse effects on pain control or patient-provider communication. Patient education regarding disposal of unused opioid pain medications significantly increases rates of proper opioid disposal. While perioperative counseling has proven successful in reducing quantity of opioid consumption following upper extremity orthopedic surgery, there is a paucity of data available regarding the potential effects of opioid counseling following primary TJA.

The primary aim of the present study was to examine the efficacy of perioperative patient counseling on reducing the quantity and duration of opioid consumption following primary TJA. At 2 weeks postoperatively, we observed no difference in the quantity of opioid consumption between the Control, Video Only, and Video + ACT groups in best-case and worst-case scenarios. However,
at 6 weeks postoperatively, participants in the Video Only and Video + ACT group consumed significantly less MMEs relative to the control group in the best-case scenario. Additionally, participants in the Video + ACT consumed less MME relative to the control group in the worst-case scenario at 6 weeks postoperatively. The difference in opioid consumption in the Video Only versus Control group trended towards but did not reach significance in the worst-case scenario at 6 weeks postoperatively. Participants in intervention groups were also less likely to obtain an opioid refill relative to participants in the control group.

Alter et al. evaluated opioid consumption in the first three days after surgery in a prospective RCT in which patients undergoing mini-open carpal tunnel release were randomized to preoperative opioid counseling or a control group. The authors noted that patients who underwent preoperative counseling consumed less opioid medication on postoperative day 1; however, there was no difference in opioid consumption between counseling and control groups on postoperative day 2 or 3. Syed et al. evaluated opioid consumption in a cohort of patients undergoing arthroscopic rotator cuff repair, comparing consumption between patients who underwent preoperative opioid counseling in the form of a short video and a control group. They found no difference in total number of opioid pills consumed in the first 2 weeks after surgery in the counseling versus control groups. However, at 6 weeks postoperatively, the counseling group consumed significantly fewer opioid tablets relative to the control group. Taken together, these data suggest that the largest effect of perioperative opioid counseling may occur by decreasing the likelihood of a given patient obtaining an opioid refill. Anthony et al. evaluated the efficacy of ACT delivered by text-messaging to decrease quantity of opioid consumption following orthopedic trauma surgery. Patients who received ACT consumed 37% fewer opioid tablets relative to patients in the control group at 2 weeks after surgery. Notably, the patient cohort in this study was relatively heterogenous in regards to surgical procedure; as such, the expected duration of pain and opioid consumption may not be directly comparable to participants in the present study.

Participants in the Video Only and Video + ACT group ceased consumption of opioid medications significantly sooner than participants in the control group, with a median time to cessation on postoperative day 8, 12, and 14, respectively. While cessation of opioid a few days earlier may seem clinically insignificant, Shah et al. demonstrated a two-fold increased risk of chronic opioid use in patients whose initial episode of opioid consumption lasted longer than 8 days. Syed et al. noted that patients who received opioid counseling prior to arthroscopic rotator cuff repair were 6.8 times more likely to have ceased opioid consumption by their 3-month follow-up visit relative to patients with no opioid counseling. Dindo et al. provided ACT to a population of veterans undergoing orthopedic surgery and noted that veterans who received preoperative ACT ceased opioid consumption a median of 9 days sooner than veterans who received no therapy. Implementation of educational and therapy-based interventions regarding opioids in patients undergoing TJA has the potential to be a low-cost yet high-volume intervention that may

<table>
<thead>
<tr>
<th>Value</th>
<th>Group</th>
<th>1. Control</th>
<th>2. Video Only</th>
<th>Video + ACT</th>
<th>p-value</th>
<th>p-value (corrected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td></td>
<td>14</td>
<td>8</td>
<td>12</td>
<td>1v2: &lt;0.001*</td>
<td>1v2: &lt;0.001*</td>
</tr>
<tr>
<td>IQR</td>
<td></td>
<td>11-23</td>
<td>3-14</td>
<td>3-15</td>
<td>1v3: 0.01*</td>
<td>1v3: 0.03*</td>
</tr>
<tr>
<td>Min</td>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2v3: 0.38</td>
<td>2v3: 0.38</td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td>47</td>
<td>43</td>
<td>49</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6. Duration of Opioid Consumption

Median, interquartile range (IQR), minimum (min), and maximum (max) values are reported in morphine milliequivalents (MME). * denotes statistical significance.

<table>
<thead>
<tr>
<th>Group/Effect</th>
<th>Refills n (%) with ≥1 refill</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Control</td>
<td>28 (44%)</td>
<td>Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Video Only</td>
<td>16 (29%)</td>
<td>0.51</td>
<td>0.24</td>
<td>1.10</td>
</tr>
<tr>
<td>3. Video + ACT</td>
<td>18 (27%)</td>
<td>0.48</td>
<td>0.23</td>
<td>0.99</td>
</tr>
<tr>
<td>Trend</td>
<td></td>
<td>0.69</td>
<td>0.47</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Table 7. Odds of Any Opioid Refill

CI – confidence interval. * denotes statistical significance.
decrease the likelihood of patients progressing to long-term opioid consumption.12

We observed no difference in PROMIS Pain Interference Scale v1.0 scores between groups preoperatively or at 6 weeks postoperatively. In a cohort of orthopedic trauma patients, Anthony et al.9 noted lower PROMIS Pain Interference Scale v1.0 scores at 2 weeks postoperatively in patients that received ACT relative to those who did not; however, the authors noted that the observed difference in scores may not have represented a clinically important difference. There was no difference in median VAS pain scores between the three study groups during the first 14 days postoperatively. Alter et al.1 noted no differences in mean VAS pain scores between preoperative counseling and control groups in the first 3 days following mini-open carpal tunnel release. Syed et al.6 noted a statistically significant decrease in VAS pain scores in the preoperative counseling group relative to the control group at 2 weeks and 6 weeks after arthroscopic rotator cuff repair; however, this difference was lost at 3 months follow-up. The authors postulated that preoperative opioid education may improve patient’s ability to cope with postoperative pain; the mechanism for this effect was not immediately clear.6 While ACT seemed to exhibit no effect on postoperative VAS pain scores in present study, prior studies have demonstrated ACT to decrease pain scores following orthopedic surgery by increasing pain acceptance.23

The present study has several limitations. This prospective RCT was non-blinded. Opioid consumption measured in the first 14 days postoperatively was self-reported, and may not be accurate. Response rates to queries posed by the automated text-messaging robot were much lower than previously reported response rates in a similar patient population.2 We were only able to account for opioids prescribed from our institution, and were not able to account for opioids consumed as a part of a separate prescription from outside our institution. This may be especially problematic as the trial was conducted at a tertiary referral center, where a significant number of patients have been cared for previously by outside institutions.

In conclusion, perioperative opioid counseling may decrease the quantity of opioids consumed at 6 weeks after primary TJA. A combination of a preoperative educational video and postoperative ACT was most effective, but an educational video alone was effective in some analyses. Perioperative opioid counseling decreases duration of postoperative opioid consumption following primary TJA. Implementation of these telehealth-based, low-cost interventions into primary TJA care pathways should be considered.

### REFERENCES


8. ClinicalTrials.gov. Checklist for Evaluating Whether a Clinical Trial or Study is an Applicable Clinical Trial (ACT) Under 42 CFR 11.22(b) for Clinical Trials Initiated on or After January 18, 2017. https://prsinfoclinicaltrials.gov/ACT_Checklistpdf


OUTCOMES FOLLOWING PRIMARY ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING A PARTIAL TRANSPHYSEAL (OVER-THE-TOP) TECHNIQUE IN SKELETALLY IMMATURE PATIENTS

Alan G. Shamrock, MD1; Kyle R. Duchman, MD1; William T. Cates, DO1; Robert A. Cates, DO1; Zain M. Khazi, MD1; Robert W. Westermann, MD1; Matthew J. Bollier, MD1; Brian R. Wolf, MD, MS1

1Department of Orthopedics and Rehabilitation, University of Iowa Hospitals and Clinics, Iowa City, Iowa, USA
Corresponding Author: Alan Shamrock, MD, Alan-shamrock@uiowa.edu, 319-356-1616
Disclosures: The authors report no potential conflicts of interest related to this study.
Sources of Funding: No sources of funding declared.

ABSTRACT

Background: The incidence of anterior cruciate ligament (ACL) injuries in skeletally immature patients is increasing, with ACL reconstruction preferred in this population due to reported chondroprotective benefits. Due to concerns with growth disturbance following ACL reconstruction in skeletally immature patients, various physeal-sparing and partial transphyseal techniques have been developed. Currently, there is no consensus on the most effective ACL reconstruction technique in skeletally immature patients. The purpose of the current study was to report the outcomes of a partial-transphyseal over-the-top (OTT) ACL reconstruction in a cohort of skeletally immature patients.

Methods: All patients with radiographic evidence of open tibial and femoral physes that underwent primary ACL reconstruction using a partial-transphyseal OTT technique between 2009-2018 at a single tertiary-care institution with at least twelve months of clinical follow-up were retrospectively reviewed. Patient demographics, physical examination findings, graft ruptures, return to sport, and Tegner activity levels were analyzed. Statistical significance was defined as p<0.05.

Results: Overall, 11 males and 1 female (12 knees) with a mean age of 12.8±1.8 (range: 10-16) years were included in the study. The mean postoperative follow-up of the cohort was 2.3±1.2 (range: 1.1-5.2) years. All ACLs were reconstructed with hamstring autograft with allograft augmentation utilized in a single patient. There were two cases of ACL graft rupture (16.7%). All patients were able to return to the same or higher level of sporting activity at an average of 7.4±2.7 months. There were no cases of clinically significant longitudinal or angular growth disturbance.

Conclusion: Partial transphyseal ACL reconstruction using a transphyseal tibial tunnel and an extra-articular OTT technique on the femur in skeletally immature patients affords minimal risk of growth disturbance with a graft rupture rate consistent with what has been reported in this high-risk population. All patients were able to return to sport at the same or higher level.

Level of Evidence: IV

Keywords: ACL tear, pediatric, skeletally immature, partial transphyseal

INTRODUCTION

The incidence of anterior cruciate ligament (ACL) injuries in skeletally immature patients is increasing secondary to the surge in competitive sport participation at younger ages.16 ACL deficient knees, particularly in young, active individuals, are at increased risk for subsequent cartilage, meniscal, and ligamentous injuries.3,7,13 In this skeletally immature population, several studies have recommended early ACL reconstruction over non-operative management in the setting of acute ACL injury despite the presence of open physes.3,5,13,17

Numerous ACL reconstructive techniques for skeletally immature patients have been described, including physeal-sparing, partial-transphyseal, or complete-transphyseal techniques.18,32 The aim of these techniques is to restore knee stability while minimizing iatrogenic physeal injury and subsequent growth disturbance.3,32 Currently, there is no consensus on the most effective ACL reconstructive technique in the skeletally immature population.3,5,33,34

In 1972, Galway and colleagues described an anterolateral stabilization technique for ACL insufficiency using a strip of the iliotibial band (ITB) secured to the distal femur.35 This technique was later modified by Bertola et al. to include a longer, intra-articular graft that went ‘over-the-top’ (OTT) of the lateral femoral condyle and into the notch.36 In 1994, Andrews et al. reported their outcomes using a transphyseal tibial tunnel with OTT, extra-articular fixation on the femur.37 A similar technique has been utilized frequently at our institution. Reported outcomes using this technique in skeletally immature patients are limited to small case series’ with a total of 36 patients identified throughout the available
Therefore, the purpose of this study is to report the clinical outcomes, return-to-sport, and graft rupture rates after primary ACL reconstruction using a transphyseal tibial tunnel and an OTT extra-articular technique on the femur in skeletally immature individuals.

METHODS

Patient selection
Institutional review board (IRB) approval was obtained for this study. All electronic medical records of patients less than 18 years old that underwent primary ACL reconstruction between 2009 and 2018 at a single tertiary-care institution were retrospectively reviewed. Patients with radiographic evidence of open tibial and femoral physes that were treated with the partial-transphyseal OTT technique using autograft tendon with at least twelve months of clinical follow-up were included for analysis. Exclusion criteria consisted of closure of either the distal femur or proximal tibia physis, OTT ACL reconstruction using allograft, and clinical follow-up of less than one year. Suspected ACL injuries were diagnosed on physical examination and confirmed with preoperative magnetic resonance imaging (MRI). Demographic variables, including sex, age, body mass index (BMI), and medical comorbidities, were documented for each patient. Surgical variables, including graft type, graft diameter, and concomitant injuries, were also recorded. The time elapsed from ACL reconstruction to return-to-sport participation, as well as preinjury and postoperative Tegner activity levels, were documented. The current study received no external funding.

Surgical technique
All partial-transphyseal OTT ACL reconstructions were performed by board-certified, sports fellowship-trained orthopaedic surgeons. All patients were treated with hamstring autograft, which was harvested in standard fashion. One patient’s graft was noted to be small intraoperatively and augmented with allograft. The graft was prepared using #2, non-absorbable, braided sutures in a locking fashion on both sides of the tendon. It was then doubled over and sized based on surgeon preference. A standard diagnostic arthroscopy was then carried out to assess ACL integrity and concomitant injuries, all of which, if present, were treated prior to ACL reconstruction.

The tibial tunnel was drilled utilizing a tip-pointing tibial guide centered in the anatomic footprint of the ACL and set at 55-60 degrees. Fluoroscopy was utilized to ensure the tunnel was oriented vertically to reduce the obliquity across the physis and to confirm that the starting point was distal to the proximal tibial physis.

Next, a three-centimeter (cm) lateral incision was made sharply through skin and subcutaneous tissue just proximal to the palpable lateral femoral epicondyle. The ITB was divided longitudinally and the vastus lateralis was mobilized and elevated anteriorly off the intermuscular septum. The posterior aspect of the femur was bluntly dissected until the posterior aspect of the femoral notch was palpable. With the use of a gaff hook, a passing suture was then passed around the back of the femur and into the notch. The ACL graft was then pulled into the knee joint through the tibial tunnel and notch and over the top of the lateral femoral condyle, until it was palpable posteriorly. The graft was then delivered out of the skin wound on the lateral aspect of the femur. Utilizing fluoroscopy, the graft was secured to the femur approximately 1.5-3.0 cm proximal to the distal femoral physis using a fully threaded AO cancellous screw and washer (Synthes, Switzerland), or cannulated cancellous screw and spiked washer (ConMed Corporation, NY, USA) (Figure 1A/1B). While applying a posterior drawer, the graft was tensioned with the knee in approximately 15° of flexion and secured distal to the proximal tibial...
physis using a Richard’s staple (Smith and Nephew, London, UK) or a fully threaded AO cancellous screw with washer (Synthes, Switzerland) (Figure 2A/B). Both femoral and tibial fixation methods were based on surgeon preference. The knee was copiously irrigated, and incisions were closed in standard fashion. Standard anteroposterior (AP) and lateral radiographs were obtained two weeks postoperatively (Figure 3A/B).

Isolated ACL reconstructions were made weight-bearing and range of motion (ROM) as tolerated without the use of a brace. Patients that underwent concomitant procedures, such as meniscal repair, had restricted weight bearing, range of motion, and brace use for a minimum of 6 weeks postoperatively.

Postoperative rehabilitation and return-to-sport
Postoperatively, patients initiated the Multicenter Orthopaedic Outcomes Network (M.O.O.N.) ACL rehabilitation protocol.39 The time elapsed from ACL reconstruction to return-to-sport participation, as well as preinjury and postoperative Tegner activity levels, were documented.

Clinical outcomes
The Lachman test, anterior drawer, pivot shift test, varus and valgus stability, and knee ROM were assessed and recorded. The Lachman test was defined as negative (< 3 millimeters [mm] of laxity), grade 1 (3-5 mm of laxity), grade 2 (5-10 mm of laxity), and grade 3 (> 10 mm of laxity). The pivot shift was defined as negative (no instability), grade I (glide), grade II (clunk) and grade III (gross clunk with locking).40

Statistical analysis
Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 25 (Chicago, IL). Fisher’s exact test was used for categorical variables, and Student’s t-test (2-tailed) was used for continuous variables with statistical significance defined as p<0.05.

RESULTS
Demographics
Overall, 11 males and 1 female (12 knees) with a mean postoperative follow-up of 2.3±1.2 (range: 1.1-5.2) years were included in the study. Mean age and BMI at the time of surgery were 12.8±1.8 (range: 10-16) years and 20.3±3.7 (range: 15.7-27.7) kg/m², respectively. Patients indicated the sport at the time of injury as American football (n=6), basketball (n=2), motocross (n=2), soccer (n=1), and snow skiing (n=1). Lateral meniscus tears were the most common concomitant injury (n=4; 33.3%), followed by injury to the medial meniscus (n=1; 8.3%) and medial collateral ligament (MCL) (n=1; 8.3%). The MCL injury was treated with concomitant repair at the time of OTT ACL reconstruction while all but one meniscus tear was managed with arthroscopic all-inside repair. One lateral meniscus injury consisted of a small radial white-white tear amenable to debridement. All patients underwent ACL reconstruction with hamstring autograft with one patient’s graft reinforced with allograft due to small diameter. The average graft diameter was 7.1 (range: 6.0-10.0) mm.

Clinical outcomes
Following ACL OTT reconstruction, 11 patients exhibited a stable Lachman exam with a firm endpoint and one patient had Grade I anterior translation with a firm endpoint. No patients demonstrated a clinical pivot shift. By a mean 3.5 months (range: 0.5-6.4) postoperatively, all knees had at least 0-125° of active motion.

Surgical outcomes
A total of 2 (16.7%) patients (1 male, 1 female) sustained an ACL graft rupture at 0.7 and 1.0 years after surgery. The mechanism of re-injury was competitive basketball and American football. Patient and operative characteristics of the patients stratified by graft tear can be found in Table 1.

Table 1. Patient and Operative Characteristics in Graft Tear vs Intact Graft Groups

<table>
<thead>
<tr>
<th></th>
<th>Graft tear</th>
<th>Intact graft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Patients (%)</td>
<td>2 (16.7)</td>
<td>10 (83.3)</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>1 (50.0)</td>
<td>10 (100)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>1 (50.0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Laterality, right, n (%)</td>
<td>2 (50)</td>
<td>9 (42.9)</td>
</tr>
<tr>
<td>Average Age (years)</td>
<td>13.5 (range: 13-14)</td>
<td>12.6 (range: 10-16)</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td>18.5 (range: 18.4-18.6)</td>
<td>20.7 (range: 15.7-27.7)</td>
</tr>
</tbody>
</table>
Return-to-Sport
The average time to return-to-sport was 7.4±2.7 months (range: 4.6-12.7). The mean preinjury Tegner activity level was 8.8 (range: 7.0-9.0) and mean postoperative Tegner activity level at final follow-up was 8.9 (range: 7.0-10.0). All patients either maintained (n=11) or increased (n=1) their Tegner activity level scores following OTT ACL reconstruction.

Complications and Subsequent Injuries
Complications after surgery included one superficial wound infection that resolved after a five-day course of oral antibiotics and one hardware removal for a painful staple on the medial aspect of the tibia (Table 2). Subsequent injuries following primary ACL reconstruction included ACL graft rupture (n=2), contralateral ACL rupture (n=2), ipsilateral lateral meniscus tear treated with an all-inside repair (n=1), and patella dislocation treated with physical therapy (n=1).

DISCUSSION
The incidence of ACL injuries in patients 6 to 18 years of age is approximately 121 per 100,000 persons per year and continues to increase.

Conservative management of ACL tears in skeletally immature individuals leads to an unacceptably high rate of subsequent knee morbidity, including meniscal tears, cartilage damage, and instability. Traditional ACL reconstruction techniques involve transosseous tibial and femoral tunnels which confer a risk of physeal closure in the skeletally immature patient. Here, we describe a cohort of skeletally immature patients that underwent primary ACL reconstruction using a transphyseal tibial tunnel and a physeal-sparing OTT technique on the femur. We observed a 100% return to at least preinjury sporting level with a 16% ipsilateral ACL re-rupture rate. No growth disturbances or cases of angular deformity were observed.

Bertoia and colleagues were the first to describe an ACL reconstruction with an OTT technique using the ITB. This was a modification of MacIntosh's lateral extra-articular tenodesis (LET), first published in 1972. In 1994, Andrews et al. reported their results after ACL reconstruction with Achilles allograft using a transphyseal tibial tunnel and an extra-articular, OTT technique on the femur in eight skeletally immature patients with a mean age of 13.5 years. At 4.8-year follow-up, they found six excellent, one good, and one fair result. One of the patients with an initial 'excellent' outcome sustained a graft rupture four years postoperatively playing competitive soccer. All patients returned to some level of sport postoperatively, but only 4/8 (50%) were able to return-to-sport at the same level or greater. To date, few studies have reported outcomes utilizing this partial-transphyseal OTT technique in skeletally immature patients.

In 1997, Lo et al. reported seven year outcomes of five patients that underwent an autograft reconstruction using a transphyseal tibial tunnel and OTT technique on the femur IKDC grade was A in four patients and C in one patient who sustained a subsequent patella dislocation. There were no graft tears and all patients returned to sport. Shortly after this, Bisson and colleagues reported three year outcomes on nine patients. Seven had excellent results and returned to sport. The other two patients sustained graft tears after returning to sport ten months and three years postoperatively. In a more recent study with 18-year follow-up, Demange and Camanho described outcomes in twelve immature patients in both Tanner Stage 1 (n=4) and Tanner Stage 2 (n=8) at the time of surgery. Three (25%) patients sustained a graft tear at a mean 6.6 years (range 4.7-9) postoperatively. Graf and colleagues also reported good outcomes in two patients that underwent a partial-transphyseal technique with semitendinosus autograft.

The aim of the partial transphyseal OTT technique is to restore knee stability and minimize growth disturbances in skeletally immature patients, particularly those with 'wide open' physes or in Tanner stages 1 and 2. The ideal technique involves drilling a small vertical tunnel (< 8 mm in diameter), through the center of the tibial physis, using an all-soft tissue autograft, and securing it extra-articularly on the femur to avoid injuring the distal femoral physis. However, this non-anatomic location for femoral fixation may portend to the slightly higher failure rate seen observed in this population. Although evidence is limited, transphyseal techniques theoretically have a higher risk of physeal injury and subsequent growth abnormalities or deformity, with the distal femoral and proximal tibial physes contributing approximately 9 mm and 6 mm of growth per year, respectively. In 2002, Kocher et al. reported survey results from 140 orthopaedic surgeons who performed
transphyseal and/or physeal sparing ACL reconstructions in skeletally immature patients. A total of 15 cases of growth disturbances were identified (out of an unknown total number of reconstructions), of which 80% occurred on the femoral side. In a more recent study published in 2016, Collins and colleagues identified 39 cases of growth abnormalities in a cohort of 313 patients (12.5%) following transphyseal and physeal-sparing reconstructions in skeletally immature patients. Nearly a quarter of the growth abnormalities were reported in patients treated with physeal-sparing techniques. Despite these reports, the majority of skeletally immature patients undergoing ACL reconstruction end up with an average LLD of < 1 cm and angular deformities less than 3 degrees.

In a recent systematic review by Pierce and colleagues that included 18 transphyseal and 6 physeal-sparing studies with over 600 total knees, leg length discrepancy ≥ 10 mm were only found in 0.81% and 1.23% of patients after transphyseal and physeal-sparing techniques, respectively. Furthermore, the incidence of angular deformity after transphyseal and physeal-sparing techniques was 0.61% and 0%, respectively. A meta-analysis of 55 studies (941 knees) by Frosch and colleagues estimated the overall risk of postoperative LLD >1 cm or angular deformity > 3 degrees at 2.1%. Previously identified risk factors for growth disturbances after transphyseal techniques include graft type, graft diameter and angular trajectory of the tibial tunnel.

The 16% graft tear rate found in our series is consistent with previously published partial-transphyseal OTT outcomes. Reported graft rupture rates after primary ACL reconstruction in skeletally immature patients ranges from 0-25% depending on the technique utilized. We observed no cases of physeal closure although patients were not followed until skeletal maturity. Additionally, a large proportion of the patients in our series were able to return-to-sport at the same level or higher postoperatively. Given this information, we believe that the optimal ACL reconstructive technique should be dictated by graft failure rates, return-to-sport rates, and surgeon familiarity with the technique.

This study is limited by its retrospective nature and the use of clinical and surgical notes that rely on accurate and consistent documentation. Detailed information including ROM, Lachman exam, pivot-shift, return-to-sport, bilateral long-leg radiographs and graft diameter was not available for every patient included in this study. Additionally, "non-significant" univariate findings may indicate that the study in underpowered to detect difference. Due to the small sample size of graft ruptures, multivariate analysis was not possible and independent risk factors for graft failure were not able to be assessed.

As mentioned previously, although we did not observe any cases of angular deformity during postoperative follow-up, patients were not clinically followed until radiographic confirmation of physeal closure. Lastly, a standardized protocol was not utilized to measure motor strength and functional movement prior to allowing patients to return to sport. However, this is the largest single series to date reporting on the outcomes of a partial transphyseal OTT technique for primary ACL reconstruction in skeletally immature patients.

CONCLUSION

ACL reconstruction using a transphyseal tibial tunnel and an extra-articular OTT technique on the femur in skeletally immature patients appears to be safe with minimal risk of growth disturbance. It is associated with a comparable graft rupture rate compared to other physeal-sparing or transphyseal techniques in the active, skeletally immature patient population. All patients were able to return to sport at the same level or higher in the current cohort. While the ideal technique for ACL reconstruction in skeletally immature patients continues to be a topic of debate, we believe it should be dictated by graft tear rates, return-to-sport rates, and surgeon familiarity with the technique, as opposed to risk of growth disturbances. Future studies are needed to directly compare the outcomes after the various ACL reconstruction techniques in patients with open physes.

REFERENCES


DO CURRENT STABILITY SCORES AFTER MPFL RECONSTRUCTION CORRELATE WITH PATIENT SATISFACTION POSTOPERATIVELY?

Matthew T. Gulbrandsen, MD; David Hartigan, MD; R. Casey Rice, MD; David E. Ruckle, MD
Karan Patel, MD; Anikar Chhabra, MD, MS

ABSTRACT

Background: Patellar dislocation can lead to instability, pain, limited function, and recurrent dislocations. Medial patellofemoral ligament (MPFL) reconstruction leads to favorable patient reported outcomes, but many patients fail to return to previous activity levels. The purpose of this study is to determine how well patients do after MPFL reconstruction and to determine the most important factors for evaluation of patellar instability following MPFL reconstruction.

Methods: After IRB approval, a retrospective chart review was performed on all patients who underwent MPFL reconstruction from January 2006 to January 2014 by two board-certified sports orthopaedic surgeons. Patients were then contacted to complete a follow-up questionnaire about satisfaction, functional status, pain, and patellar stability. Patients with at least one-year of follow-up data, a complete data set, and a completed questionnaire were included in the final analysis. Charts of 100 patients were reviewed and 54 patients met all criteria for inclusion in the study. Chi-square analysis, t-tests, and multivariate and univariate logistic regression models were used to estimate the effects of multiple variables on return to activity, satisfaction, and function while controlling for covariates with p<0.05 considered significant.

Results: When asked about subluxation, 20% (11/54) reported recurrent patellar subluxation (without re-dislocation). Of the 11 patients who reported re-subluxation, 54% (6/11) reported being highly satisfied (rating of 9-10/10) with the outcome of their knee. Of the 54 patients, 54% (29/54) did not return to previous levels of activity, nevertheless, 31% (9/29) of these 29 patients reported being highly satisfied with the outcome of their knee.

Conclusion: Patients report high levels of satisfaction even if they have recurrent instability or are unable to return to prior activity levels. Current scoring systems do not accurately depict patients’ post-operative outcomes after MPFL Reconstruction.

Level of Evidence: III

Keywords: mpfl, patella instability, mpfl reconstruction

INTRODUCTION

Patellar instability is a debilitating condition that can result in prolonged impairment and recurrent pain. While it varies by age, it has been reported that the incidence for primary dislocation of the patellofemoral joint can be up to 112 in 100,000. Dislocation of the patellofemoral joint is an injury that tends to impact younger patients, with peak incidence between 15-19 years of age; and initial injury often occurring during athletic activity. Nearly half of all patients who have patellar dislocations go on to have recurrent patellar instability. Previously identified risk factors for patellofemoral instability include age, gender, bony and soft tissue abnormalities, and high body mass index (BMI).

The medial patellofemoral ligament (MPFL) is considered the most important soft tissue stabilizer in preventing excessive lateral translation of the patella when the knee is in 0 to 30 degrees of flexion. The anatomical structure of the patellofemoral joint makes it susceptible to dislocation and subluxation due to the compromised degree of congruency that can occur. Patellofemoral joint instability can result from anatomical abnormalities and/or deficient soft tissue restraints. Some degree of damage to the MPFL is seen in almost all acute lateral patellar dislocations. Further, MPFL insufficiency is seen in all cases of recurrent patellar dislocation, resulting in an unstable patellofemoral joint, knee pain, and disability. Reconstruction of the MPFL is a favorable treatment approach to instability because not only does the MPFL play a vital role in the stability of the patellofemoral joint, but also studies have shown that the results of conservative treatment are poor.
The general practice of most orthopedic surgeons is to treat primary dislocations conservatively unless there is an obvious osteochondral fracture with a loose intra-articular fragment or the patient has already dislocated again prior to being seen initially. Conservative treatment typically consists of 3 to 6 months of physical rehabilitation that focuses on optimizing lower extremity balance, strength, and function. However, failure to reestablish patellar stability after conservative treatment is common and can indicate a patient for surgical intervention. Current trends in surgical management of patellofemoral instability typically include some variation of soft tissue reconstruction, sometimes in combination with bony realignment, depending on patient anatomic factors such as the Q-angle, congruency of the patellofemoral joint, and lateral femoral condyle morphology.

Assessing the success of surgical treatment is difficult as current outcome scoring systems do not consider some important factors such as patient reported outcomes (PROs). Patient reported outcomes have become a pillar of modern, quality driven healthcare; however, few studies have assessed PROs following reconstruction of the MPFL.

There are a number of functional outcome scores reported to improve after MPFL reconstruction surgery. Examples of such scores include: Kujala patellofemoral disorder score, Tegner score, Lysholm score, Fulkerson score, and the Modified Cincinnati score. These scores attempt to categorize success in certain areas or domains after surgery, such as pain and function. However, these knee specific functional scores fail to capture a patient’s overall satisfaction or the patient’s ability to return to prior activity levels. These scores that are currently used to assess patellar instability were actually created for other diagnoses; patellofemoral pain, arthritis, or assessment after an intra-articular knee ligament injury. The only scoring system created for patellar instability is the Norwich Patellar Instability (NPI) score, which is used to assess the severity of patellar instability in deciding if surgery is warranted, not as a post-op score to assess the success of the surgery. Therefore, the purpose of this study is to determine if successful surgery, as measured by current scoring systems, correlates with patient satisfaction after MPFL reconstruction.

**METHODS**

**Study Design**

After institutional review board approval, a retrospective chart review was performed on all patients who underwent MPFL reconstruction at a single institution from January 2006 through January 2014 by two sports medicine-trained orthopaedic surgeons. Inclusion criteria was a patient who had undergone MPFL reconstruction identified by CPT code 27420 and/or 27422. Exclusion criteria included: follow-up less than 1-year, incomplete data sets, or failure to complete telephone questionnaire. Charts were reviewed and 100 patients (57 women and 43 men) met the inclusion criteria. All patients were attempted to be contacted by telephone to complete a follow-up questionnaire (Figure 1) pertaining to their satisfaction, functional status, pain, and patellar stability. Of the 100 patients, 54 completed the questionnaire, had follow-up greater than 1 year, and had complete data sets.

Other pre-op and post-op information was gathered by reviewing the patients’ medical records. This information included: gender, previous procedures, date of birth, TT-TG pre-op measurement, height, weight, BMI, age at injury date, smoking status, sport played, pre-op and post-op J sign, pre-op and post-op SF36 score, and pre-op and post-op NPRS-VAS (Numeric Pain Rating Scale version of the Visual Analog Scale) pain score. A descriptive analysis of pain, function, satisfaction of knee function, and re-dislocation/subluxation rates was performed via questionnaire. Means and standard deviations were reported for all variables that were normally distributed.

**Data Analysis**

Univariate analysis was done with Student's t-test and Chi-squared to evaluate differences between current levels of activity, SANE scores, gender, smoking status,VAS pain scores, satisfaction with knee function and overall care, re-dislocation and re-subluxation events, and if additional surgical intervention was needed. Data

<table>
<thead>
<tr>
<th>Question</th>
<th>Response Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Has your patella (kneecap) dislocated since your surgery?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>2. Since surgery, has your patella (kneecap) felt like it shifted unnaturally or nearly dislocated?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>3. On a scale of 0 to 100, how would you rate your knee’s function, with 100 being completely normal?</td>
<td>0 to 100</td>
</tr>
<tr>
<td>4. Were you able to return to your pre-injury level of activity/ sport participation after your surgery?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>5. Currently, how would you rate your knee pain on a scale of 0 to 10? Zero is ‘no pain’ and 10 is the worst pain you have ever felt or could imagine.</td>
<td>0 to 10</td>
</tr>
<tr>
<td>6. Have you had any additional surgeries on your knee since Dr. (name of surgeon) operated on your knee?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>7. How satisfied are you with the current level of function of your knee, zero for not at all satisfied and 10 for completely satisfied?</td>
<td>0 to 10</td>
</tr>
<tr>
<td>8. How satisfied are you with the care you received, zero for not at all satisfied and 10 for completely satisfied?</td>
<td>0 to 10</td>
</tr>
<tr>
<td>9. Given what you know now about the outcome of your surgery, if you were presented with the same circumstances, would you decide to have the surgery done again?</td>
<td>Yes/No</td>
</tr>
</tbody>
</table>

Figure 1. A copy of the telephone questionnaire given to the participants in the study.
were organized into an excel spreadsheet which was then imported into R studio version 4.0.4. Multivariate analysis was done with logistic regression models to estimate the effect of multiple variables on return to activity, satisfaction, and function while controlling for possible confounding variables. Statistical significance was set at p<0.05.

**RESULTS**

The study cohort comprised 23 males and 31 females. Average follow-up time of the questionnaire was 40.9 ± 21.6 months. Mean patient age was 24.5 ± 9.6. The mean BMI was 26.6 kg/m² ± 6.1.

Those reporting a lower knee satisfaction score were more likely to have had post-operative subluxation events (p<0.001). Patients reported poorer knee function (SANE) post-operatively if they had post-operative subluxation (p=0.003).

Of the 54 patients, 54% (29/54) reported being highly satisfied after surgery with a rating of 9 or 10 out of 10. The average SANE score was 80.6 ± 16.6 out of 100 (range: 45-100). Of the 21 patients who reported a SANE of 90 or higher, 91% (19/21) reported being highly satisfied. Of the 23 who reported a SANE of <80, only 13% (3/23) reported being highly satisfied. Average preoperative VAS was 5.4 ± 2.5 and the average VAS after at least one-year follow-up was 1.7 ± 2. Of the 34 patients who reported a VAS pain score less than 2 (little to no pain) at one-year follow-up, 68% (23/34) reported being highly satisfied. Of the 20 patients who reported a VAS score of 2 or more, only 30% (6/20) reported being highly satisfied.

Of the 54 patients, 30% (16/54) reported recurrent subluxation (with or without re-dislocation) and 9% (5/54) reported recurrent dislocation. Of the 5 patients who reported re-dislocation, 0 expressed that they were highly satisfied. Fifty-five percent of patients who reported recurrent subluxation without recurrent dislocation (6/11) reported being highly satisfied.

Of the 54 patients, 54% (29/54) reported being unable to return to previous activity, though 31% (9/29) of these patients still reported being highly satisfied with their knee.

When assessed by the physician for preoperative and postoperative J sign, 35% (19/54) of patients had the sign preoperatively while 0% did postoperatively. There was no relationship between preoperative J sign and postoperative return to activity (p=0.58).

When asked if they would undergo the surgery again, 89% (48/54) of patients reported they would. The average knee satisfaction score was an 8.0 ± 2.3 on a scale of 0 to 10 (range: 2-10). The average satisfaction of the care received was a 9.6 ± 1.0 on a scale of 0 to 10 (range: 5-10).

Table 1 depicts the comparison of outcomes between patients who did and did not return to prior activity levels. Patients who reported returning to prior levels of function had higher SANE scores (p<0.001), higher knee satisfaction scores (p<0.001), and lower VAS scores (p=0.019) than those who did not return to prior levels of function. However, there were no differences for patients who did and did not return to their prior level of function after MPFL surgery in regards to gender (p=0.45), BMI (p=0.073), satisfaction with overall care received (p=0.132), pre-op pain scores (p=0.225), if they would have the surgery again (p=0.254), re-dislocation (p=0.386), re-subluxation (p=0.205), and if they had additional surgeries (p=0.058) (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>Aggregate</th>
<th>Returned to Prior Function</th>
<th>Did Not Return to Previous Function</th>
<th>P Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>54</td>
<td>25</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>SANE Score (0-100)</td>
<td>80.6 ± 16.6</td>
<td>87.9 ± 12.6</td>
<td>74.2 ± 17.3</td>
<td>0.001</td>
</tr>
<tr>
<td>Knee Satisfaction (0-10)</td>
<td>8.0 ± 2.3</td>
<td>9.1 ± 1.4</td>
<td>7.1 ± 2.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Overall Care Satisfaction (0-10)</td>
<td>9.6 ± 1.0</td>
<td>9.7 ± 0.7</td>
<td>9.5 ± 1.1</td>
<td>0.153</td>
</tr>
<tr>
<td>Postoperative Pain Scores (0-10)</td>
<td>1.7 ± 2.0</td>
<td>1.1 ± 1.4</td>
<td>2.2 ± 2.3</td>
<td>0.019</td>
</tr>
<tr>
<td>Preoperative Pain Scores (0-10)</td>
<td>5.4 ± 2.5</td>
<td>5.7 ± 2.6</td>
<td>5.2 ± 2.4</td>
<td>0.225</td>
</tr>
<tr>
<td>Would Have Surgery Again (N)</td>
<td>48 (89%)</td>
<td>23 (92%)</td>
<td>25 (86%)</td>
<td>0.254</td>
</tr>
<tr>
<td>Patients with Re-dislocation (N)</td>
<td>5 (9%)</td>
<td>2 (8%)</td>
<td>3 (10%)</td>
<td>0.386</td>
</tr>
<tr>
<td>Patients with Re-subluxation (N)</td>
<td>16 (30%)</td>
<td>6 (24%)</td>
<td>10 (35%)</td>
<td>0.205</td>
</tr>
<tr>
<td>Had Additional Knee Surgery (N)</td>
<td>9 (17%)</td>
<td>2 (8%)</td>
<td>7 (24%)</td>
<td>0.058</td>
</tr>
</tbody>
</table>
DISCUSSION
Knee pain and discomfort are the most common symptoms among patients with patellar instability; more than 50% of conservatively treated patients suffer from residual pain.\textsuperscript{21,22} Patellar instability can result in increased pain due to microlesions or inflammation of the primary and secondary stabilizing structures of the patellofemoral joint.\textsuperscript{22} The results showed that patients who undergo MPFL surgery report less pain at long term follow-up compared to pre-surgery. The average decrease in pain was a decrease by 3.7 VAS points on a scale of 0 to 10, which meets the minimum clinically important difference (MCID) of 2.\textsuperscript{23-26} Interestingly, in this study, pain ratings among those who did not return to prior activity also decreased significantly from 5.2 ± 2.6 to 2.2 ± 2.3. This suggests that the change in pain score does not discriminate between patients who were and were not able to return to preoperative activity levels.

Satisfaction is a complex construct and can be evaluated with many different types of PROs. However, satisfaction is not a perfect outcome measure because doctor-patient interaction, nurse-patient interaction, expected versus actual pain and function levels, as well as other aspects often affect satisfaction reports.\textsuperscript{27} Therefore, we decided to include multiple measurements of satisfaction including: a knee satisfaction score, an overall care satisfaction score, and if the patient would have the surgery again knowing their outcome. Overall, our findings suggested that even patients unable to return to preoperative activity levels were satisfied. Of the 29 patients unable to return to pre-op activity levels, 31% were highly satisfied with their knee, 90% were highly satisfied with the care they received for their knee, and 86% reported they would have the surgery again knowing their outcome. Other studies evaluating outcomes after MPFL reconstruction reported similar findings to ours regarding satisfaction following the surgery.\textsuperscript{21,28,29} The high levels of satisfaction despite an inability to return to previous levels of function suggests that other factors, such as overall treatment by medical personal, pain levels, and other individual biases may affect satisfaction ratings.

Our study also evaluated knee function as a postoperative assessment of knee stability. Preoperative patient outcomes related to knee function were not available, and therefore a MCID cannot be used to assess changes in knee function. The post-operative mean SANE score was 80.6 ± 16.6 out of 100. This relatively high score suggests that patients had a good level of knee function at the latest follow-up post-operatively. Nine patients gave their knee a perfect SANE score postoperatively. The use of SANE in patellar instability patients has not been reported in previous studies but results of a study by Shelbourne et al. showed that SANE scores exhibited moderate to strong positive correlations with the modified Cincinnati Knee Rating System and International Knee Documentation Committee Subjective Knee survey (IKDC) after anterior cruciate ligament (ACL) reconstruction and knee arthroscopy.\textsuperscript{30} Other previous studies comparing a SANE rating with other valid knee patient-rated outcome measures verify the results of the study by Shelbourne et al., showing SANE scores correlate well with Lysholm scores, Knee injury and Osteoarthritis Outcome Score (KOOS) pain, and KOOS quality of living scores in ACL reconstruction patients.\textsuperscript{30-32}

Patients who reported being able to return to their previous activity level had a mean SANE score of 87.9, whereas the mean SANE score for those who reported being unable to return to their previous activity level was 74.2, which was a statistically significant difference (p=0.001). These numbers suggest that SANE score is a good factor to include in assessing surgical outcome of MPFL reconstruction. However, the fact that 41% (12/29) of patients who did not return to previous levels of function reported a SANE score of 85 or higher suggests that SANE score cannot stand alone as an indicator of surgical success.

Failure rate was also assessed during our study. In this study, 30% of knees that had MPFL reconstruction were considered failures because of post-op patient reports of subluxation. Of these failures, 5 of these 16 patients also reported re-dislocation. Other studies that evaluated outcomes in patients with patellar instability following MPFL reconstruction have reported failure rates similar to ours.\textsuperscript{30,16,33,34} However, it is important to note that in our study, the failure rate was high since we included subluxations as failure whereas other studies only include dislocations.\textsuperscript{35} Of these 16 failures, 38% reported returning to prior activity, 63% reported they would have the surgery again, 25% reported a SANE score of 90 or higher, 69% reported being highly satisfied with the outcome, and 31% reported a NPRS-VAS pain score less than 2. This suggests that these other outcome measurements do not differentiate patients who do and do not have re-subluxation. Therefore, our analysis indicates that re-subluxation should be included as a separate measurement in determining the success of MPFL surgery.

Looking only at pain scores, satisfaction scores, and SANE function scores prevents physicians from recognizing patients who continue to have post-operative instability and who are unable to return to previous activities. SANE scores are a good indicator of a patient’s pain ratings and satisfaction; however, SANE scores often fail to account for postoperative stability and return to activity. A successful surgical outcome for MPFL reconstruction
occurs when: the procedure is performed technically correct (no postoperative J sign) resulting in a satisfied patient with a pain-free knee (high SANE score) and a stable knee (no recurrent subluxations) that allows the patient to return to previous levels of activity.

**Limitations**

This project only included 54 patients because only 54 of the 100 patients answered the questionnaire. The study was retrospective in nature therefore there may be bias introduced because of that. Twelve subjects had not reached 2-years post MPFL reconstruction yet, often considered the standard for postoperative studies and success. There were no preoperative SANE scores for comparative analysis.

**CONCLUSION**

Patients report high levels of satisfaction even if they have recurrent instability or are unable to return to prior activity levels. Current scoring systems do not accurately depict patients’ post-operative outcomes after MPFL Reconstruction.

**REFERENCES**

23. Farrar JT, Young JP, LaMoreaux L, Werth JL, Poole MR. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. Pain. 2001;94(2).
27. Mehta SJ. Patient Satisfaction Reporting and Its Implications for Patient Care. AMA journal of ethics. 2015;17(7).
30. Shelbourne KD, Barnes AF, Gray T. Correlation of a single assessment numeric evaluation (SANE) rating with modified Cincinnati knee rating system and IKDC subjective total scores for patients after ACL reconstruction or knee arthroscopy. The American journal of sports medicine. 2012;40(11).
ABSTRACT

Background: Avascular necrosis (AVN) is a rare albeit serious condition that has a high risk for long term morbidity given the risk of chronic pain and arthroplasty after diagnoses. The recent rise in sports participation in the pediatric population demonstrates the importance of evaluating functional limitations after AVN treatment. Return to sport (RTS) rates after treatment for AVN have not been evaluated in pediatric or adolescent populations.

It is necessary to evaluate all joints impacted by AVN due to heterogenous nature of the disease and the variety of sports that could be impacted by disease specific activity restrictions. Thus, this present study aimed to characterize RTS rate after AVN treatment, determine if there was a difference in RTS rates after operative versus nonoperative management, and identify demographic and treatment factors associated with RTS rates.

Methods: This retrospective cohort study evaluated patients ages eight to twenty years old who were treated for symptomatic AVN of any joint between January 2005 and August 2021. Patient records were reviewed for demographic, disease, and treatment variables. Standard descriptive statistics and bivariate analyses were performed to describe and compare groups who did and did not RTS. A generalized estimating model was used to determine variables that were associated with better RTS rates.

Results: A total of 144 patients and 190 lesions were evaluated in the study, 60 patients (43%) were female with a mean age of 14.36±3.24 years. The overall RTS rate after AVN treatment was 67% (64/96). Roughly 8% of patients (5/64) were able to return to multiple sports, however of those that returned to sports, 6% (4/64) reported playing at a lower level of competition. There was not a significant difference between the RTS rate for those who underwent operative versus nonoperative management (70% versus 62%, p=0.38). Males were almost 2.5 times more likely to return to sport than females (OR: 2.46, p=0.018).

Conclusion: The ability to return to sports after AVN treatment has largely remained unknown in the pediatric and adolescent populations. Our data suggests that a majority of patients are able to RTS in the short term follow up with males being twice as likely to RTS compared to females. Physicians should maintain awareness of the long-term morbidity of AVN and understand the unique patient and disease characteristics that optimize functional outcomes in this population.

Level of Evidence: III

Keywords: AVN, avascular necrosis, sports, return to sport, pediatrics, lesion, RTS, adolescent, arthroplasty

INTRODUCTION

Avascular necrosis (AVN) is a morbid condition that can be understood as a final shared pathway where blood supply to the bone is impaired causing necrosis. Numerous etiologies lead to this shared pathway, including Legg-Calve-Perthes disease, sickle cell disease, corticosteroid exposure, slipped capitol femoral epiphysis, and idiopathic causes. Although relatively rare in the general population, estimates place new diagnoses of AVN around 10,000 to 30,000 a year in the U.S. While AVN is often diagnosed in older patients aged 30 to 65, children and adolescents with the aforementioned conditions are at higher risk of developing AVN than their healthy counterparts.

In this younger at-risk population, the outcomes and long-term prognosis are less than ideal. Lesions in weight-bearing joints, like the hip, commonly cause symptoms of pain and can eventually progress to joint collapse. While there are many nonoperative and operative treatments for AVN such as hyperbaric-oxygen, bisphosphonate therapy, zoledronic acid, osteotomy, core decompression with or without bone marrow aspi-
rate concentrate (BMAC), many patients will require a joint arthroplasty for definitive treatment.

Previous literature examining AVN outcomes have evaluated pain, rates of arthroplasty, and rates of hardware survival. However, there is a need to better understand functional outcomes for those diagnosed with AVN in any joint, especially in pediatric and adolescent populations. Given the increasing amount of youth sport participation and earlier ages of sports specialization, there is a need to evaluate return to sports (RTS) rates in pediatric and adolescent patients treated for AVN. Furthermore, it is critical to evaluate all joints impacted by AVN due to the heterogeneous nature of the disease and the variety of sports that could be impacted by disease specific activity restrictions. To address this gap in literature, this study aims to characterize RTS rates after AVN treatment in any joint, determine if there was a difference in RTS rates after operative versus nonoperative management, and identify demographic and treatment factors associated with better RTS rates in pediatric and adolescent patient populations.

METHODS

Following institutional review board-approval, we performed a retrospective cohort study evaluating patients who were diagnosed with avascular necrosis (AVN) of any joint at a single tertiary pediatric hospital. Patients eight to twenty years old who were treated for symptomatic AVN between 1/1/2005 and 12/31/2021 were included. Patients who were asymptomatic, did not have AVN confirmed by radiographs or advanced imaging, or did not have at least 12 months of follow up were excluded from the study.

AVN diagnosis was confirmed based on EMR documentation, radiographs, and the following ICD-9 and ICD-10 codes: 733.4, 733.41, 733.42, 733.43, 733.44, 733.49, M87, M87.0, M87.00, M87.01, M87.012, M87.019, M87.02, M87.021, M87.022, M87.029, M87.03, M87.031, M87.032, M87.033, M87.034, M87.035, M87.036, M87.037, M87.038, M87.039, M87.05, M87.050, M87.051, M87.052, M87.059, M87.06, M87.061, M87.062, M87.063, M87.064, M87.065, M87.066, M87.07, M87.071, M87.072, M87.073, M87.074, M87.075, M87.076, M87.08, M87.09, M87.8, M87.80.

Authors collected demographic and treatment data for all patients who met inclusion criteria, including variables such as age, sex, AVN location, treatment type (operative vs. nonoperative), and etiology of AVN. Data was also collected on the patient’s ability to RTS, the type of sport returned to, and impact level of the sport. Each patient’s sport involvement status was based on chart review of all Orthopedic specific visits combined with a complimentary text search of all hospital encounters that referenced sports during their treatment. As per routine institutional practice, treating physicians documented each patient’s baseline activity level and the activities they are involved in, including sports. Patients were classified as returned to sport if there was post-treatment documentation of sport involvement or the treatment plan referenced sport specific advancements in activity levels. Common post-treatment visit statements included, “patient returned to…” and “patient is now involved in…”.

Standard descriptive statistics were used to report demographic variables. Bivariate analyses of the primary outcomes of interest (RTS) were performed using Chi-square, Fisher’s test, Mann-Whitney U, and Kruskal-Wallis tests. Considering that some patients had multiple AVN-affected joints, we utilized generalized estimating equations model (GEE model) for regression to account for correlated repeated measures among our study population. All statistical analysis was completed with Stata 15 (College Station, TX) and statistical significance was considered to be p< 0.05.

RESULTS

Demographics

Over the sixteen-year period ending in 2021, 265 patients were initially identified as eligible (Figure 1). There were 47 patients excluded for having asymptomatic AVN or being outside the age range, leaving 218 for review. A total of 74 patients were removed for having less than 1 year of follow up, leaving a total of 144 patients with 190 AVN-affected joints available for study. Of the 144 patients, 60 (43%) were female with...
Table 1. Population Demographics for Patients with AVN Treatment in Surgical and Nonoperative Populations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total Population (n=144, lesions =190)</th>
<th>Surgical Treatment (n=89, lesions=106)</th>
<th>Nonoperative Treatment (n=55, lesions=84)</th>
<th>Chi Square</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td>1.03</td>
<td>0.31a</td>
</tr>
<tr>
<td>Male</td>
<td>84 (57%)</td>
<td>49 (55%)</td>
<td>35 (63%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>60 (43%)</td>
<td>40 (45%)</td>
<td>20 (37%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td></td>
<td>10.87</td>
<td>0.055c</td>
</tr>
<tr>
<td>Caucasian</td>
<td>49 (34%)</td>
<td>38 (43%)</td>
<td>11 (20%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>23 (16%)</td>
<td>14 (16%)</td>
<td>9 (16%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>6 (4%)</td>
<td>4 (4%)</td>
<td>2 (4%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indian</td>
<td>1 (1%)</td>
<td>0 (0%)</td>
<td>1 (2%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>8 (6%)</td>
<td>3 (3%)</td>
<td>5 (9%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>57 (39%)</td>
<td>30 (34%)</td>
<td>27 (49%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
<td>4.303</td>
<td>0.116c</td>
</tr>
<tr>
<td>Non-Hispanic</td>
<td>76 (52%)</td>
<td>53 (60%)</td>
<td>23 (42%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>11 (8%)</td>
<td>6 (6%)</td>
<td>5 (9%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>57 (40%)</td>
<td>30 (34%)</td>
<td>27 (49%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age at First Lesion</strong></td>
<td>14.36 +/-3.24</td>
<td>13.88 +/- 3.08</td>
<td>14.96 +/- 3.35</td>
<td></td>
<td>0.023c</td>
</tr>
<tr>
<td><strong>Location of Lesion</strong></td>
<td></td>
<td></td>
<td></td>
<td>12.018</td>
<td>0.035c</td>
</tr>
<tr>
<td>Hip</td>
<td>108 (57%)</td>
<td>69 (65%)</td>
<td>39 (47%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td>43 (23%)</td>
<td>21 (20%)</td>
<td>22 (26%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ankle</td>
<td>21 (11%)</td>
<td>10 (9%)</td>
<td>11 (13%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td>12 (6%)</td>
<td>3 (3%)</td>
<td>9 (11%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td>4 (2%)</td>
<td>3 (3%)</td>
<td>1 (1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand</td>
<td>2 (1%)</td>
<td>0 (0%)</td>
<td>2 (2%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Laterality</strong></td>
<td></td>
<td></td>
<td></td>
<td>1.176</td>
<td>0.555c</td>
</tr>
<tr>
<td>Right</td>
<td>83 (44%)</td>
<td>47 (44%)</td>
<td>36 (43%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>77 (41%)</td>
<td>40 (38%)</td>
<td>37 (44%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td>30 (15%)</td>
<td>19 (18%)</td>
<td>11 (13%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cause of Lesion</strong></td>
<td></td>
<td></td>
<td></td>
<td>14.628</td>
<td>0.102c</td>
</tr>
<tr>
<td>Steroid Induced (Cancer)</td>
<td>59 (31%)</td>
<td>34 (32%)</td>
<td>25 (30%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sickle Cell Anemia</td>
<td>48 (25%)</td>
<td>23 (22%)</td>
<td>25 (30%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idiopathic</td>
<td>25 (13%)</td>
<td>16 (14%)</td>
<td>9 (11%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septic Arthritis</td>
<td>9 (5%)</td>
<td>2 (2%)</td>
<td>7 (8%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trauma</td>
<td>8 (4%)</td>
<td>7 (7%)</td>
<td>1 (1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDH</td>
<td>7 (3%)</td>
<td>5 (5%)</td>
<td>2 (2%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perthes</td>
<td>4 (2%)</td>
<td>3 (3%)</td>
<td>1 (1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCFE</td>
<td>3 (2%)</td>
<td>3 (3%)</td>
<td>0 (0%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juvenile Idiopathic Arthritis</td>
<td>1 (1%)</td>
<td>0 (0%)</td>
<td>1 (1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Length of Follow Up (months)</strong></td>
<td>27.50 (18 to 43.5)</td>
<td>32.5 (23.5 to 51)</td>
<td>24 (16 to 29)</td>
<td></td>
<td>0.0001c</td>
</tr>
</tbody>
</table>

Data is presented as n(%), mean +/- SD, or median (IQR). a- chi square test, b- independent t test, c-Kruskal Wallis. P value less than 0.05 in bold.
a mean age of 14.36 ± 3.24 years (Table 1). AVN lesions were most commonly located in the hips (57%, 108/190), followed by the knees (23%, 43/190), ankles (11%, 21/190), and shoulders (6%, 12/190). High dose courses of steroids were the most common etiology for AVN lesions followed by sickle cell anemia and idiopathic causes (Table 1). Over 50% of lesions (56%, 106/190) underwent operative treatment, whereas 44% (84/190) received nonoperative management with physical therapy and observation. The majority of patients who underwent operative treatment received core decompression and bone marrow aspiration (Table 2).

### Table 2. Surgical Treatment Type Overview

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total Population (n=106)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Decompression with Bone Marrow Aspiration</td>
<td>63 (59%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>12 (11%)</td>
</tr>
<tr>
<td>Joint Replacement</td>
<td>9 (8%)</td>
</tr>
<tr>
<td>Osteotomy (femoral, tibial)</td>
<td>7 (7%)</td>
</tr>
<tr>
<td>Hardware Removal</td>
<td>4 (4%)</td>
</tr>
<tr>
<td>Pelvic Acetabular Osteotomy with Bone Graft</td>
<td>3 (3%)</td>
</tr>
<tr>
<td>Surgical Debridement</td>
<td>3 (3%)</td>
</tr>
<tr>
<td>Epiphysiodesis</td>
<td>2 (2%)</td>
</tr>
<tr>
<td>Arthrogram</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Surgical Dislocation with femoral neck lengthening</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Screw Fixation with Allograft</td>
<td>1 (1%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>106</strong></td>
</tr>
</tbody>
</table>

Data is presented as n(%)

The median post treatment follow-up for all patients was 27.5 months (IQR: 18 to 43.5 months).

### Return to Sport Rate After AVN Treatment

The overall return to sport rate after AVN treatment was 67% (64 of 96). Swimming, basketball, and baseball/softball were the most commonly played sports after treatment (Table 3). However, roughly 8% of patients (5/64) were able to return to multiple sports. Of those that returned to sports, 6% (4/64) reported playing at a lower level of competition and 3% (3/64) reported switching their primary sport after their treatment.

### Difference in RTS Rates After Operative Versus Nonoperative Management

There was not a significant difference between the return to sport rate for those who underwent operative versus nonoperative management (70% [40/57] versus 62% [24/39] respectively, p=0.38). There also was no difference in the type of sport returned to or impact level of the sport between the two treatment cohorts (Table 3).

### Demographic, Lesion, and Treatment Factors Associated With Better RTS Rates

Based on the GEE model, males were almost 2.5 times more likely to return to sport than females (OR: 2.46, 95% CI: 1.16 to 5.20, p=0.018). There was not a difference in proportion of patients who returned to sport based on age, race, ethnicity, location of the lesion, cause of the lesion, or type of treatment.

### DISCUSSION

Our study, a cohort of 144 patients and 190 joints, described the epidemiology and factors associated with return to sport rates among pediatric and adolescent pa-
tients treated for AVN. To our knowledge, this is the first study to evaluate return to sports rates, as a functional outcome, in this patient population. Our results suggest that a majority of patients are able to return to sport in some form in the short term and that males were significantly more likely to return to sport than females.

The epidemiologic results of our patient population mirror those found in prior studies. Most pediatric and adolescent literature report that common AVN-affected joints are the hips and knees, followed by the shoulders, ankles, and elbows. The majority of patients had a history of corticosteroid treatment which redemonstrates the risk of AVN following treatment for cancer or autoimmune conditions. A majority of the patients in the study cohort were able to return to sport. Given that the ability to return to activity after AVN treatment has largely remained unknown in the pediatric and adolescent populations, our study provides an importation foundation for postoperative expectations for both providers and patients. A recent study demonstrated that there is low return to impact activity after core decompression of femoral head AVN. However, this study was conducted in military members who were significantly older and had higher activity requirements than our study. Furthermore, our study also evaluated lesions in non-weightbearing joints where there may be less risk of joint collapse and quicker return to activity. Although our study did not find a difference between return to sport and AVN location, there may be a difference at mid to long term follow up.

Our study also surprisingly demonstrated that there was no difference in return to sport rates between those treated operatively and nonoperatively. Given that treatment outcomes for AVN are associated with disease severity, with most studies showing advanced disease has poorer outcomes, one might expect that those receiving operative care would have more advanced disease and lower likelihood of return to sport. However, our study demonstrated that a majority of operative patients return to sport in the short term follow up. Patients who received operative intervention were younger than those in the nonoperative cohort therefore there could be a treatment bias where the younger patients had more severe disease requiring surgery. However, the clinical influence of patient age is unclear since there is less than one year difference between the cohorts and no overall difference in return to sport rate. In addition, our study evaluated return to sport in patients with over a year of follow up, however there could be long term differences between those who undergo operative and nonoperative management.

The result that males are more likely to return to sport than females has been reported in other conditions, including concussions and anterior cruciate ligament reconstructions. A recent meta-analysis on anterior cruciate ligament reconstruction reported that females differed in both subjective and functional outcomes post reconstruction, and had lower return to sport rates than their male counterparts. One theory for the difference in return to sports rates between sexes is psychological and developmental differences between males and females. It is important to note that successful return to sport is a multifactorial outcome dependent on risk of re-injury, presence of clear athletic goals, and other psychosocial factors. Due to the heterogeneity of AVN lesions and the corresponding recovery timelines, further research is needed to identify subgroups at risk for worse recovery. However, our results can provide an initial framework for generalized recovery expectations after AVN treatment.

We were unable to identify any other patient, AVN lesion, or treatment characteristics to define a subgroup of patients that would be more likely to return to sport. Our findings suggest that it is difficult to predict which pediatric patients will return to sport, however other AVN lesion and treatment characteristics should be explored before definitive recommendations are issued. Specifically, outcome studies using lesion classification systems such as the Steinberg Classification System for AVN of the femoral head could be used to further define hip lesion specifics. Given the rare and heterogenous nature of AVN, randomized trials comparing return to sport after specific treatment may not be feasible, although future studies could investigate other aspects of treatment and recovery strategies such as frequency of physical therapy, types of surgery, cost-effectiveness of surgery, and psychosocial implications for patients.

**Limitations**

Foremost, our study is not designed to answer definitely the question of whether specific patient or operative interventions allow for long term return to sport after AVN treatment, as it does not account for other considerations such as the long-term morbidity associated with lesion size, nor have we performed a psychosocial evaluation of patients returning to sport. Second, this study is limited by the sample size related to the rarity and heterogeneity of AVN. In particular, our study may have been underpowered to detect difference in the type of sports played, impact of sport, or competition level. However, the inclusion of these variables was to provide an epidemiologic framework for future studies to use while evaluating patients. It is also likely that other factors we did not consider, such as poorly understood variables related to specific lesion biology, may be useful in identifying patients at risk for
high recurrence and failure to return to sport. Thirdly, this study characterized return to sport after at least one year of follow, but future studies should look for long term return to sport rate and associated retention rates. It is possible some or many of these patients return to sport initially after treatment, only to worsen to the point of needing arthroplasty in the long-term. Finally, this study is limited by certain biases related to its retrospective design. While this study sought to use preexisting data to establish whether there are factors influencing return to sports rates, future studies could utilize patient callback or prospective study design to further characterize the results.

CONCLUSION

Rates of arthroplasty have been historically helpful in characterizing end stage outcomes of AVN, however functional outcome measures like return to sport provide valuable information to providers treating pediatric and adolescent patients. The ability to return to sports after AVN treatment has largely remained unknown in this population. Our data suggests that a majority of patients are able to return to sport in the short term follow up. Furthermore, males are over twice as likely to return to sport compared to females. We were unable to further define a subgroup that could return to sport in the short term follow up. Physicians should maintain awareness of the long-term morbidity of AVN and understand the unique patient and disease characteristics that optimize functional outcomes in this population.

REFERENCES

11. Agarwala S, Banavali SD, Vijayvargiya M. Bisphosphonate Combination Therapy in the Management of Postchemotherapy Avascular Necrosis of the Femoral Head in Adolescents and Young Adults: A Retrospective Study From India. J Glob Oncol. 2018;4:1-11.


ABSTRACT

Background: Traditional rehabilitation protocols for surgically treated metacarpal shaft fracture allow for return to play at 6-8 weeks post-operative. This may be devastating for the elite athlete. We outline a protocol that may allow for professional basketball players to successfully return to sport within four weeks following surgery.

Methods: Professional basketball players who sustained non-thumb metacarpal shaft fractures were included. All athletes underwent open reduction and internal fixation of the injured metacarpal. Patients were subsequently enrolled into an accelerated rehabilitation protocol.

Results: The five athletes in our case series successfully passed return to sport testing within four weeks of surgery.

Conclusion: A plate and screw construct can potentially allow for professional basketball players to return to play within half the time. Future research studies should include a larger pool of athletes to further investigate accelerated rehabilitation following surgical fixation of metacarpal fractures.

Level of Evidence: IV

Keywords: hand, wrist, metacarpal, nba, basketball, elite athletes

INTRODUCTION

Catching aggressive passes, securing rebounds, and protecting the basket leave the basketball player prone to upper extremity injury – metacarpal shaft fractures in particular. Sporting activities account for the second largest cause of metacarpal fractures, encompassing 34% of all sport-related upper extremity injuries.1,2

Metacarpal shaft fractures can be treated nonoperatively or operatively. Stable fracture patterns with no rotational deformity and acceptable tolerances for angulation/displacement can be managed non-operatively with immobilization in an orthosis and early range of motion exercises.3 Indications for operative management include unstable fracture patterns, intraarticular fractures, rotational deformity, significant displacement or angulation, multiple metacarpal shaft fractures and open injuries.2 Hardware used for reduction and fixation can consist of Kirschner wires, plates and screws, or screws alone.4 Complications such as malalignment, rotational deformity, and extensor lag may occur if not treated appropriately.5

Traditional rehabilitation protocols are conservative in nature. Regardless of type of fixation, return to sport is typically not permitted until 6-8 weeks post-surgery. If the fracture is reduced with Kirschner wire fixation, motion is not permitted until the wires are removed at 3-4 weeks post-surgery.6 Progressive strengthening is often delayed until the fracture is well healed. If the metacarpal fracture is surgically managed by open reduction and internal fixation (ORIF) and the surgeon deems the fracture stable, traditional protocols encourage early motion 2-3 days post-surgery with use of a protective orthosis for the first 4-6 weeks post-surgery. Progressive strengthening is initiated 4-6 weeks post-surgery. Although heavy lifting is still restricted, unrestricted hand activities are encouraged 6-8 weeks post-surgery.7

The most pressing issue for athletes is determining the timeline for return to sport, as this may have direct implications on their season. A previous study on National Basketball Association (NBA) players with metacarpal fractures reported a mean time for return to play of 57 days in patients treated operatively and 26 days in patients treated non-operatively.8 The average number of missed games was 16 games for those treated operatively and non-operatively.8 In a report of National Collegiate Athletic Association (NCAA) men’s basketball players, the mean time for return-to-play in non-operative metacarpal fractures was 14 days, compared to 32 days in patients undergoing surgical fixation.9

The recent push to improve return-to-sport times for elite athletes seems to be explained by modifications in surgical technique and earlier initiation of range-of-motion exercises.6,8 This is done with the hope of giving athletes the best chance of returning to sport while
minimizing potential risk of non-union, malunion, or loss of fixation. However, literature describing accelerated return to play following fixation of metacarpal fractures remains limited. In this case series, we illustrate five cases of professional basketball players who safely and successfully returned to sport within four weeks postsurgery, faster than previously reported.

METHODS

Patients in our retrospective, single-center, consecutive case series are all professional basketball players who sustained any non-thumb metacarpal shaft fracture. Exclusion criteria included: multiple ipsilateral metacarpal shaft fractures, open fracture, or ipsilateral upper extremity injury. None of the patients in our cohort of study were excluded. All closed fracture patterns (i.e. transverse, oblique, spiral, comminuted) with any displacement and malalignment were included for study. All patients had surgery performed by a single fellowship-trained hand surgeon over a five-year span, from 2016 to 2021. The athletes in our series subsequently underwent rehabilitation from the same board-certified occupational hand therapist.

Surgical Technique

Each patient underwent open reduction internal fixation of their metacarpal shaft fracture using a dorsal approach. Once adequate exposure was achieved, provisional reduction of the metacarpal fracture was obtained using a reduction clamp and/or Kirschner wires. A 2.0 mm titanium alloy plate was applied to the dorsal metacarpal spanning the fracture site and the length of the metacarpal shaft. The senior surgeon prefers titanium alloy over stainless steel given favorable biocompatibility and strength characteristics. Interfragmentary screws were used when possible. Anatomic reduction and proper placement of the plate were confirmed with fluoroscopic guidance. All screw holes in the plate were filled with locking and/or non-locking screws; no hole was left open that might act as a potential stress riser (figure 1). Prior to closure, normal rotational alignment of the finger was confirmed. An intrinsic-plus plaster splint was applied for the short period of time prior to initiation of rehabilitation. Post-operative x-rays were taken routinely until return to play. Radiographs were not taken afterwards due to absence of pain or other symptoms of hardware failure.

Rehabilitation

The rehabilitation process occurred at a rate of five to seven times per week. Rehabilitation session lengths varied between thirty to one hundred twenty minutes depending on the time point post-surgery. Each player underwent a thorough initial evaluation including a series of objective and subjective assessments. A subset of the assessments was performed at every follow-up visit, with a formal comprehensive re-evaluation occurring at least twice during their rehabilitation length of stay.

Formal rehabilitation began 2-3 days post-operatively, where a custom static volar wrist orthosis was fabricated. The custom fabricated orthosis (figure 2) allows for early transition out of the post-operative cast and permits full digital motion. Unrestrictive active and gentle passive range of motion was also initiated at that time. At 5-7 days post-surgery, proximal strengthening of the shoulder,

Figure 1. Plate fixation of metacarpal shaft fracture. Note that the plate spans the entire length of the metacarpal shaft and every screw hole is filled.

Figure 2. Custom fabricated wrist-specific orthosis permitted early transition out of the post-operative cast and early digital range of motion.
elbow, forearm and wrist was initiated. At 1-2 weeks post-surgery, a custom sport orthosis was fabricated, graded sport-specific basketball skills retraining was initiated, and hand (grip and pinch) strengthening started. The custom sport orthosis (figure 3) is customized to the athlete’s needs and comfort. They range from being contoured directly onto the dorsal hand, or some variation of building in gel and padding to disperse pain if struck dorsally. Athlete input is involved in the design and adherence technique to maximize “feel” while maximizing protection. The orthosis mainly allowed for patients to return to play with confidence and comfort. It was up to the athlete whether or not the orthosis was worn during gameplay, and if so, how long it was worn for until being weaned off. Basketball specific skills addressed in rehabilitation included: dribbling, passing, catching, and shooting. Athlete sessions were graded by size of ball, weight of ball, single-hand vs. both-hands, speed, controlled versus continuous repetitions. This is performed until the athlete is engaged in normal use of their hand and upper extremity with a regulation NBA basketball. Patients subsequently returned to sport at 4 weeks post-surgery. Our protocol is summarized in Table 1.

**Return to Play**

Return to play was a collaborative decision between the surgeon, therapist, and athlete. From the surgeon perspective, resolution of pain was suggestive that enough healing has occurred for the patient to safely return to sport. From the therapist perspective, the athlete was able to demonstrate full motion, resolution of pain and edema, functional strength and ability to handle specific demands of the sport (non-contact skills and contact re-integration with teammates). From the athlete’s perspective, the patient needs to report confidence prior to returning to sport.

**Data collection**

All data was collected at occupational therapy follow-up, including when patients were removed from their initial post-surgical splint; were fitted for a custom orthosis; were started on range-of-motion exercises, strengthening and sport-specific skills; and were ultimately cleared for return-to-sport. No statistics were required for our dataset and the scope of our case series.

**Case Review**

**Case 1:** This player sustained a dominant long finger metacarpal fracture during gameplay and underwent ORIF the following day (figure 4). A custom static volar wrist orthosis was fabricated on post-operative day (POD) 1. Both active and passive range-of-motion exercises were initiated at that time. On POD 7, proximal upper extremity strengthening was initiated. On POD 9, a dorsal hand-based protective orthosis was fabricated and low impact graded sport-specific basketball skills.
were initiated. At two weeks post-surgery, the athlete started hand strengthening (grip and pinch) exercises while continuing to work on basketball-specific skills retraining. At four weeks post-surgery, the athlete was cleared for return to game-play, but could not actually do so due to the team not advancing in the playoffs. The patient was formally discharged from rehabilitative services.

**Case 2:** This athlete suffered an extra-articular non-dominant index finger metacarpal fracture during a game and underwent ORIF the following day. A custom static volar wrist orthosis was fabricated on POD 3. Both active and passive range-of-motion exercises were initiated at that time. Proximal strengthening was initiated on POD 5. Graded basketball-specific skills retraining, fabrication of a dorsal hand-based protective orthosis, and hand strengthening (grip and pinch) were initiated on POD 10. The athlete was cleared for return to game-play prior to four weeks post-surgery and did so successfully on POD 24. The patient followed-up at three weeks after return to play for reassessment and finalization of home exercises. The patient was formally discharged from rehabilitative services at that time.

**Case 3:** This athlete suffered a non-dominant ring finger metacarpal fracture during practice and underwent ORIF two days after (figure 5). A custom static volar wrist orthosis was fabricated on POD 3. Both active and passive range of motion exercises were initiated at that time. Proximal strengthening was initiated on POD 5. Hand strengthening (grip and pinch) was initiated on POD 8. Graded basketball-specific skills retraining and fabrication of a dorsal hand-based protective orthosis were started on POD 10. The athlete was cleared for return to play at four weeks post-surgery and did so successfully. The patient followed-up at ten days after return to play for reassessment and finalization of home exercises. The patient was formally discharged from rehabilitative services at that time.

**Case 4:** This athlete suffered an extra-articular dominant long finger metacarpal fracture during a game and underwent ORIF the following day. A custom static volar wrist orthosis was fabricated on POD 2. Both active and passive range-of-motion were initiated at that time. Proximal strengthening was initiated on POD 6. Hand strengthening (grip and pinch) was initiated on POD 7. Graded basketball-specific skills retraining was initiated on POD 9. Fabrication of a dorsal hand-based protective orthosis was delayed until seventeen days following surgery due to concerns with swelling from traveling at altitude. The athlete was cleared for return to game-play at four weeks post-surgery and successfully did so at five weeks post-surgery. The patient followed-up for two days after return to play for evaluation of soft tissue response. The patient was formally discharged from rehabilitative services at that time.

**Case 5:** This athlete suffered an extra-articular non-dominant ring finger metacarpal fracture during a game and underwent ORIF the following day. A custom static volar wrist orthosis was fabricated on POD 2. Both active and passive range-of-motion were initiated at that time. Proximal strengthening was initiated on POD 4. Graded basketball-specific skills retraining was initiated on POD 5. Hand strengthening (grip and pinch) was initiated on POD 7. Fabrication of a dorsal hand-based protective orthosis occurred on POD 17 in anticipation of clearance for contact play on POD 21—this was not needed for the player to progress through rehabilitation. The athlete was cleared for return to game-play prior to four weeks post-surgery and successfully did so on POD 25. The patient followed-up for two days after return to play for evaluation of soft tissue response. The patient was formally discharged from rehabilitative services at that time.

---

Figure 5. Spiral extra-articular fourth metacarpal fracture sustained during practice.

Figure 6. Favorable fracture healing of an athlete at 3 years post-surgery who returned to play at 5 weeks.
Follow-up
To date, all athletes in our series have progressed well since returning to sport. None of the patients have required plate removal since initial surgical intervention. Patients were evaluated one month after return to sport. Evidence of bony callus formation was noted on post-operative radiographs. Following confirmation of bony healing, patients were advised to follow-up on an as-needed basis. Patients returning to be evaluated for other injuries would have x-rays taken, demonstrating favorable healing (figure 6). However, patients did not complain of any subsequent pain following return-to-sport.

DISCUSSION
Playing basketball at the professional level requires optimal strength, conditioning and agility to excel in their sport. Professional basketball athletes must be in the best possible health to constantly push their limits in ball-handling, shooting, and defending. Upper extremity injuries, notably metacarpal fractures, can prevent these athletes from competing at the highest level. Historically, the recovery for these injuries has been six to eight weeks. This has not been well-defined in the elite athlete population, including professional basketball athletes. In this case series, we demonstrate five professional basketball athletes who have been able to progress through rehabilitation and return to play within four weeks of surgical intervention without complication. Of note, patients demonstrated favorable post-operative recovery regardless of initial fracture pattern. In addition, athletes in our cohort did not complain of any pain following return to sport that may suggest possible delayed fracture healing.

The return to play timeline for the athletes in our series is shorter than what is reported in the literature. Carlson et al. report a return to play time of 56 days post-operatively, almost double that in our cohort. Data on men’s collegiate basketball players showed a much faster average return to play of 32 days. A potential explanation for this finding could be related to differences in sample size and rehabilitation between the two studies. In a survey of surgeons on return to play times following metacarpal fracture, surgeons treating basketball players were less likely to recommend early return to play compared to those treating other athletes. Moreover, 73% of surgeons recommended unprotected play from four to eight weeks following injury.

The professional basketball players in our cohort demonstrate the possibility of returning to sport more rapidly than what is traditionally believed. We attribute this to both surgical and rehabilitation aspects of their care. From a surgical perspective, the authors of this paper advocate for use of a locking plate that spans the length of the fractured metacarpal with every hole filled by a screw (locking or non-locking). We believe that this provides the optimal stability for the fracture as it heals and decreases the chance of later plate failure through an empty screw hole. This also protects the metacarpal from further injury, allowing the athlete to initiate early and daily rehabilitation. From the rehabilitation perspective, this surgical approach gives clinicians confidence to accelerate all aspects of rehabilitation including motion, strengthening and sport-specific skills retraining to successfully and safely return their athletes to competition in advance of traditional protocols. As demonstrated above, range-of-motion exercises are started early at 2-3 days post-surgery and strengthening is initiated at 1-2 weeks post-surgery (compared to 4-6 weeks outlined in other protocols). Graded sport-specific skills retraining is also safely initiated at 1-2 weeks post-surgery. We believe that earlier initiation of each of these components of rehabilitation is critical for facilitating an accelerated return to sport following surgery.

Future Research
We hope that the results of the current study will aid in the development of a prospective cohort study in a larger sample size of patients. Futures studies may consider investigation of differences in patient-reported outcomes for professional basketball players who returned to sport earlier than the traditional 6-8 weeks.

CONCLUSION
For the professional basketball player, missed time from play due to injury can have important implications for both the player and the team. Traditional rehabilitation protocols for surgically-treated metacarpal fractures range from 6-8 weeks, but we feel that these protocols could be safely shortened to allow for accelerated and safe return to sport.

REFERENCES
COMPARING ACCURACY OF WRIST INTRA-ARTICULAR NEEDLE PLACEMENT VIA ULNOCARPAL APPROACH BY TRAINING LEVEL: A CADAVERIC STUDY

Sierra Phillips, MD1; Megan Lameka, MD1; Christopher Beaumont, MD1; Nileshkumar Chaudhari, MD1; Jared Halstrom, BSc1; James Rush Jones, BSc1; Nicholas A. Andrews, BSc1; Ashish Shah, MD1

1Department of Orthopaedic Surgery, University of Alabama, Birmingham, Alabama, USA

Corresponding Author: Ashish Shah, MD, ashishshah@uabmc.edu, 205-930-6722

Disclosures: The authors report no potential conflicts of interest related to this study.

Sources of Funding: No sources of funding declared.

ABSTRACT

Background: Intra-articular injections are a standard therapy and diagnostic tool for a variety of wrist conditions. Accurate needle placement is crucial for proper therapeutic benefit and prevention of complications. While some studies claim accurate needle placement requires imaging, others conclude that anatomical guidance is sufficient. This study aimed to evaluate the accuracy of intra-articular wrist needle placement with the ulnocarpal approach across differing levels of training using clinical anatomy alone.

Methods: Fourteen fresh-frozen, above-elbow cadaveric specimens were used. Intra-articular needle placement into the wrist via an ulnocarpal approach was attempted by nine study participants: two interns, two junior-level residents, two senior-level residents, two hand fellows, and one attending hand surgeon. Each injection was performed based on clinical examination and landmarks alone. The number of attempts and total time taken for each injection was recorded.

Results: Overall success rate was 71%, (89 of 126 attempts) and did not vary significantly across levels of training. Average time for needle placement among all participants was 10.9 ± 6.5 seconds. Timing of successful intra-articular needle placement (10.4 ± 5.2 seconds) significantly differed between levels. However, timing did not trend in any direction with more or less training. No significant difference was noted in total attempts or attempts with successful outcomes when comparing level of training.

Conclusion: The ulnocarpal approach is a viable option for injection or aspiration of the wrist without image guidance. We were unable to show any relevant trends with timing or number of attempts in comparison to level of training.

INTRODUCTION

Therapeutic intra-articular injections are routinely performed in painful joints of the hand and wrist.1 The wrist is a complex synovial joint consisting of the articulation between the distal radius, ulna, and proximal carpal row. Dislocations, chronic instability, and osteoarthritis may all cause functional and often painful limitations. In patients who fail early conservative management, injections may be considered.2 Additionally, arthrocentesis is an important diagnostic tool for various arthritic conditions. Accurate placement of the needle is of paramount importance in achieving desired therapeutic benefit and reducing the incidence of complications.1 Although recent studies suggest the use of imaging guidance for injections, many support the use of anatomic landmark palpation to inject without the aid of fluoroscopy or ultrasound.1,3,4 The dorsal approach is commonly advocated for wrist injections and arthrocentesis.5 The approach is just distal and ulnar to Lister’s tubercle, between the distal radius and lunate. It utilizes the palpable sulcus between the extensor pollicis longus (EPL) and the index finger extensor digitorum communis (EDC) tendon.6 We hypothesized that an ulnocarpal approach similar to the 6U arthroscopy portal would be more accurate than the traditional dorsal approach when performing anatomically based intra-articular injections.

METHODS

Fourteen fresh-frozen, above-elbow cadaveric specimens were obtained for completion of this study (75.7 ± 11.6; 8 F, 6 M; 7 left, 7 right). Prior to the start of the study, each specimen was deidentified and numbered 1-14. Specimens were allowed sufficient time for thawing prior to any attempt at injection to allow for adequate palpation of landmarks. Two specimens were noted to have healed surgical scars on the volar wrist, and after completion of the injections, they were confirmed fluoroscopically to have distal radius plates in place. We did not exclude these cadavers, as these variations are likely encountered in a clinical setting in which intra-articular wrist access would be necessary.
Nine participants from various levels of orthopedic surgery training were recruited to complete the injections: two interns (PGY-1), two junior-level residents (PGY-2 and 3), two senior-level residents (PGY-5), two Hand/Upper Extremity fellows, and one practicing orthopedic hand surgeon (10 years in practice). As a group, the participants were instructed on how to complete intra-articular needle placement in the wrist via an ulnar approach. The instruction consisted of a single demonstration and explanation by the participating attending physician just prior to the start of the study. Participants were instructed to palpate the ulnar head and ulnar styloid and locate the extensor carpi ulnaris (ECU) tendon running over the distal ulna on the dorsal-ulnar aspect of the wrist. Palpating just ulnar to the ECU tendon will identify a “soft-spot” that correlates with the ulnar fovea and the intra-articular space that the needle should be directed towards. The triquetrum also forms the distal border of this portal and its slope runs slightly retrograde going ulnarly to radially, thus the needle should also be angled in a slightly retrograde fashion as well. Of note, this injection approach is comparable to the intra-articular wrist access gained using the 6U wrist arthroscopy portal.

Each study participant then attempted to insert a 25-gauge injection needle into the wrist joint via the described ulnar approach. This process was completed in each of the 14 cadaveric specimens. The total number of attempts per cadaver was recorded, and the collective attempts on each cadaver were timed until the participating surgeon was satisfied with the location of the needle. After insertion of the needles, they were left in place for fluoroscopic examination. Two blinded orthopedic residents who did not participate in the injections performed anteroposterior (AP) and lateral fluoroscopic images of each wrist to confirm the location of the needles as intra- or extra-articular (Figures 1-2). When definitive confirmation was difficult to obtain with

---

**Table 1. Comparison of Successful Intra-Articular Needle Placement and Mean Time to Needle Placement by Training Level**

<table>
<thead>
<tr>
<th>Training Level</th>
<th>Successful N (%)</th>
<th>Total (N)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attending</td>
<td>10 (71.4)</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Fellow</td>
<td>20 (71.4)</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Senior</td>
<td>21 (75)</td>
<td>28</td>
<td>0.466</td>
</tr>
<tr>
<td>Junior</td>
<td>22 (78.6)</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Intern</td>
<td>16 (57.1)</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>89 (70.6)</td>
<td>126</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Training Level</th>
<th>Mean time to needle placement, seconds (±S.D.)</th>
<th>Attempts (N)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attending</td>
<td>12.0 (±8.9)</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Fellow</td>
<td>8.1 (±3.6)</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Senior</td>
<td>8.7 (±3.6)</td>
<td>28</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Junior</td>
<td>15.3 (±8.7)</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Intern</td>
<td>11.1 (±4.7)</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10.9 (±6.5)</td>
<td>126</td>
<td></td>
</tr>
</tbody>
</table>

*Standard deviation*
the two orthogonal images, an air arthrogram under live fluoroscopy was performed.

The primary outcome measure included determining the accuracy of intra-articular wrist injection via an ulnar approach and comparing accuracy across different levels of training. Secondarily, the number of attempts and total time taken to perform each injection was recorded to evaluate efficiency across the various levels of training. Study participants were blinded to their performance during the study. Additionally, surgeons performing fluoroscopic evaluation and those performing statistical analysis remained blinded. A Pearson Chi-square test was used to compare accuracy among the different levels of training. One-way ANOVA was used to compare timing and number of attempts between different levels. A two-sample t-test was used to compare outcome parameters between successful attempts and non-successful attempts.

RESULTS

Fourteen cadavers were included in the study; seven were left elbows and seven were right elbows. The mean age was 75.7 ± 11.6 years with eight female and six male elbows. Among all participants, the accuracy rate was 71% with 89 of the 126 injections being confirmed as intra-articular with the majority of misses being either midcarpal or dorsal. Accuracy did not vary significantly across different training levels (p = 0.466) (Table 1).

The average time for needle placement, whether successful or unsuccessful, among all participants was 10.9 ± 6.5 seconds. There was a significant difference in timing between levels of training (p<0.001) (Table 1). The average time for successful placement of the needle among all participants was 10.4 ± 5.2 seconds; for unsuccessful placement, it was 12.3 ± 8.8 seconds (p = 0.139) (Table 2). When evaluating the timing of only successful intra-articular needle placement, a significant difference (p<0.001) was present when comparing the junior-level residents’ time to each other level of training (Table 3).

The average number of total attempts among all participants was 1.6 ± 1.07, and there was no significant difference noted between different levels of training (p = 0.291). Similarly, no difference was noted when comparing total number successful versus unsuccessful attempt (1.53 ± 0.89; 1.76 ± 1.4; p = 0.275) outcomes. When evaluating number of attempts to achieve only successful intra-articular needle placement, the average number of attempts among all participants was 1.5 ± 0.6, and this value was not statistically significant when comparing levels of training (p = 0.408) (Table 3).

DISCUSSION

The overall success rate of intra-articular needle placement was 71%, and this was comparable to previously cited accuracy rates of 50-97% when using the traditional dorsal approach to the wrist. Luz et al., Cunnington et al., and To et al. compared the accuracy of anatomically-based injections with image-guided injections for a dorsal wrist approach, and found no increase in accuracy using image guidance. There are currently no studies reporting the accuracy of injections via the ulno-carpal approach using clinical assessment alone.

Our study found no significant difference between the accuracy rates or number of attempts between the different levels of training. There was a significant difference in timing between levels of training, specifically when comparing the junior-level residents’ time for successful intra-articular placement to the other levels of training.

<table>
<thead>
<tr>
<th>Table 2. Comparison of Time Taken For Placement of Needle Between Successful and Unsuccessful Attempts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Successful</td>
</tr>
<tr>
<td>Unsuccessful</td>
</tr>
</tbody>
</table>

¥Standard deviation

<table>
<thead>
<tr>
<th>Table 3. Comparison of Average Number of Number of Attempts and Average Time For Successful Intra-Articular Needle Placement by Training Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training Level</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Attending</td>
</tr>
<tr>
<td>Fellow</td>
</tr>
<tr>
<td>Senior</td>
</tr>
<tr>
<td>Junior</td>
</tr>
<tr>
<td>Intern</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Training Level</th>
<th>Mean time to needle placement, seconds (±S.D.)</th>
<th>Number of successfully placed attempts (N)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attending</td>
<td>10.6 (±4.1)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Fellow</td>
<td>8.5 (±2.2)</td>
<td>10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Senior</td>
<td>8.5 (±2.2)</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Junior</td>
<td>14.5 (±2.8)</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Intern</td>
<td>8.6 (±1.1)</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

¥Standard deviation
However, this difference does not seem to be relevant as there are no other pertinent trends in timing, accuracy rates, or number of attempts in comparison to level of training. Similarly, other studies have also reported conflicting results in regard to different levels of training. One clinical study found that their junior-level trainees had significantly higher accuracy rates for joint injections when using ultrasound guidance compared to their senior trainees and consultants using clinical examination. Another study looking at accuracy of common hand injections reported that a participant with fewer years of experience had better overall accuracy rates without using image guidance compared to another participant with more years of experience. Due to the contradictory nature of these findings, the results of this study support the previous literature.

Prior to attempting access to the wrist, study participants were briefly educated on the ulnocarpal approach. Participants were instructed to palpate and locate the extensor carpi ulnaris (ECU) tendon and place the needle just ulnar to the ECU tendon in the “soft-spot” that correlates with the intra-articular space. Our study did not evaluate for nearby structures at risk, but this is similar to the 6U wrist arthroscopy portal, which is not routinely used because of its proximity of the dorsal sensory branch of the ulnar nerve. Additionally, the triangular fibrocartilage complex is also close in proximity and is at theoretical risk for injury when using the ulnocarpal approach.

Our study does have the same limitations commonly associated with cadaveric studies in that it is difficult to extrapolate clinical outcomes in a patient undergoing injection via this approach. Although there was variety in the levels of orthopedic surgery training, this study only had a total number of nine participants. It is possible that a larger number of participants would discern further statistical differences in regard to levels of training. The presence of an additional attending physician may have also uncovered more statistically significant trends. Another limitation was the need for radiographic confirmation of needle placement whereas normally there is the expected tactile feedback associated with an injection. For equivocal cases, needle location was determined by air arthrograms performed by two independent observers. Air arthrograms have been reported in literature as an acceptable alternative to dye arthrograms. Air arthrograms were chosen for this study over dye arthrograms as dye could have played a factor in obscuring anatomical landmarks on radiographic imaging and would have limited the repeated use of cadavers in the study.

The strengths of this study include a large number of total attempts across a variety of training levels. Also, anatomic variability was not a confounding factor in this study since all participants used the same cohort of wrists. The use of a small-caliber (25G) needle was purposely chosen to help limit the creation of visible skin punctures, keeping the participants blinded to previous entry sites made by other study participants. Also, each participant was not aware of their performance during the study, which helped to prevent technique adjustments. Future studies should include an image-guided ulnocarpal approach for direct comparison of accuracy rates and an in vivo study to evaluate clinical outcomes.

Knowledge of multiple approaches for joint injection and aspirations is a helpful tool for providers in a variety of clinical situations including limited joint access due to skin integrity or anatomy variation. This study proposes a viable, alternative approach for wrist injections and aspirations that is not dependent on image guidance or user experience level. The 71% success rate is comparable to cited rates of successful intra-articular needle placement of the wrist with and without the use of supplemental imaging which can add procedural time, resources, and cost.

The level of participant training did not have an effect on the number of attempts or outcomes for successful intra-articular placement of the needle. It is plausible to consider the use of image guidance to achieve greater confidence of intra-articular needle placement of the wrist and to assist with navigation of difficult anatomic variations and avoidance of known structures at risk including the dorsal sensory branch of ulnar nerve and the triangular fibrocartilage complex.

REFERENCES


THE OPERATIVE TREATMENT OF SCAPULA FRACTURES:
AN ANALYSIS OF 10,097 PATIENTS

Wyatt Vander Voort, MD; Brandon Wilkinson, MD; Nicholas Bedard, MD; Nathan Hendrickson, MD; Michael Willey, MD

ABSTRACT

Background: The indications for operative treatment of scapula fractures have been debated over the past decade. Our purpose was to determine 1) the incidence and trends in the operative treatment of scapula fractures, 2) the incidence of conversion from operative fixation to total or hemi-shoulder arthroplasty (THSA) and 3) rates of associated injuries in scapula fractures. We hypothesized that the operative treatment of scapula fractures is increasing over time and that scapula fractures treated with open reduction and internal fixation (ORIF) would have increased risk for conversion to THSA.

Methods: The Humana Inc. administrative claims database was queried from 2008 to 2015. Patients with any scapular fracture, ORIF of scapula fracture, total or hemi-shoulder arthroplasty, and associated injuries were identified by ICD-9 and CPT codes. Analysis was performed for 1) all patients with a scapula fracture undergoing operative fixation (i.e. ORIF and THSA), 2) all scapular fractures treated with ORIF with subsequent conversion to ipsilateral THSA, and 3) all associated injuries.

Results: There were 10,097 scapula fractures (28.4% glenoid, 48% female). 60% occurred in patients 65 years and older. There were 198 (1.96%) fractures (70% glenoid) treated with ORIF. There were 287 (2.84%) fractures (45% glenoid) treated with THSA (76% total shoulder). The rate of ORIF of scapular fractures did not significantly increase (RR=0.87, p=0.58). There was a significant increase in THSA as primary treatment of scapula fractures in 2015 compared to 2007 (RR=0.43, p=0.0016). Conversion from ORIF to THSA was 12.6% (25/198). Scapula fractures treated with ORIF were at significant risk for conversion to THSA (RR=4.77, p<0.0001). Associated injuries occurred in nearly 50% of scapula fractures—other fractures, lung contusion and pneumothorax/hemothorax ranking the highest, accounting for 37%, 14.5% and 8.3% of all associated injuries, respectively.

Conclusion: The incidence of operative treatment of scapula fractures was 1.96% and 2.84% for ORIF and THSA, respectively. Scapular fractures previously treated with ORIF were at significant risk for conversion to THSA. Although ORIF in scapular fractures did not significantly increase over time, both THSA and overall (ORIF+THSA) operative treatment of scapula fractures increased significantly.

Level of Evidence: IV

Keywords: scapula fractures, operative fixation, shoulder arthroplasty, associated injuries

INTRODUCTION

Scapula fractures are relatively uncommon, accounting for approximately 0.5% of all fractures. They typically result from high energy trauma, and as such, are associated with multiple concomitant injuries. The majority of scapula fractures are extra-articular, with fractures of the body or glenoid neck accounting for 62% to 98% of all cases. Historically, management of these fractures has been conservative, consisting of benign neglect and motion as tolerated.

The indications for surgical management of scapula fractures is not well established. There are no clear evidence-based guidelines, and the decision to operate remains largely based on expert opinion. It is generally accepted that fractures with glenoid involvement or highly displaced extra-articular fractures may warrant surgical intervention. Recent studies report that intra-articular fractures are being treated operatively in up to...
80% of cases, while isolated body fractures and glenoid neck fractures are being treated non-operatively in up to 99% and 83% of cases, respectively.\(^5\)

In addition, recent studies have shown predictably good functional outcomes of both intra and extra-articular scapular fractures treated with operative fixation. In 2016, Schroder et al. showed good outcomes and low complication rates in patients treated surgically for extra-articular glenoid neck and scapular body fractures.\(^2\) Similarly, Anavian et al. showed restoration of function and satisfactory muscular recover in patients treated surgically for complex and displaced intra-articular glenoid fractures.\(^4\)

Due to the growing body of evidence of satisfactory post-operative outcomes in patients who sustain scapula fractures, along with improved technology and a higher number of patients surviving high energy trauma, a continued interest in the incidence and operative trends in management of scapula fracture patients exists.\(^3\) The purpose of this study is to 1) determine the incidence of operative fixation of scapula fractures and analyze recent trends in management, 2) determine the incidence of conversion from operative fixation to total or hemi-shoulder arthroplasty following scapula fracture, and 3) determine the rates of associated injuries.

**METHODS**

The Pearldiver Research Program (www.pearldiver-inc.com; Pearldiver Inc., West Conshohocken, PA) was utilized to query the Humana Inc. administrative claims database from 2007 to the second quarter of 2015 for patients with scapula fractures. A cutoff at the second quarter of 2015 was chosen because after this time period administrative claims transitioned to International Classification of Disease, 10th Revision coding system. This dataset represents approximately 30 million lives and includes both privately insured patients and those who have purchased their Medicare/ Medicaid Advantage plans through Humana Inc. All data within this database are Health Insurance Portability and Accountability Act compliant and this study was deemed exempt from institutional review board approval by our institution’s Human Subjects Office.

Patients with scapula fractures were identified using International Classification of Disease, 9th Revision (ICD-9) coding system and Current Procedural Terminology (CPT) codes. These patients were sub-grouped by specific anatomic location (glenoid, acromion, coracoid, and/or body). Patients undergoing surgical intervention for scapula fracture, either via open reduction internal fixation (ORIF) or total or hemi shoulder arthroplasty (THSA), were also identified using ICD-9 and CPT codes. The rates of operative intervention for scapula fractures were trended through the years of the dataset. These same search methods were utilized to identify scapula fracture patients with additional injuries at the time of presentation. The rates of associated injuries were calculated to identify those that most commonly occur in the setting of scapula fractures. Subgroup analysis was performed on patients initially receiving ORIF as primary treatment for scapula fracture who then subsequently underwent ipsilateral THSA. This cohort was compared to scapula fracture patients initially treated non-operatively who subsequently underwent THSA.

Data analysis was conducted using relative risk (RR) with corresponding 95% confidence interval (95% CI) to
evaluate the annual trends in the operative management of scapula fractures. Chi-squared testing and RR with corresponding 95% CI was conducted for the subgroup analysis comparing THSA rates in scapula fracture patients treated initially with ORIF vs. non-operative management.

RESULTS

10,097 scapula fractures were identified within the time interval assessed. Of those, 1517 (15.0%) involved the acromion, 1985 (19.7%) involved the body, 2869 (28.4%) involved the glenoid, and 676 (6.7%) involved the coracoid process. 4882 (48.4%) of cases occurred in females. 6648 (65.8%) of cases occurred in individuals aged 65 years or older.

198 scapula fractures were treated with ORIF. Incidence of operative fixation following scapula fracture was 1.96%. Of those treated with ORIF, 137 (69.2%) involved the glenoid. In 2007, 12/669 (1.8%) scapula fractures were treated with ORIF; in 2015, 32/1471 (2.2%). The increase in incidence of ORIF for scapula fracture from 2007 to 2015 was not statistically significant (p=0.54, RR=1.06). See Table 1.

There were 287 scapula fractures treated with THSA. Incidence of THSA following scapula fracture was 2.84%. 128 (44.6%) scapula fractures treated initially with THSA involved the glenoid. In 2007, 12/669 (1.8%) of scapula fractures were treated with THSA; in 2015, 76/1427 (5.3%) of scapula fractures were treated with THSA. There was a significant increase in incidence of THSA as initial management for scapula fracture from 2007 to 2015 (p=.0001, RR=1.27). In addition, rates of total operative management for scapula fractures (ORIF plus THSA) increased from 2007 to 2015. In 2007, 24/669 (3.6%) of cases were treated operatively, versus 108/1427 (7.6%) of cases in 2015. This was a significant increase in operative trends over the interval (p=0.0001, RR=1.20). See Table 1.

Of the 198 cases initially treated with ORIF, 25 went on to receive subsequent ipsilateral THSA. The conversion rate from ORIF to THSA for scapula fracture patients was 12.6%. This risk of conversion to THSA following ORIF was significantly higher than patients who did not initially receive ORIF as management for scapula fracture (p=0.0001, RR=4.77).

4907 (48.6%) cases presented with an additional associated injury. The most common associated injury was an additional fracture, seen in 3698 (36.6%) cases. 1467 (14.5%) cases of lung injury, including lung contusion, pneumothorax, and hemothorax, occurred. Shoulder dislocation occurred in 1078 (10.7%) cases. See Table 2.

DISCUSSION

Scapula fractures make up approximately 0.5% of all presenting fractures, they are associated with high energy mechanisms and as such, many patients have concomitant injuries. Although historically the large majority of these fractures are treated non-operatively, evidence supports good functional outcomes following operative fixation.

This study assessed the recent trends in the operative management of scapula fractures from 2007 to 2015. Overall, surgical management (ORIF plus THSA) and THSA as primary treatment for these fractures has increased significantly in the time interval studied, while ORIF has not shown significant increase. Patients
who undergo ORIF as primary treatment for scapula fractures are at a significantly greater risk of future conversion to THSA, likely due to glenoid involvement and post-traumatic osteoarthritis. Unsurprisingly, nearly 50% of patients presented with other injuries.

There are multiple limitations to this study. First, this study is limited by its retrospective nature. Additionally, fracture severity was unable to be assessed through the database search, providing a potential confounding variable for risk of conversion to THSA following ORIF for scapula fractures. There was also limited demographic information, including medical comorbidities, which may have influenced management strategies for the study population.

CONCLUSION

The incidence of operative treatment of scapula fractures was 1.96% and 2.84% for ORIF and total or hemi-shoulder arthroplasty, respectively. Scapular fractures previously treated with ORIF were at significant risk for conversion to total or hemi-shoulder arthroplasty. Although ORIF in scapular fractures did not significantly increase over time, both THSA and overall (ORIF+THSA) operative treatment of scapula fractures increased significantly as hypothesized—indicating an increase in the operative treatment of scapula fractures in 2015 compared to 2007.

REFERENCES

ABSTRACT

Background: The purpose of this study was to determine risk factors for blood transfusion in primary anatomic and reverse total shoulder arthroplasty (TSA) performed for osteoarthritis.

Methods: Patients who underwent anatomic or reverse TSA for a diagnosis of primary osteoarthritis were identified in a national surgical database from 2005 to 2018 by utilizing both CPT and ICD-9/ICD-10 codes. Univariate analysis was performed on the two transfused versus non-transfused cohorts to compare for differences in comorbidities and demographics. Independent risk factors for perioperative blood transfusions were identified via multivariate regression models.

Results: 305 transfused and 18,124 non-transfused patients were identified. Female sex (p<0.001), age >85 years (p=0.001), insulin-dependent diabetes mellitus (p=0.001), dialysis dependence (p=0.001), acute renal failure (p=0.012), hematologic disorders (p=0.010), disseminated cancer (p=0.001), ASA ≥3 (p<0.001), and functional dependence (p=0.001) were shown to be independent risk factors for blood transfusions on multivariate logistic regression analysis.

Conclusion: Several independent risk factors for blood transfusion following anatomic/reverse TSA for osteoarthritis were identified. Awareness of these risk factors can help surgeons and perioperative care teams to both identify and optimize high-risk patients to decrease both transfusion requirements and its associated complications in this patient population.

INTRODUCTION

Total shoulder arthroplasty (TSA) is an effective treatment modality for various pathologies of the glenohumeral joint. Indications for anatomic TSA include avascular necrosis of the humeral head, inflammatory arthritis, proximal humerus fractures, and osteoarthritis (OA) whereas reverse TSA is typically indicated primarily for arthropathy secondary to irreparable/chronic rotator cuff tears. With excellent clinical outcomes for both anatomic and reverse TSA in the treatment of glenohumeral OA, the popularity of TSA for the treatment of primary OA continues to increase. Indeed, Trofa et al. report a 5.0-fold increase in TSA within a span of ten years for the treatment of glenohumeral joint OA.

With both reverse and anatomic TSA’s increasing popularity, it is imperative to try and mitigate complications that may arise from this operative intervention. Minimizing blood transfusions following reverse/anatomic TSA may be one way to reduce complications to patients as blood transfusions have been associated with adverse events such as allergic reactions, delayed immune mediated reactions, iron overload, and cardiopulmonary adverse effects. Even with these potential complications, however, the rates of blood transfusion following TSA have been reported to range from 6.1% to as high as 43%. As such, blood transfusions in TSA have been garnering increasing interest amongst surgeons. However, to the author’s knowledge, most studies analyzing predictors of blood transfusion needs following TSA have been at single-institutions. In addition, studies that utilize nationwide databases with larger patient samples examine risks for blood transfusion in reverse and anatomic TSA for various etiologies. However, different etiologies of TSA requirements, such as trauma to the proximal humerus, are known to have increased...
rates of transfusion compared to others such as OA. Anthony et al. had previously reported significant risk factors for morbidity and transfusions in a study analyzing TSA patients from 2005 to 2011; however, their study cohort included TSA patients with multiple etiologies, including both OA and upper extremity fractures. With OA being the primary leading diagnosis for TSA needs, it is important to identify risk factors for blood transfusion utilizing a large sample size in the specific subset of patients who require TSA due to OA.

The current study sought to utilize the American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) database to identify significant risk factors for blood transfusions following reverse/anatomic TSA for the treatment of OA from a larger cohort of patients undergoing surgery from 2005 to 2018. Although rates of blood transfusions have been reported to vary between reverse and anatomic TSA, we have analyzed risk factors for both reverse/anatomic TSA in aggregate similar to other studies. In doing so, our study may shed light on how surgeons can better counsel high-risk patients, optimize management, and prevent complications secondary to blood transfusions.

METHODS

This study was conducted and published in accordance with the STROBE Statement guidelines for case-control studies. As this study utilized a publicly available multi-institutional surgical registry, no Institutional Review Board approval was required. No patient consent was required for the present study. The ACS-NSQIP database was queried to identify all patients who had undergone total shoulder arthroplasty (TSA) from 2005 to 2018 by Current Procedure Terminology (CPT) codes. Patients with CPT code 23472 were included in this study, which includes both reverse TSA and anatomic TSA. Patients who underwent shoulder hemiarthroplasties (CPT code 23470) and revision shoulder arthroplasties (CPT codes 23473 and 23474) were excluded from this study. Patients were further filtered based on ICD-9 and ICD-10 codes for diagnoses related to primary osteoarthritis. Patients were excluded if they had diagnoses related to rheumatoid arthritis, fractures/trauma, malunions, nonunions, dislocations, infections, bursae/tendon-related pathologies, ruptured rotator cuffs, traumatic arthropathies, and post-traumatic osteoarthritis. Patients with incomplete demographic and preoperative comorbidity data were also excluded to reduce the confounding effects of missing data. After all inclusion and exclusion criteria were applied, 18429 TSA patients with osteoarthritis were included in our study. These patients were then stratified into two separate cohorts: controls who had not received transfusions (n=18124) and those who received transfusions within the 72 hour period of procedure start (n=305). Transfusions were defined by the ACS-NSQIP as, “At least 1 unit of packed or whole red blood cells given from the surgical start time up to and including 72 hours postoperatively. If the patient receives shed blood, autologous blood, cell saver blood or pleurovac postoperatively, count this blood in terms of equivalent units. For a cell saver, every 500 ml’s of fluid will equal 1 unit of packed cells. If there are less than 250 ml of cell saver, round down and report as 0 units. If there are 250 cc, or more of cell saver, round up to 1 unit. The blood may be given for any reason.”

Patient demographics and preoperative comorbidities were analyzed to better characterize the TSA cohort with primary osteoarthritis. Demographic factors include age, sex, race, and body mass index (BMI). Preoperative comorbidities include diabetes mellitus, smoking history, chronic obstructive pulmonary disease (COPD), dyspnea, congestive heart failure, hypertension requiring medication management, acute renal failure, dialysis-dependence, disseminated cancer, open wound/wound infections, chronic steroid usage, hematologic disorders (i.e. Vitamin K deficiency, thromboctopenia, hemophilia, etc.), systemic sepsis, and functional dependence (i.e. requiring an orthotic device to walk, wheelchair bound, etc.). Perioperative variables such as type of anesthesia administered and American Society of Anesthesiologists (ASA) classification were also included. Complications were categorized as minor and major complications, following previously published guidelines in the orthopaedic literature. Minor complications included superficial surgical site infections (SSI), wound dehiscence, pneumonia, urinary tract infections (UTI), and progressive renal insufficiency. Major complications included deep SSI, organ/space SSI, unplanned intubation, ventilator dependence, acute renal failure, cardiac arrest requiring CPR, myocardial infarctions, pulmonary embolisms, deep venous thromboembolisms, systemic sepsis, septic shock, unplanned readmissions, unplanned reoperations, and mortality occurring in the 30-day postoperative period.

To determine differences in patient demographic factors, preoperative comorbidities, and perioperative/postoperative outcomes, univariate analyses were first utilized in establishing differences in these variables between the transfused and non-transfused cohorts. Pearson’s chi-squared tests were implemented in analyzing categorical variables, while one-way analysis of variance (ANOVA) and independent T-tests were used to assess for differences in mean values of continuous variables such as age and time. Continuous variables are expressed as mean values with their respective standard deviations, while categorical variables are reported as...
Blood Transfusions in Total Shoulder Arthroplasty

Multivariate logistic regression models were utilized in identifying significant risk factors for blood transfusions. Significantly different demographic factors and preoperative comorbidities were entered into the regression model as covariates. The predicted probabilities given by the logistic regression model were used to generate a receiver operating characteristic (ROC) curve to assess the discriminatory ability of the regression model in assigning patients into the transfused or non-transfused cohort based on the controlled variables. Post-regression diagnostics were assessed with C-statistic and the Hosmer-Lemeshow Test. All statistical findings with p-values less than or equal to 0.05 were considered significant in this analysis. All statistical analyses were performed using the IBM® SPSS® Statistics Version 25 software (IBM Corporation, Armonk, NY).

RESULTS

18,124 patients who had undergone TSA for primary osteoarthritis were included in this study, of which 305 (1.66%) had received blood transfusions within 72 hours of the start of their procedures. The transfused cohort was significantly older (x̄=72.53, SD 9.937; p<0.001) than the control cohort (x̄=68.84, SD 9.415) and was comprised of a larger proportion of female patients (73.11%
vs. 53.11%; p<0.001) than the control cohort. The transfused cohort consisted of a smaller proportion of obese patients (41.31% vs. 51.79%; p<0.001) than the control cohort. No significant differences were observed in the distribution of self-reported race/ethnicity. (Table 1)

A larger proportion of the transfused cohort presented with diabetes mellitus (p<0.001), dyspnea (p=0.015), COPD (p<0.001), ascites (p=0.017), congestive heart failure (p=0.040), hypertension requiring medication management (p=0.010), acute renal failure (p=0.009), dialysis (p<0.001), disseminated cancer (p=0.001), hematologic disorders (p<0.001), preoperative blood transfusions (p=0.003), and functional dependence (p<0.001). (Table 1)

On multivariate logistic regression analyses, numerous risk factors for blood transfusions were identified. Age (> 85 years) (OR 3.192, 95% CI 1.604-6.350; p=0.001), female sex (OR 2.258, 95% CI 1.738-2.935; p<0.001), insulin-dependent diabetes mellitus (IDDM) (OR 2.045, 95% CI 1.331-3.141; p=0.001), acute renal failure (OR 9.178, 95% CI 1.630-51.684; p=0.012), dialysis dependence (OR 4.816, 95% CI 1.874-12.371; p=0.001), disseminated cancer (OR 7.915, 95% CI 2.514-24.919; p<0.001), hematologic disorders (OR 1.923, 95% CI 1.173-3.154; p=0.010), functional dependence (OR 2.244, 95% CI 1.377-3.656; p<0.001), and ASA ≥ 3 (OR 1.835, 95% CI 1.394-2.417; p<0.001) were shown to be significant independent risk factors for blood transfusions. (Table 2) The Hosmer-Lemeshow Test had a significance of 0.257, while the C-statistic or Area Under ROC (AUROC) was 0.728 (p<0.001), indicating relatively strong predictability and discriminatory ability of the logistic regression model in predicting blood transfusions based on the entered variables. (Figure 1)

**DISCUSSION**

Blood transfusions have been associated with a multitude of different complications that can have adverse effects on patients in the perioperative period. As such, taking steps to mitigate blood transfusion needs remains an important way that orthopaedic surgeons can help to minimize avoidable risks. By identifying high risk patients, perioperative management can be optimized and better informed patient counseling can be done prior to surgery. The present study identified age > 85 years, female sex, IDDM, acute renal failure, dialysis dependence, disseminated cancer, hematologic disorders, functional dependence, and ASA ≥ 3 as independent risk factors for blood transfusion requirements following TSA for OA.

Advanced age and female gender have previously been reported as risk factors for blood transfusion requirements in various orthopaedic procedures including

| Table 2. SIGNIFICANT RISK FACTORS for Intra-op/Post-op Blood Transfusions |
|--------------------------|-------|----------|--------|
| **RISK FACTORS** | **OR** | **95% CI** | **P-value** |
| Age | | | |
| x ≤ 55 | Reference | - | - |
| 55 < x ≤ 65 | 0.899 | 0.499 | 1.619 | 0.723 |
| 65 < x ≤ 75 | 1.107 | 0.637 | 1.923 | 0.718 |
| 75 < x ≤ 85 | 1.674 | 0.958 | 2.927 | 0.071 |
| x > 85 | 3.192 | 1.604 | 6.350 | 0.001 |
| Gender | | | | |
| Male | Reference | - | - |
| Female | 2.258 | 1.738 | 2.935 | <0.001 |
| Obesity (> 30 kg/m2) | 0.585 | 0.457 | 0.750 | <0.001 |
| Diabetes Mellitus | | | |
| No-DM | Reference | - | - |
| NIDDM | 1.344 | 0.964 | 1.876 | 0.082 |
| IDDM | 2.045 | 1.331 | 3.141 | 0.001 |
| Dyspnea | | | |
| No Dyspnea | Reference | - | - |
| Moderate Exertion | 0.971 | 0.637 | 1.48 | 0.891 |
| At Rest | 1.766 | 0.516 | 6.044 | 0.365 |
| COPD | 1.362 | 0.922 | 2.012 | 0.120 |
| Acute Renal Failure | 9.178 | 1.630 | 51.684 | 0.012 |
| Dialysis | 4.816 | 1.874 | 12.371 | 0.001 |
| Disseminated Cancer | 7.915 | 2.514 | 24.919 | <0.001 |
| Hematologic Disorders | 1.923 | 1.173 | 3.154 | 0.010 |
| Transfusion (within 72 hours of start of surgery) | 3.538 | 0.856 | 14.626 | 0.081 |
| Functional Status | | | | |
| Independent | Reference | - | - |
| Partially or Totally Dependent | 2.244 | 1.377 | 3.656 | 0.001 |
| ASA Classification | | | |
| ASA 1, 2 | Reference | - | - |
| ASA 3, 4, 5 | 1.835 | 1.394 | 2.417 | <0.001 |

OR: Odds Ratio; CI: Confidence Interval; DM: Diabetes-mellitus; NIDDM: Non-insulin dependent diabetes mellitus; IDDM: Insulin-dependent diabetes mellitus; COPD: Chronic obstructive pulmonary disease; CHF: Congestive Heart Failure; ASA: American Society of Anesthesiologists
Blood Transfusions in Total Shoulder Arthroplasty

Figure 1. ROC Curve Assessing Multivariate Logistic Regression Model for Risk Factors for Transfusions Following Total Shoulder Arthroplasty

<table>
<thead>
<tr>
<th>Area Under ROC</th>
<th>Standard Error</th>
<th>P-Value</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.728</td>
<td>0.014</td>
<td>&lt;0.001</td>
<td>0.700 0.755</td>
</tr>
</tbody>
</table>

Unsurprisingly, the present study identified hematologic disorders as an independent risk factor for increased transfusion in reverse/anatomic TSA in line with the current literature. Kandil et al. reports a 3.5 times increased risk of blood transfusion in deficiency anemia patients following reverse/anatomic TSA. Makhni et al. also report lower preoperative Hgb levels as an independent risk factor for blood transfusion in reverse/anatomic TSA. Hypervigilance for patients with underlying anemia or hematologic disorders should be exercised for all operations, including TSA.

To the author’s knowledge, the effects of acute renal failure and dialysis dependence as independent risk factors for transfusion in TSA have not been well studied. Although the risk of acute renal failure/acute kidney injury as a result of blood transfusions is a subject of current debate, the reciprocal relationship of acute renal failure increasing blood transfusion needs has not been demonstrated. Regarding dialysis dependence, Cancienne et al. previously reported over a four-fold increased incidence of dialysis-dependent patients undergoing TSA from 2005 to 2014. As such, it is increasingly relevant and essential to further elucidate how this preoperative comorbidity affects the reverse/anatomic TSA patient population. End stage renal disease has been previously demonstrated to increase the risk of blood transfusion in lower extremity procedures such as TKA. As such, the results of the present study also support this relationship in reverse/anatomic TSA patients for OA management. As the kidneys are responsible for erythropoietin production and bone marrow stimulation, development of anemia in dialysis dependent patients is common. With baseline anemia, it is plausible that these patients would be at higher risk for transfusion needs in the perioperative period.

Similarly, there is limited literature regarding disseminated cancer as a risk factor for transfusion in TSA. Newman et al. previously reported significantly higher rates of postoperative transfusion following THA in patients with various hematologic malignancies. Menendez et al. also demonstrated that multiple myeloma was associated with an increased the risk of blood transfusions following total joint arthroplasty, possibly due to impaired bone marrow function. However, to the author’s knowledge, no previous relationship between malignancy and increased blood transfusion needs in the anatomic/reverse TSA patient populations has been reported. Although the exact mechanism as to how malignancy increases blood transfusion needs following TSA is likely multifactorial, further work elucidating the relationship between transfusion needs and different types of cancers/stages of disease is required.

Additional risk factors identified by the present study include IDDM, ASA $\geq 3$, and functional dependence. Consistent with these findings, Fu et al. also report increased rates of transfusion in IDDM patients following reverse/anatomic TSA. Anthony et al. and Dacombe et al. also report increased risk of blood transfusion in total knee arthroplasty (TKA), total hip arthroplasty (THA), and spinal fusion.

Age has been analyzed as a risk factor for blood transfusion following TSA. The majority of the literature consistently demonstrates age to increase the risk of blood transfusion needs in reverse/anatomic TSA. Decreased hematopoiesis and decreased physiologic reserve as bone marrow function declines with aging is likely responsible for the increased rates of transfusion that are seen following TSA and other various orthopaedic procedures.

The present study’s results regarding increased risk of transfusion with female patients have been reported previously in the literature. Hemoglobin levels are generally lower at baseline in female patients as opposed to male patients due to multiple factors including different hormonal balances and higher rates of iron deficiency anemia from menstrual loss. A decreased baseline hemoglobin in female patients may lead to increased blood transfusion levels in surgical procedures, such as reverse/anatomic TSA.

Unsurprisingly, the present study identified hematologic disorders as an independent risk factor for increased transfusion in reverse/anatomic TSA in line with the current literature. Kandil et al. reports a 3.5 times increased risk of blood transfusion in deficiency anemia patients following reverse/anatomic TSA. Makhni et al. also report lower preoperative Hgb levels as an independent risk factor for blood transfusion in reverse/anatomic TSA. Hypervigilance for patients with underlying anemia or hematologic disorders should be exercised for all operations, including TSA.

To the author’s knowledge, the effects of acute renal failure and dialysis dependence as independent risk factors for transfusion in TSA have not been well studied. Although the risk of acute renal failure/acute kidney injury as a result of blood transfusions is a subject of current debate, the reciprocal relationship of acute renal failure increasing blood transfusion needs has not been demonstrated. Regarding dialysis dependence, Cancienne et al. previously reported over a four-fold increased incidence of dialysis-dependent patients undergoing TSA from 2005 to 2014. As such, it is increasingly relevant and essential to further elucidate how this preoperative comorbidity affects the reverse/anatomic TSA patient population. End stage renal disease has been previously demonstrated to increase the risk of blood transfusion in lower extremity procedures such as TKA. As such, the results of the present study also support this relationship in reverse/anatomic TSA patients for OA management. As the kidneys are responsible for erythropoietin production and bone marrow stimulation, development of anemia in dialysis dependent patients is common. With baseline anemia, it is plausible that these patients would be at higher risk for transfusion needs in the perioperative period.

Similarly, there is limited literature regarding disseminated cancer as a risk factor for transfusion in TSA. Newman et al. previously reported significantly higher rates of postoperative transfusion following THA in patients with various hematologic malignancies. Menendez et al. also demonstrated that multiple myeloma was associated with an increased the risk of blood transfusions following total joint arthroplasty, possibly due to impaired bone marrow function. However, to the author’s knowledge, no previous relationship between malignancy and increased blood transfusion needs in the anatomic/reverse TSA patient populations has been reported. Although the exact mechanism as to how malignancy increases blood transfusion needs following TSA is likely multifactorial, further work elucidating the relationship between transfusion needs and different types of cancers/stages of disease is required.

Additional risk factors identified by the present study include IDDM, ASA $\geq 3$, and functional dependence. Consistent with these findings, Fu et al. also report increased rates of transfusion in IDDM patients following reverse/anatomic TSA. Anthony et al. and Dacombe et al. also report increased risk of blood transfusion in total knee arthroplasty (TKA), total hip arthroplasty (THA), and spinal fusion.

Age has been analyzed as a risk factor for blood transfusion following TSA. The majority of the literature consistently demonstrates age to increase the risk of blood transfusion needs in reverse/anatomic TSA. Decreased hematopoiesis and decreased physiologic reserve as bone marrow function declines with aging is likely responsible for the increased rates of transfusion that are seen following TSA and other various orthopaedic procedures.

The present study’s results regarding increased risk of transfusion with female patients have been reported previously in the literature. Hemoglobin levels are generally lower at baseline in female patients as opposed to male patients due to multiple factors including different hormonal balances and higher rates of iron deficiency anemia from menstrual loss. A decreased baseline hemoglobin in female patients may lead to increased blood transfusion levels in surgical procedures, such as reverse/anatomic TSA.

Unsurprisingly, the present study identified hematologic disorders as an independent risk factor for increased transfusion in reverse/anatomic TSA in line with the current literature. Kandil et al. reports a 3.5 times increased risk of blood transfusion in deficiency anemia patients following reverse/anatomic TSA. Makhni et al. also report lower preoperative Hgb levels as an independent risk factor for blood transfusion in reverse/anatomic TSA. Hypervigilance for patients with underlying anemia or hematologic disorders should be exercised for all operations, including TSA.

To the author’s knowledge, the effects of acute renal failure and dialysis dependence as independent risk factors for transfusion in TSA have not been well studied. Although the risk of acute renal failure/acute kidney injury as a result of blood transfusions is a subject of current debate, the reciprocal relationship of acute renal failure increasing blood transfusion needs has not been demonstrated. Regarding dialysis dependence, Cancienne et al. previously reported over a four-fold increased incidence of dialysis-dependent patients undergoing TSA from 2005 to 2014. As such, it is increasingly relevant and essential to further elucidate how this preoperative comorbidity affects the reverse/anatomic TSA patient population. End stage renal disease has been previously demonstrated to increase the risk of blood transfusion in lower extremity procedures such as TKA. As such, the results of the present study also support this relationship in reverse/anatomic TSA patients for OA management. As the kidneys are responsible for erythropoietin production and bone marrow stimulation, development of anemia in dialysis dependent patients is common. With baseline anemia, it is plausible that these patients would be at higher risk for transfusion needs in the perioperative period.

Similarly, there is limited literature regarding disseminated cancer as a risk factor for transfusion in TSA. Newman et al. previously reported significantly higher rates of postoperative transfusion following THA in patients with various hematologic malignancies. Menendez et al. also demonstrated that multiple myeloma was associated with an increased the risk of blood transfusions following total joint arthroplasty, possibly due to impaired bone marrow function. However, to the author’s knowledge, no previous relationship between malignancy and increased blood transfusion needs in the anatomic/reverse TSA patient populations has been reported. Although the exact mechanism as to how malignancy increases blood transfusion needs following TSA is likely multifactorial, further work elucidating the relationship between transfusion needs and different types of cancers/stages of disease is required.

Additional risk factors identified by the present study include IDDM, ASA $\geq 3$, and functional dependence. Consistent with these findings, Fu et al. also report increased rates of transfusion in IDDM patients following reverse/anatomic TSA. Anthony et al. and Dacombe et al. also report increased risk of blood transfusion in total knee arthroplasty (TKA), total hip arthroplasty (THA), and spinal fusion.

Age has been analyzed as a risk factor for blood transfusion following TSA. The majority of the literature consistently demonstrates age to increase the risk of blood transfusion needs in reverse/anatomic TSA. Decreased hematopoiesis and decreased physiologic reserve as bone marrow function declines with aging is likely responsible for the increased rates of transfusion that are seen following TSA and other various orthopaedic procedures.

The present study’s results regarding increased risk of transfusion with female patients have been reported previously in the literature. Hemoglobin levels are generally lower at baseline in female patients as opposed to male patients due to multiple factors including different hormonal balances and higher rates of iron deficiency anemia from menstrual loss. A decreased baseline hemoglobin in female patients may lead to increased blood transfusion levels in surgical procedures, such as reverse/anatomic TSA.
patients with a higher ASA grade. To the authors' knowledge, functional dependence and its role as a risk factor for blood transfusions has not been previously demonstrated in reverse/anatomic TSA. However, increased perioperative complications, including blood transfusions, have been reported in other orthopaedic procedures, such as total hip arthroplasty, in patients with increased functional dependence.

The present study highlights various risk factors, both modifiable and non-modifiable, for increased blood transfusion in reverse/anatomic TSA. By identifying non-modifiable risk factors, such as age and gender, orthopaedic surgeons can better counsel these high-risk patients on the risks of blood transfusion for reverse/anatomic TSA for OA treatment. A thorough discussion between provider and patient should strongly consider whether elective TSA is the best treatment modality in high-risk patients. Increased vigilance in the postoperative period for potential transfusion needs should also be exercised in patients with numerous non-modifiable risk factors. Surgeons should work with patients with modifiable risk factors together to best optimize the patient preoperatively in order to minimize the risk of transfusion. Similar to prior reports in the literature, the present study has also demonstrated increased complication rates, unplanned reoperation/readmission rates, and mortality following blood transfusions for reverse/anatomic TSA. By understanding the risk factors for blood transfusions in reverse/anatomic TSA, blood transfusions and their associated complications can be minimized.

Several limitations are present in this retrospective study. Patients with missing data in any of the variables analyzed were excluded to reduce the confounding effects of missing data; however, these patients still represent those with osteoarthritis who were indicated for TSA. Excluding these patients may potentially result in small variations in our results, though these effects seem minimal given the large cohort that was analyzed. Another limitation with the present study is the number of patients with missing pre-operative hemoglobin levels. Intuitively, lower pre-operative hemoglobin levels would logically be the greatest risk factor for increased transfusion risks. However, less than 50% of the patients who met inclusion criteria had pre-operative hemoglobin/hematocrit (Hgb/Hct) values recorded. With only a minority of patients with these pre-operative lab values, it is difficult to accurately ascertain at which specific pre-operative Hgb/Hct value greatly increases risk of transfusion. Future studies are warranted to better ascertain at what pre-operative Hgb/Hct levels greatly increases transfusion risk for TSA. In addition, another limitation specific to this large-scale database study is the lack of recorded transfusion thresholds. Lack of such data may introduce potential confounding variables that this study could not account for. The present study also utilized CPT codes that were not intended for research purposes. As a result, potential data skewing based on financial incentive cannot be controlled for.

Specific to this study, the ACS-NSQIP database cannot differentiate between reverse TSA and anatomic TSA as they are both identified by the same CPT codes. Although previous reports have demonstrated increased rates of transfusion in reverse TSA compared to anatomic TSA, the present study has analyzed reverse and anatomic TSA as a whole similar to other reports in the literature. Finally, another limitation inherent to all database studies is the inability to confirm the accuracy of the information inputted into the nationwide database.

As the incidence of TSA continues to increase, it is important to recognize and identify complications that can arise from this operative intervention. One way to curtail complications is to prevent precipitating events, such as blood transfusions. Previous studies have analyzed risk factors for blood transfusions in TSA for a variety of indications in aggregate. However, the present study analyzed risk factors for blood transfusion needs in reverse/anatomic TSA for the management of OA. As OA continues to be the leading indication for TSA, analyzing risk factors for transfusion in this specific patient population is warranted. The present study identified various risk factors for increased blood transfusion requirements following reverse/anatomic TSA for the management of osteoarthritis, including age > 85 years, female sex, IDDM, acute renal failure, dialysis dependence, disseminated cancer, hematologic disorders, increased functional dependence, and ASA Class ≥ 3. By identifying high-risk patients, surgeons can both better counsel and optimize management to prevent secondary complications from blood transfusions.

REFERENCES


ABSTRACT
Background: Reverse shoulder arthroplasty (RSA) is associated with high rates of midterm complications including scapular notching, implant wear, and mechanical impingement. Scapulo-humeral rhythm (SHR), described by Codman in the 1920's, is defined as the ratio of glenohumeral motion to scapulothoracic motion. SHR is used as an indicator of shoulder dysfunction, as alterations in SHR can have profound implications on shoulder biomechanics. The determination of SHR can be hindered by soft-tissue motion artifacts and high radiation burdens associated with traditional surface marker or fluoroscopic analysis. EOS low dose stereoradiographic imaging analysis utilizing 3D model construction from a 2D X-ray series may offer an alternative modality for characterizing SHR following RSA.

Methods: Patients (n=10) underwent an EOS imaging analysis to determine SHR at six and twelve months post-RSA. Leveraging 3D models of the implants, 2D/3D image registration methods were used to calculate relative glenohumeral and scapulothoracic positioning at 60, 90 and 120° of shoulder elevation. Subject-specific SHR curves were assessed and midterm changes in post-RSA SHR associated with follow-up time and motion phase were evaluated. Pearson correlations assessed associations between patient-specific factors and post-RSA SHR.

Results: Mean post-RSA SHR was 0.81:1 across subjects during the entire midterm postoperative period. As a cohort, post-RSA SHR was more variable for 60-90° of shoulder motion. SHR for 90-120° of motion decreased (0.43:1) at twelve months post-RSA. Post-RSA SHR could be categorized using three relative motion curve patterns, and was not strongly associated with demographic factors such as BMI. 50% of subjects demonstrated a different SHR relative motion curve shape at twelve months post-RSA, and SHR during the 90-120° of motion was found to generally decrease at twelve months.

Conclusion: Midterm post-RSA SHR was successfully evaluated using EOS technology, revealing lower SHR values (i.e., greater scapulothoracic motion) compared to normal values reported in the literature. SHR continued to change for some subjects during the midterm post-RSA period, with the greatest change during 90-120° of shoulder motion. Study findings suggest that future post-RSA rehabilitation efforts to address elevated scapulothoracic motion may benefit from being patient-specific in nature and targeting scapular stabilization during 90-120° of shoulder motion.

Level of Evidence: IV

Keywords: reverse shoulder arthroplasty, Scapulohumeral rhythm, EOS imaging

INTRODUCTION
Reverse shoulder arthroplasty (RSA) has demonstrated great clinical benefits for an increasing array of indications ranging from rotator cuff arthropathy to revision arthroplasty. RSA can demonstrably restore function and range of motion for patients with glenohumeral and rotator cuff compromise by enabling the deltoid to power humeral abduction. However, there remains a relatively high rate of RSA procedure failures and a high prevalence of midterm (6-12 months post-operative) complications, with scapular notching (49.8%), and shoulder instability (4.7%) among the most common issues.

Scapulo-humeral rhythm (SHR), the ratio of glenohumeral (GH) motion to scapulothoracic (ST) motion, serves as a helpful means of assessing post-RSA shoulder function and muscle activation. Normal SHR is key for efficient shoulder functioning, as abnormal alteration in the positioning of the scapula relative to the humerus can impair coordinated movement of the shoulder girdle and impair joint biomechanics, which can have repercussions further down the kinetic chain. In a normal shoulder, the
humerus and scapula typically move in an established normative 2:1 ratio so that when the arm completes a full abduction arc to 180°, 120° of rotation occurs at the shoulder joint, and 60° of this rotation is contributed by rotation of the scapula.⁶ SHR is a sensitive measure of shoulder function that provides key information as to the relative movement of the scapula and the humerus.⁴,⁷ For example, altered scapulothoracic motion has been observed amongst patients with shoulder instability and impingement.⁸,⁹ Quantitative monitoring enabling us to understand post-RSA SHR mechanics is thus essential, since recurrent instability and lack of adequate scapular control during movement patterns may result in RSA failure. Recurrent shoulder instability resulting in increased implant and polyethylene liner wear, which in turn can lead to decreased prothesis longevity, is also a significant concern.¹⁰ Surgical revision after RSA may not be an option due to challenges with remaining glenoid bone stock, which can catastrophically result in a nonfunctional upper extremity.¹¹ Residual abnormalities in SHR post-RSA may therefore influence a patient’s risk of mid-term functional complications. In converse, SHR may be possibly modified with skilled physical therapy, enabling improvements in function and decreasing impingement.

Study of aberrant scapulohumeral motion has often been restricted to evaluation of overhead athletes in the sports medicine literature, but recently focus has turned to SHR evaluation following surgical procedures like RSA.⁷,¹²,¹³ A recent surface marker study characterized differences in pre- to post-operative SHR in a RSA population with a heterogenous length of follow-up, adding to a body of literature suggesting lower SHR (1.3:1) with less glenohumeral motion is observed post-RSA compared to the normal shoulder.¹⁴ However, patients undergoing RSA do not have a “normal” shoulder pre-operatively, with wide variations in constraining rotator cuff soft-tissue condition and integrity, and glenoid and humeral head surface geometry.¹⁵,¹⁶ Reversal of the glenohumeral joint and force coupling in RSA leads to further changes in mechanical load sharing during dynamic tasks and alterations in muscle activation patterns compared to a normal joint.¹⁷ Therefore, it is currently unclear if differences in post-RSA SHR are related to anatomical considerations, pre-operative structural damage, RSA implant-dictated mechanical constraints, or post-operative functional limitations. Questions also surround the clinical implications of the time-course of restoration towards “normal” SHR following RSA and what the biomechanically ideal SHR pattern is for minimization of post-RSA implant wear and instability.

Historically, assessment of SHR has been hampered by a combination of multiple factors such as the depth of osseous structures of interest and unconstrained movement of overlying soft-tissue.¹⁴ The scapula serves as the attachment site of the four rotator cuff muscles as well as 13 other muscles allowing for it to have complex multi-planar motion: protraction, retraction, elevation, depression, and upwards and downwards rotation.¹⁸ Technical innovations have facilitated an evolution of increasing SHR assessments over time. Initial studies defined two-dimensional (2D) SHR in healthy subjects followed by three-dimensional (3D) analysis via the use of indwelling bone pins to track scapulohumeral motion.¹⁹ Evaluation then progressed to predominantly using surface markers with both optical camera and electromagnetic tracking systems to define normative scapulohumeral motion.²⁰,²¹,²² However, such surface assessment methods have known limitations, especially due to error introduction secondary to movement of the skin and attached surface markers that are not rigidly affixed to the deep osseous structures of interest that are undergoing complex multi-planar movements.²² Bi-planar fluoroscopy also affords an additional non-invasive assessment method.²³ However, the methodology is associated with a relatively high radiation burden and differences in ratio assessment methods (i.e. linear regression vs area under the curve) have been reported throughout the literature.²³

EOS 2D/3D reconstructions have emerged as a dynamic imaging modality for evaluation of relative osseous positioning during complex motions. EOS imaging consists of a radiographic capture system using two highly collimated orthogonal x-ray beams to produce dynamic 2D images that can be reconstructed into a 3D model of both RSA implant and osseous structures.²⁴ This technology has the added advantage of high reliability for both the thorax and upper extremity, but it is also able to produce higher quality 1:1 size images with less artifacts and a lower dose of radiation compared to a traditional CT series.²⁴,²⁵ However, the significant financial investment necessary for EOS equipment has limited its widespread application for research and clinical assessment purposes.

EOS technology has demonstrated reliable results, especially for spine and hip imaging, but has had less application for the upper extremity which to-date has mostly focused on glenohumeral motion and has not been used to study more complex scapulohumeral motion.²⁶,²⁷,²⁸ Therefore, there is interest in expanding EOS dynamic radiographic assessment to scapulohumeral motion, particularly in an RSA population, where there is simultaneous visualization of osseous and implant position, and the technique does not have the soft tissue limitations associated with surface markers. Improved study of changes in SHR during the post-operative period
may have positive implications as specific PT programs can be developed to improve SHR and possibly avoid mechanical complications of RSA which in turn can increase prosthesis longevity.

The objective of this study was to characterize SHR following RSA at six months and twelve months post-operatively by using EOS stereoradiographic imaging. We hypothesized that post-RSA shoulders would exhibit lower SHRs compared to the normative 2:1 pattern reported for normal shoulders, but that this would improve from 6 to 12 months.

**METHODS**

**Subjects**

Ten subjects, three males and seven females, provided informed consent to participate in this prospective, cross-sectional institutional review board approved study. Subjects had an average age of 68 ± 7 years (range: 57-80 y), and a mean BMI of 31.59 ± 3.92 (Table 1). All patients were required to be over age 18 and to have undergone a primary RSA with implantation of a Tomier Ascend Implant by a single fellowship trained shoulder surgeon (C.M.H). Patients with a previous history of RSA were excluded from study enrollment. All enrolled subjects were indicated for RSA secondary to rotator cuff arthropathy. No patients had a history of proximal humeral fracture or revision RSA.

**Data Collection**

Subjects underwent acquisition of a standard imaging series of the entire shoulder girdle and humerus using the EOS imaging system (EOS Imaging, Paris, France) at both six and twelve months post-RSA. Subjects were positioned in a standing position with their body angled at 30-40° relative to the radiographic axis with upper arm in a neutral position and the palm facing forward in an effort to mimic the standard Grashey radiograph view and to avoid superposition of the shoulder structures over the ribcage and spine. Biplanar (anteroposterior and lateral) simultaneous low-dose EOS x-rays were obtained of the arm in a neutral position resting at the subjects’ side and at 60°, 90°, and 120° of shoulder elevation in the scapular plane.

**Modeling**

Simultaneous radiographic capture in two orthogonal planes using the EOS imaging system, allowed for subsequent 3D reconstruction of the relative in-vivo positioning of implant and osseous structures of interest (Figure 1). In-vivo contours of the implant components were created from each subject’s 2D EOS x-rays using SterEOS software (EOS Imaging, Paris, France). A generic contour model was first applied to an operator selected and validated set of anatomical landmarks, and slight further manual adjustment was subsequently performed in order to ensure a subject-specific 2D model of best fit. After the anatomical landmarks were registered the collected 2D x-rays were then used to create a 3D model system. 3D CAD surface models of the humeral stem and glenosphere implant components were then registered to each subject’s 2D implant contours. A 3D reconstruction was then performed using a validated series of upper extremity anatomic contours and points including the tip of the coracoid process and anterosuperior point of the acromion according to methodology by Cauchon et al. Anatomical axes were defined in accordance with International Society of Biomechanics recommendations for the humerus coordinate system: the X and Y-axes
were defined in the posteroanterior and lateromedial directions respectively, with the Z-axis established in the vertical direction. Each subject-specific 3D model reconstruction was then used to calculate relative scapulothoracic and glenohumeral angles to derive overall scapulohumeral rhythm in MATLAB (vR2018b, The MathWorks Inc., Natick, MA).

**Data Analysis**

Relative glenohumeral and scapulothoracic angles were calculated following the 3D to 2D image registration. Average SHR was calculated between 60-90°, 90-120°, and 60-120° of shoulder elevation. Scapulothoracic and glenohumeral angles were calculated at 60°, 90°, and 120° of shoulder elevation. SHR was calculated using the formula SHR = (∆H-∆S)/∆S, with ∆H representing change in humeral elevation and ∆S representing change in scapular elevation. Statistical analysis was performed including Pearson and Spearman correlations of maximum scapula-thoracic motion to simultaneous magnitude of glenohumeral motion. Pearson correlations assumed linear relationships, and Spearman correlations assumed monotonic data.

**RESULTS**

Mean post-RSA SHR was 0.81 ± 0.79 for 60-120° across all subjects during the entire midterm post-operative period (six to twelve months post-RSA) (Table 2).

**SHR Across Phases of Motion (Comparison by Angle)**

Mean SHR of the entire subject cohort decreased for 90-120° of arm elevation compared to 60-90° at both six months and twelve months post-RSA (Figure 2). This indicates the ST motion was more dominant over GH in that range. Patient-specific analysis also consistently revealed that SHR was generally lower for 90-120° phase of motion compared to the 60-90° phase of motion. At both six and twelve months post-RSA, only 2 of 10 (20%) subjects displayed substantially greater SHR for 90-120° of motion compared to 60-90° (Figure 3).

**Outliers and Interquartile Range Analysis**

The interquartile range of SHR for both 60-90° and 90-120° of arm elevation ranged from 0.29 to 0.44 at six and twelve months post-RSA (Table 2). Interquartile range analysis identified the presence of several strong SHR outliers (greater than 1.5 standard deviations above the SHR mean) at both six months (subject 2=2.94, subject 4=3.99) and twelve months (subject 10=2.28, Figure 2). Identified outliers were not excluded from analysis based on the wide range of SHR variables consistently reported throughout the scientific literature, including values higher than 17.1 reported for healthy, normal shoulders.

**SHR Changes Across the Midterm Postoperative Period (Comparison by Time)**

SHR during 60-90° of motion did not substantially decrease during the midterm post-operative period when comparing SHR at 6-months vs 12-months post-RSA (mean decrease: 0.07 ± 1.10, Figure 4a). SHR during 90-120° of motion generally decreased during the midterm post-RSA period (mean decrease: 0.42 ± 1.13). Eight of the 10 subjects displayed substantially lower 90-120° SHR at twelve months compared to six months (Figure 4b). This indicates that over time, ST motion increased as compared to GH motion.

**SHR Patterns**

Across all subjects, a weak Pearson correlation was observed at six months (r=0.243, p=0.195) post-RSA, while a moderate Pearson correlation was noted at twelve months post-RSA (r=0.484, p=0.007). Similarly, weak and moderate Spearman correlations were observed respectively at six (r=0.311, p=0.095) and twelve (r=0.560, p=0.001) months post-RSA. Evaluation of in-
Individual subjects’ SHR relative motion curves revealed three consistent SHR patterns (Table 3). These patterns consisted of linear (n=9), concave (n=7), convex (n=4) curve types. Subjects categorized with a linear pattern displayed consistent SHR from 60-90° and 90-120° of motion. Convex and concave patterns were associated with greater and less glenohumeral motion relative to scapulothoracic motion respectively during the 90-120° phase of motion compared to from 60-90° of motion. Five of the 10 subjects maintained the same SHR relative motion curve type between six and twelve months post-RSA (Figure 5). The most common (n=3) transformation of curve type was a linear pattern at six months changing to a convex pattern at twelve months. Overall, mean within-subject variability in SHR across 60-90° and 90-120° of motion at six and twelve months post-RSA was only 0.64.

SHR vs Patient-Specific Factors
Subject BMI was not found to be associated with SHR values calculated for 60-90° and 90-120° of motion at either six (r=0.103, p=0.792) or twelve months post-RSA (r=0.051, p=8.95). No other demographic details, including age, height, or weight, demonstrated significant Pearson correlations with calculated SHR values during either phase of motion or either post-RSA time point.

DISCUSSION
In this post-RSA investigation of SHR using an EOS system, we established the feasibility of successful assessment of SHR patterns using this new imaging modality. We were specifically able to assess SHR values for the midterm post-operative period, which is associated with a moderate complication and prosthesis failure rate in RSA patients.5 Our hypothesis that post-RSA patients will exhibit decreased SHR compared to normative values for the normal shoulder was confirmed. Additionally, this study successfully evaluated changes in SHR across multiple time points during the mid-term post-operative period (six months and twelve months) using a single implant system, as well as during different phases of motion between the 60 to 90° and 90 to 120° portions of the shoulder motion arc.

Low Post-RSA SHR Values
Lower than normal literature values of SHR were observed for relative scapulohumeral motion in our post-RSA population.6,14 These observations suggest in-
Figure 5. Patient-specific post-RSA relative glenohumeral and scapulothoracic motion. Patients (n=10) displayed three distinct relative motion curve types: linear, convex, and concave curve shapes at six and twelve months post-RSA.

Table 3. Patient-Specific SHR Relative Motion Curve Types. Fifty Percent of Subjects (5/10) Displayed Changes in SHR Relative Motion Curve Shape Between Six Months and Twelve Months Post-RSA

<table>
<thead>
<tr>
<th>Subject</th>
<th>6-month curve type</th>
<th>12-month curve type</th>
<th>Δ curve type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>linear</td>
<td>linear</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>concave</td>
<td>concave</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>linear</td>
<td>convex</td>
<td>Y</td>
</tr>
<tr>
<td>4</td>
<td>convex</td>
<td>linear</td>
<td>Y</td>
</tr>
<tr>
<td>5</td>
<td>linear</td>
<td>concave</td>
<td>Y</td>
</tr>
<tr>
<td>6</td>
<td>concave</td>
<td>concave</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>linear</td>
<td>linear</td>
<td>N</td>
</tr>
<tr>
<td>8</td>
<td>concave</td>
<td>concave</td>
<td>N</td>
</tr>
<tr>
<td>9</td>
<td>linear</td>
<td>convex</td>
<td>Y</td>
</tr>
<tr>
<td>10</td>
<td>linear</td>
<td>convex</td>
<td>Y</td>
</tr>
</tbody>
</table>

Figure 6. Midterm Post-RSA SHR compared to literature reported values. Common SHR literature values are elevated (A) in comparison to midterm post-RSA SHR observed in this study, which does not tightly align with literature reported rates (B).
creased relative scapulothoracic motion and decreased glenohumeral motion post-RSA, including continued elevated scapulothoracic motion even at one year after surgery. During the course of activities of daily living, it is hypothesized that increased scapulothoracic motion especially during shoulder elevation is a compensatory mechanism to account for range of motion limitations, especially during low abduction angles.\textsuperscript{17,35} Scapulothoracic motion beyond a certain threshold may be associated with negative outcomes including periscapular and acromioclavicular musculoskeletal pain, subscapular bursitis, stress fractures of the scapular spine.\textsuperscript{3,8,14,36} Recognition of the possibility for persistently increased scapulothoracic motion and relatively decreased glenohumeral motion may therefore have important implications for long-term post-RSA management. Potential compensatory steps could possibly be adopted during post-RSA rehabilitation to increase stabilization or motion of the scapula in specific planes, such as through periscapular muscle strengthening and neuromuscular control exercises.\textsuperscript{37}

**SHR Changes During Different Phases of Motion**

Changes in post-RSA SHR were also observed for different phases of shoulder motion using EOS analysis. Generally decreased SHR was found for 90 to 120° compared to 60 to 90° of motion. This observation is consistent with prior literature reports of SHR decreasing after 60° of motion, and it is consistent with expectations regarding differences in muscle contribution throughout shoulder range of motion with a greater contribution of the trapezius and serratus anterior to assist with motion past 90°.\textsuperscript{21} This is especially interesting to consider in the context of the post-RSA shoulder, where the deltoid assumes a primary role to power the glenohumeral joint.\textsuperscript{4,38}

In this study, greater variability was noted for the 60-90° phase of motion at both six and twelve months post-RSA, which may point to differences in functional control throughout the motion arc. This is also consistent with literature observations of greater SHR variability during the scapular setting phase (<60°) across multiple studies.\textsuperscript{17,35} Mechanically, post-RSA values especially with greater variability during early phases of motion may point towards differences in the musculature responsible for powering this motion in the RSA shoulder, which may have differences in supraspinatus and deltoid load sharing.\textsuperscript{4,38} Furthermore, especially in an RSA population with variable rotator cuff integrity and soft-tissue condition, rotator cuff contribution to overall shoulder stability may be variable. For example, a lack of supraspinatus and infraspinatus to assist the deltoid in arm elevation and depression may be compounded by a dysfunctional motor pattern and may result in deltoid inhibition.\textsuperscript{4} Differences could also possibly be related to RSA implant restriction of glenohumeral motion\textsuperscript{4} or change in torque generation requirement with implant lateralization or excessive tension generated across the joint due to poor quality soft-tissue\textsuperscript{39} or a combination of anatomical and prosthetic factors\textsuperscript{40} not explicitly studied in this small population. However, we were able to establish in our small study cohort that SHR is not strongly associated with demographic factors including BMI, as it was initially unclear if greater BMI (and central adipose mass) might influence arm positioning relative to the side of the body which could dictate positioning and initiation of shoulder motion. Therefore, further study is needed to isolate the influence of additional soft-tissue and implant parameters that might influence variability in post-RSA SHR. However, this study did include efforts to assess SHR at both the cohort and subject-specific level, including the analysis of subject-specific relative motion curves.

**SHR Changes During the Midterm Post-RSA Period**

SHR was also found to change during the mid-term post-RSA period. Relative changes in scapulothoracic and glenohumeral motion were most likely to occur for the 90-120° phase of motion. While SHR for 60-90° phase stayed relatively similar between six and twelve months, SHR for 90-120° of shoulder motion continued to decrease. Overall, SHR for the complete shoulder motion arc (60-120°) did not begin to approach normative SHR values post-RSA during the twelve-month follow-up period in this study. However, 50% of subjects in this study cohort were found to alter their SHR pattern during the follow-up time period, which suggests that patients’ SHR and motion patterns are continuing to evolve towards a new baseline out to one-year post-RSA and could be amenable to PT intervention. The timeline, type, and degree of relative motion pattern changes may not be identical for all patients, which may be reflected in the data range of this study.

Prior study of SHR in patients at six and twelve months post-RSA found no changes in SHR including flexion and external rotation during elevation in the scapular plane from 0-90°. Both biomechanical and patient-reported outcome measures have also suggested that post-RSA kinematics does not change significantly following six months post-operatively.\textsuperscript{41} However, the variation noted among our study population in the form of outlying values for a few select patients might also suggest that patients do not all progress at the same rate in re-establishing their specific post-RSA mechanics at a new baseline level, especially among the heterogeneous
population indicated for RSA with varying rotator cuff integrities and glenoid geometries. Isolated outlying SHR values for individual subjects may reflect adaptation and learning of motion strategies as patients progress to their own individual post-RSA baseline. These observations suggest that normalization of SHR may be an iterative, and longer-term process during RSA rehabilitation that may continue past the midterm post-operative for some patients. This is an important realization that highlights the potential for possible intervention and modification of SHR during the post-operative period in the event of possible functional limitation/pain and emphasizes the need for patient-specific study of SHR especially in a post-RSA population.

**SHR Displays Patient-Specific Pattern Types**

Patient-specific analysis of SHR relative motion curves also reinforces the idea that some subjects’ SHR pattern has not reached a new established baseline during the midterm post-operative period. Bagg and Forrest, followed by Zaferiou et al., previously identified three curve types associated with SHR, with each linked to a different muscle activation pattern/motion strategy. Type C curves are linear and display a relatively constant SHR through the arc of arm motion. Whereas curve types A and B displayed greater scapular rotation compared to glenohumeral rotation during mid-range abduction, but scapular rotation decreased for type B curves after 130° of abduction. Similarly, in this subject cohort three consistent curve types were observed: linear, concave, and convex.

Persistence of the same motion pattern type for 50% of subjects might suggest some patients have reached a new baseline functional pattern, which aligns with the idea that RSA mechanics have been observed to not significantly change after six months post-RSA. However, the change in curve shape for 50% of subject suggest that some subjects may be amenable to alterations in their individual SHR pattern during the midterm post-RSA period, which might allow for intervention to correct very aberrant patterns for symptomatic patients. For example, the most prevalent change in curve shape between six months and twelve months (3/5 subjects) from linear to convex, suggests that perhaps some subjects are still developing greater relative glenohumeral range of motion even out to the one year time point, which could be helpful information for guidance of post-RSA rehabilitation.

**Post-RSA SHR Differs From Literature Values**

Consistent with literature reports, we observed decreased SHR in our post-RSA population compared to normative values for a normal shoulder (Figure 6a). The six-month and twelve-month RSA (Figure 6b) SHR for the normal shoulder has been established as 2:1. However, Walker et al. have reported a mean SHR of 0:1 in a population of pre-RSA shoulders and a mean SHR of 3:1 in a population of normal shoulders. This group was also among the first to report decreased SHR (1.3:1) in a small post-RSA population involving three different implant types with varied geometric configurations, establishing the trend of decreased SHR associated with post-RSA shoulder motion. Lower SHR is suggestive of less glenohumeral motion during the shoulder motion arc and greater scapular motion, with a hypothesized compensatory increase in trapezius activity. Subsequent electromyography analysis supports the idea of greater trapezius activation in post-RSA patients during abduction.

Despite the lower nature of observed SHR values in this study, there are several factors to increase confidence in these results. Observed SHR was generally consistently low amongst subjects with a few strong outliers that are within the range of values reported for even normal shoulder. Furthermore, the general trends based on mean values observed at the cohort level in this study were also reinforced by the observation of the same general trends across most subjects. Overall, SHR for the complete shoulder motion arc (60-120°) did not increase with longer post-RSA follow-up in this study or begin to approach reported normative SHR values, and was lower to other reported post-RSA studies. However, this study focused on the midterm post-RSA period (six to twelve months) and differs in length of follow-up from other studies with heterogeneous or longer term follow-up time periods (e.g. 37 months) and different implant types.

Based on both the small cohort-wide and within-subject changes in SHR across the midterm post-RSA period in this study, results suggest that patients following RSA do not return to normative SHR motion. This is expected since all subjects had a history of rotator cuff arthropathy prior to surgery and thus did not have a “normal” shoulder prior to the procedure. Furthermore, the biomechanics of the post-RSA are fundamentally different from the normal shoulder where reversal of the glenohumeral joint polarity mediates and distalizes the joint center of rotation facilitates greater reliance on the deltoid for shoulder movement. However, more work is required to establish an ideal SHR pattern for RSA patients during the midterm post-operative period, especially based on the wide array of possible contributory factors that have been suggested to influence SHR including both anatomic differences (such as variations in rotator cuff condition and integrity), implant parameters, and possibly demographics which we have made a preliminary attempt to account for in this study. The
observation that patients may still be establishing a new baseline pattern during this time period could make it an ideal time period for clinical intervention, especially if extreme and persistent outlying SHR values are observed for the same subject overtime. Heterogeneity in osseous and soft-tissue condition in our study population, a concern for the RSA population as a whole, may play a role in this observed deviation from reported SHR values. Further detailed study in a large post-RSA population is thus indicated to further characterize the influence of the possible mix of both anatomical and surgical parameters that might influence post-operative function in an effort to further characterize and isolate the strongest factors contributing to different scapulohumeral motion patterns that might lead to increased pain and RSA implant wear overtime.

Limitations

Limitations in this study include the relatively small sample size. However, this study is the first to characterize SHR using an EOS methodology, which affords decreased radiation dosage and by nature of imaging system avoids soft-tissue artifacts introduced associated with other SHR assessment modalities. Use of the EOS system also allowed for standing assessment of shoulder motion with arm in positions similar to activities of daily living, unlike other studies that have been able to assess SHR using progressive CT scans but require subjects to be placed in a prone position and range of motion is limited by the walls of the CT scanner. In addition to the benefits of the assessment of application of a new imaging modality for SHR analysis, this study also offers advantages over prior studies through inclusion of both cohort and subject-level analysis including the publication of patient-specific relative motion curves. This study presents an example of an attempt to assesses influences on calculated SHR by patient-specific factors such as BMI and implant parameters such as stem length. Furthermore, although the subject population is small in this study, the population is more homogenous in terms of surgical indication (rotator cuff arthropathy), implant type, and length of follow-up post-RSA in comparison to other similarly sized studies. However, our analysis of a single implant model within a single surgeon cohort possibly limits the applicability of study findings to other RSA implants. This proof-of-concept study has thus established the feasibility of SHR assessment using an EOS imaging system as well as highlighting the need for patient-specific SHR analysis in a post-RSA population.

Clinical Applications

Coupled relative mechanical motion between the scapula and humerus is a commonly used metric, and has been identified as a sensitive indicator for shoulder function. Adequate scapular stability is essential for force generation from muscles originating from the scapula that are key players in upper arm motion and overall shoulder stability during dynamic motion and activities of daily living. Based on the relationship of the scapula to both the glenohumeral and acromioclavicular joint, motion at the scapula and humerus serves a key link between the rest of the upper extremity kinetic chain. Aberrant relative scapular-humeral positioning can thus disrupt efficient movement patterns to possibly limit risk of implant failure and pain or functional limitations associated with shoulder instability. Therefore, improved understanding of post-RSA mechanics offered in this study is important for design of post-operative rehabilitation protocols to optimize scapulothoracic and glenohumeral motion. Study findings suggest that post-RSA rehabilitation might benefit from focus on patient-specific SHR patterns, realizing that some patients may experience changes/be establishing a newbaseline SHR past six months post-RSA which might include increased relative glenohumeral motion. However, during this time period the greatest changes can be expected during 90-120° of humeral thoracic motion, which could help to inform targeting of rehabilitation protocols to help target interventions such as periscapular muscle strengthening to help assist with modifiable functional changes to hopefully improve overall long-term shoulder stability and minimization of unfavorable outcomes of scapular notching and implant failure in RSA patients.

CONCLUSION

This study offers the first use of EOS imaging for calculation of SHR in a post-RSA population with the added benefits of less radiation and no overlying soft tissue artifact in kinematic calculations. Overall, we observed lower SHR, representative of greater scapulothoracic motion, in our post-RSA population. SHR post-RSA was also found to further decrease between 6 and 12 months. Greater variability was consistently observed from 60-90° of motion at both the six-month and twelve-month time points post-RSA. Study findings suggest that elevated scapulothoracic motion may persist following RSA, which may be monitored longitudinally using EOS. These motion patterns may place the shoulder at a greater risk for implant wear and impingement, possibly explaining why scapular notching is so prevalent after RSA and establishes the need for future large-scale study which may be facilitated via use of EOS technology. However, SHR for the post-RSA shoulder may still be changing at one-year post-operative, especially for the 90-120° phase of shoulder motion, in a subset of patients. Future post-RSA rehabilitation protocols might therefore
benefit from a patient-specific design and targeting of efforts to training and strengthening of musculoskeletal structures such as periscapular muscles responsible for scapular stabilization during this motion range.

REFERENCES


ABSTRACT
Background: Radiation therapy (RT) is often utilized in cases of high-grade soft tissue sarcoma (STS), but there remain situations where treatment is with surgical excision alone. Our goals were to determine (1) the local recurrence (LR) rate with and without perioperative RT and (2) associations between local recurrence, patient, tumor, and treatment variables.

Methods: We performed a retrospective review of 165 consecutive STS patients. A Cox proportional hazards model was used to investigate variables associated with local recurrence.

Results: LR occurred in 15/78 (19%) without RT, 4/29 (14%) with postoperative RT, and 0/58 with preoperative RT (p=0.002). We found increased rates of local recurrence at 24 months for myxofibrosarcoma (p=0.001) and no-RT (p=0.003). Myxofibrosarcoma accounted for 33 (20%) of the study patients and 12 (63%) of the local recurrences.

Conclusion: The LR rate in patients treated with surgery alone was disproportionately attributable to myxofibrosarcoma (11/23 cases, 48%). Other subtypes demonstrated a lower rate of LR in the absence of RT (4/55 cases, 7%), and no LR occurred when final margins were >2 mm. In certain circumstances treatment with a negative margin surgical resection followed by close observation is justifiable. RT is effective and should continue to be considered routinely in myxofibrosarcoma or when surgical margins are inadequate.

Level of Evidence: III

Keywords: soft tissue sarcoma, radiation therapy, local recurrence

INTRODUCTION
Soft tissue sarcomas (STS) are comparatively uncommon tumors representing 1% and 15% of adult and pediatric solid neoplasms respectively. STS can present anywhere in the body, most often arising from the extremities or trunk. Surgical excision remains critical in the treatment of STS, with a historical progression away from amputation toward limb-sparing techniques. Optimal care of these patients requires multidisciplinary involvement including oncology, surgery, pathology, radiology, and radiation oncology.1,3

A resection margin free of tumor is the most important factor for establishing local control.1,4 Margins are categorized according to the Enneking criteria as intralesional (inclusion of the mass), marginal (at the immediate border of the tumor), wide (include a cuff of healthy tissue surrounding the tumor), or radical (excision of the entire compartment containing the tumor).5 Although dissection through surrounding tissue such as muscle or subcutaneous fat requires a margin widely free of tumor, an appropriate margin can approximate one millimeter with inclusion of an anatomical barrier, such as tendon, fascia, cartilage, or periosteum.6-10 There are some studies which also suggest that the addition of radiation therapy can result in adequate margins of equal to or less than one millimeter.11,12 Indeed, such margins are often necessary in order to preserve critical neurovascular structures, organs, or bone.

Radiation therapy (RT) provides several benefits in the treatment of STS, including the ability to target microscopic extensions of the tumor, preoperative reduction in tumor size, and sterilization of the margin.13,14 Perioperative RT is justified for limb-sparing excisions of high-grade STS which are larger than five centimeters, have actual or predicted close resection margins, or have previously recurred.15 Potential drawbacks of RT include poor wound healing, pain, edema, fibrosis, and risks of secondary neoplasm.5,15 Many times, the decision to deliver perioperative RT is simple, such as a large, deep, high-grade sarcoma adjacent to bone, vessels, or nerve. Other instances present a clinical dilemma. Superficial tumors, small tumors, marginal resections thought to be adequate, patients who experience delayed wound healing prior to postoperative RT, patients presenting with metastatic disease that will negate long-term survival,

LOCAL RECURRENCE OF SOFT TISSUE SARCOMA REVISITED: IS THERE A ROLE FOR “SELECTIVE” RADIATION?
Nathan E. Saxby1; Qiang An, MBBS, MSPH1; Benjamin J. Miller, MD, MS1

1Department of Orthopedics and Rehabilitation, University of Iowa Hospitals and Clinics, Iowa City, Iowa, USA
Corresponding Author: Nathan E. Saxby, nathan-saxby@uiowa.edu, 907-301-7232
Disclosures: The authors report no potential conflicts of interest related to this study.
Sources of Funding: No sources of funding declared.
and patients who elect not to have adjuvant RT are not uncommon situations and present a challenge to treating providers to determine if deferring radiation offers an acceptable rate of local control, or if the risks of local recurrence are so great that clinicians should strongly advocate for further intervention before treatment is considered complete.

The purpose of this study was to (1) determine the local recurrence rate of STS which would have met criteria to receive perioperative RT but did not proceed with treatment when compared to those who did receive the RT treatment and (2) elucidate any associations between local recurrence and patient, tumor, and treatment variables. Ultimately, our goal was to investigate clinical features that may justify management without perioperative RT, and those that strongly support use of perioperative RT to achieve acceptable rates of local control.

METHODS

Study Design and Setting

This study was an institutional review board-approved single-institution retrospective chart review within the electronic medical record (EMR) of consecutive STS patients.

Participants

Review of patient records from our institutional EMR determined underlying patient and tumor characteristics and eligibility into the study. Patients 18 years or older with diagnosis of a primary (nonrecurrent) grade 2/3 or 3/3 STS who presented for initial tumor resection or tumor bed re-excision from September 1, 2010 and May 8, 2019 and had at least one post-surgical follow up were eligible for participation. We included pelvic and extremity tumors of all sizes and depths.

Patient and treatment variables were collected from the hospital EMR. Each sarcoma patient is reviewed in a multidisciplinary tumor board with fellowship-trained specialists from orthopedic oncology, surgical oncology, medical oncology, radiation oncology, musculoskeletal radiology, and bone and soft tissue pathology. The general indications for perioperative RT in soft tissue sarcoma are tumors that are intermediate or high grade (2-3/3), >5 cm, deep to the fascia, and the anticipation of close margins. Our institutional preference is to deliver RT in the neoadjuvant setting, and postoperative RT is reserved for when wound complications are deemed to be unacceptably high or detrimental, patients who insist in having radiation delivered locally in a non-sarcoma center, or when final margins are unexpectedly close or microscopically positive and a re-excision would result in substantial morbidity. RT is not performed on every patient, and its use is discussed individually in tumors that are small (<5 cm), superficial, low grade, or resected with margins widely free of tumor. Patients with incompletely excised tumors that receive tumor bed re-excisions with no residual identified disease are routinely treated with observation; the majority of these are small and superficial. Patients with sarcoma present in a very heterogeneous fashion and there are exceptions for each of these general guidelines.

Variables, Outcome Measures, and Data Sources

From the EMR, patient data were acquired including patient demographics, recurrence, survival, and tumor characteristics from the pathology report, including tumor type, margins, size, and grade. Radiation treatment, timing, and dose were also recorded in the EMR if received by the patient. Final surgical margins were determined by an institutional pathologist and gleaned from the pathology report. The institutional protocol for postoperative follow-up followed National Comprehensive Cancer Network (NCCN) STS surveillance guidelines. Our primary endpoint was LR, which was documented in the EMR via provider notes with histologic confirmation. MRI was not used routinely for local surveillance and LR was overwhelmingly patient-reported or noted on physical exam. Concerns for LR were addressed with a confirmatory MRI and tissue sampling. Participants who did not experience a local recurrence, defined as the time calculated from the date of surgery, were censored at the time of latest clinical evaluation. Participants who died were censored at their date of death. Time to local recurrence was defined as the time from surgery to the time of recurrence and were considered to have a competing risk of mortality for the time-based analysis.

Statistical Analysis

Patient demographics comparing local recurrences in the entire cohort and local recurrences in patients without radiation were modeled utilizing chi-squared or Fisher’s exact test for categorical variables and Wilcoxon sum rank test for continuous variables, as appropriate. The cumulative incidence for postoperative local recurrence for 12 months, 24 months, and 60 months for the entire cohort, radiation only, and no radiation groups were estimated using the Kaplan-Meier method, calculating the time of last follow-up, death, or local recurrence from the time of the definitive surgical resection. Patients were censored at the time of last follow-up if they had not experienced an LR. Local recurrence at 24 and 60 months were modeled using Cox proportional hazard ratio to estimate the independent recurrence of predicted variables and was adjusted for age, sex, histology, grade, size, depth, prior surgery, and margins while considering the competing risk of mortality. All analysis
was completed using SAS statistical software version 9.4 (SAS institute, Inc, Cary, NC) and a P-value of <0.05 was considered statistically significant.

RESULTS

Demographics and Description of Study Population

We identified 165 patients who met inclusion criteria with a median follow-up of 29 months (range 1–107 months) with 61 patients (37%) having less than 24 months of follow-up (Table 1). Of these 61 patients, only 14 (8% of the total cohort) did not experience LR or death, the remaining patients died within 2 years of surgery. Eighty-nine patients in the cohort did not experience LR or death and were censored at a median follow-up was 37 months (range 3–105 months). Histology types within the cohort included UPS with 57 (35%), myxofibrosarcoma with 33 (20%), leiomyosarcoma with 20 (12%), and all others with 55 (33%). The “others” category of histology included diagnoses of Alveolar Soft Part Sarcoma (2), Angiosarcoma (1), Clear Cell Sarcoma (2), Epithelioid Hemangioendothelioma (1), Epithelioid Sarcoma (4), Extraskeletal Osteosarcoma (1), Fibrosarcoma (1), Liposarcoma (13), Malignant Peripheral Nerve Sheath Tumor (9), malignant PVNS (spindle cell/tenosynovial giant cell tumor) (1), Rhabdomyosarcoma (3), Sarcoma NOS (5), Sclerosing Epithelioid Fibrosarcoma (1), Synovial Sarcoma (10).

For the entire cohort, there were 19 local recurrences. We observed LR in 15/78 without RT, 4/29 with postoperative RT, and 0/58 with preoperative RT (p=0.002) (Table 2). For the entire cohort, myxofibrosarcoma histology demonstrated a 36% recurrence rate (12/33 cases), compared to 4/57 (7%) for undifferentiated pleomorphic sarcoma, 0/20 for leiomyosarcoma, and a cumulative 3/55 (5%) recurrence for all other histologic subtypes, (p<0.001).

Other significant associations were demonstrated as follows: Patients who presented for tumor bed re-excision after a recent attempt at surgical excision at an outside hospital had a 9/31 (29%) recurrence rate, whereas those who presented for primary excision demonstrated a rate of 10/134 (7%) (p=0.002). Tumors recorded as superficial were also associated with higher recurrence rate of 9/44 (20%) when compared to deep tumors, at 10/121 (8%) (p=0.030). Finally, intralesional margins showed a recurrence rate of 8/27 (30%) compared to marginal (<1 mm) at 4/64 (6%) and wide (>1 mm) at 7/74 (9%), (p=0.005).

Table 1. Patient, Tumor, and Treatment Details of the Entire Cohort

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total Number (%)</th>
<th>Radiation (%)</th>
<th>No-radiation (%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Total N=165</td>
<td>N=86</td>
<td>N=78</td>
<td></td>
</tr>
<tr>
<td>&lt;65</td>
<td>81 (49.09)</td>
<td>37 (43.02)</td>
<td>44 (56.14)</td>
<td>0.0868</td>
</tr>
<tr>
<td>≥65</td>
<td>84 (50.91)</td>
<td>49 (56.98)</td>
<td>34 (43.59)</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>Female</td>
<td>73 (44.24)</td>
<td>38 (44.19)</td>
<td>34 (43.59)</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>92 (55.76)</td>
<td>48 (55.81)</td>
<td>44 (56.41)</td>
</tr>
<tr>
<td>Histology</td>
<td>Leiomysosarcoma</td>
<td>20 (12.12)</td>
<td>7 (8.14)</td>
<td>13 (16.67)</td>
</tr>
<tr>
<td></td>
<td>Myxofibrosarcoma</td>
<td>33 (20.00)</td>
<td>10 (11.63)</td>
<td>23 (29.49)</td>
</tr>
<tr>
<td></td>
<td>UPS</td>
<td>57 (34.55)</td>
<td>42 (48.84)</td>
<td>15 (19.23)</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>55 (33.33)</td>
<td>27 (31.40)</td>
<td>27 (34.62)</td>
</tr>
<tr>
<td>Grade</td>
<td>High (3/3)</td>
<td>106 (64.24)</td>
<td>55 (63.95)</td>
<td>50 (64.10)</td>
</tr>
<tr>
<td></td>
<td>Int (2/3)</td>
<td>59 (35.76)</td>
<td>31 (36.05)</td>
<td>28 (35.90)</td>
</tr>
<tr>
<td>Metastasis at diagnosis</td>
<td>Yes</td>
<td>36 (21.82)</td>
<td>21 (24.42)</td>
<td>15 (19.23)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>129 (78.18)</td>
<td>65 (75.58)</td>
<td>63 (80.77)</td>
</tr>
<tr>
<td>Size</td>
<td>&lt;5 cm</td>
<td>47 (28.48)</td>
<td>10 (11.63)</td>
<td>37 (47.44)</td>
</tr>
<tr>
<td></td>
<td>≥5 cm</td>
<td>51 (30.91)</td>
<td>31 (36.05)</td>
<td>20 (25.64)</td>
</tr>
<tr>
<td></td>
<td>≥10 cm</td>
<td>67 (40.61)</td>
<td>45 (52.33)</td>
<td>21 (26.92)</td>
</tr>
<tr>
<td>Depth</td>
<td>Superficial</td>
<td>44 (26.67)</td>
<td>6 (6.98)</td>
<td>38 (48.72)</td>
</tr>
<tr>
<td></td>
<td>Deep</td>
<td>122 (73.33)</td>
<td>80 (93.02)</td>
<td>40 (51.28)</td>
</tr>
<tr>
<td>Tumor Bed Excision</td>
<td>Yes</td>
<td>31 (18.79)</td>
<td>3 (4.99)</td>
<td>28 (35.90)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>134 (81.21)</td>
<td>83 (96.51)</td>
<td>50 (64.10)</td>
</tr>
<tr>
<td>Radiation</td>
<td>Preoperative</td>
<td>58 (35.15)</td>
<td>58 (67.44)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Postoperative</td>
<td>29 (17.58)</td>
<td>28 (32.56)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>78 (47.27)</td>
<td>0</td>
<td>78 (100)</td>
</tr>
<tr>
<td>Margins</td>
<td>Greater than 1mm</td>
<td>74 (45.12)</td>
<td>20 (23.53)</td>
<td>54 (69.23)</td>
</tr>
<tr>
<td></td>
<td>Less than 1mm</td>
<td>63 (38.41)</td>
<td>47 (55.29)</td>
<td>15 (19.23)</td>
</tr>
<tr>
<td></td>
<td>Intralesional</td>
<td>27 (16.46)</td>
<td>18 (21.18)</td>
<td>9 (11.54)</td>
</tr>
</tbody>
</table>
Local Recurrence Rate of Soft Tissue Sarcoma without Radiation Therapy

In our cohort, 78 (47%) patients were not treated with RT. The reasons for not delivering perioperative RT were for tumors that were small and superficial (25), perception of adequate margins (25), patient declined (10), tumors that were metastatic at diagnosis with a plan for systemic treatment (10), RT that was planned but not delivered due to early death or poor performance status. 

| Table 2. Univariate Analysis For the Association Between Variables Of Interests With Local Recurrences Among Cohort With 165 Patients |
|---|---|---|
| Age | Recurrence | No recurrence | p value |
| N=19 | N=146 |  |
| <65 | 6 | 75 | 0.1045 |
| ≥65 | 13 | 71 |  |
| Sex |  |
| Female | 9 | 64 | 0.7706 |
| Male | 10 | 82 |  |
| Histology |  |
| Leiomyosarcoma | 0 | 20 | <0.001 |
| Myxofibrosarcoma | 12 | 21 |  |
| UPS | 4 | 53 |  |
| Other | 3 | 52 |  |
| Grade |  |
| High (3/3) | 14 | 92 | 0.3613 |
| Int (2/3) | 5 | 54 |  |
| Metastasis at diagnosis |  |
| Yes | 3 | 33 | 0.7678 |
| No | 16 | 113 |  |
| Size |  |
| <5 cm | 9 | 38 | 0.0525 |
| ≥5 cm | 10 | 108 |  |
| Depth |  |
| Superficial | 9 | 35 | 0.0301 |
| Deep | 10 | 111 |  |
| Tumor Bed Excision |  |
| Yes | 9 | 22 | 0.0023 |
| No | 10 | 124 |  |
| Radiation |  |
| Preoperative | 0 | 58 | 0.0022 |
| Postoperative | 4 | 25 |  |
| None | 15 | 63 |  |
| Margins |  |
| Greater than 1mm | 7 | 67 | 0.005 |
| Less than 1mm | 4 | 59 |  |
| Intralesional | 8 | 19 |  |

| Table 3. Univariate Analysis For the Association Between Variables Of Interests With Local Recurrences Among Cohort With 78 Patients Treated Without Radiation |
|---|---|---|
| Age | Recurrence | No recurrence | p value |
| N=15 | N=63 |  |
| <65 | 5 | 39 | 0.0449 |
| ≥65 | 10 | 24 |  |
| Sex |  |
| Female | 8 | 27 | 0.540 |
| Male | 8 | 38 |  |
| Histology |  |
| Leiomyosarcoma | 0 | 13 | 0.0006 |
| Myxofibrosarcoma | 11 | 12 |  |
| UPS | 2 | 13 |  |
| Other | 2 | 25 |  |
| Grade |  |
| High (3/3) | 10 | 40 | 0.8178 |
| Int (2/3) | 5 | 23 |  |
| Metastasis at diagnosis |  |
| Yes | 3 | 12 | 1.000 |
| No | 12 | 51 |  |
| Size |  |
| <5 cm | 8 | 29 | 0.6108 |
| ≥5 cm | 7 | 34 |  |
| Depth |  |
| Superficial | 8 | 30 | 0.6907 |
| Deep | 7 | 33 |  |
| Tumor Bed Excision |  |
| Yes | 8 | 20 | 0.1173 |
| No | 7 | 43 |  |
| Margins |  |
| Greater than 1mm | 6 | 48 | 0.005 |
| Less than 1mm | 4 | 11 |  |
| Intralesional | 5 | 4 |  |
Selective Radiation in Sarcoma

(4), and prolonged wound complications past the time when post-operative RT would have been delivered (4).

Patients who received RT showed lower recurrence rates at 12, 24, and 60-month intervals as compared to the no-RT group (Table 4, Fig. 1). Regardless of RT category, intralesional margins demonstrated higher recurrence with the progression of time when compared to marginal and wide in both the RT and no-RT cohorts (Fig. 2, 3).

In the no-RT cohort specifically, patients of at least 65 years of age showed an increased recurrence rate at 29% compared to 11% in younger patients (p=0.045) (Table 3). Myxofibrosarcoma again demonstrated a high recurrence rate at 48% when compared to all other histological types (p<0.001). Lastly, non-wide margins recurred at 38% compared to wide at 11% (p=0.005).

**Associations Between Local Recurrence and Patient, Tumor, and Treatment Variables**

The multivariate Cox proportional hazards survival analysis of local recurrence for the full cohort, accounting for competing mortality risk, demonstrated an increased risk of LR in no-RT (24-month [p=0.003], 60-month [p=0.001]), myxofibrosarcoma (24-month [p=0.001], 60-month [p<0.001]), size ≥5 cm (60-month [p=0.026]), tumor bed re-excision (60-month [p=0.018]), and margins <1mm (60-month [p=0.036]) when controlling for age, sex, grade, and depth (Table 5,6). Similarly, the no-RT cohort showed a significantly increased risk of local recurrences with myxofibrosarcoma (24-month [p<0.001], 60-month [p=0.001]), margins <1mm (24-month [p=0.030], 60-month [p=0.011]), and tumor bed re-excision (60-month [p=0.025]).

**DISCUSSION**

Perioperative radiation is often utilized with surgical resection for treatment of high-grade STS. There are some clinical situations where surgical excision alone may be justified. Our goal was to review a retrospective cohort of patients diagnosed with intermediate and high-grade STS to assess differences in local recurrence. Next, we sought to determine risk factors associated with local recurrence to better understand clinical scenarios in which radiation can be deferred, or when radiation is critical in order to avoid an unacceptably high risk of local recurrence.

Our univariate and multivariate analyses demonstrated that patients who received surgical excision alone

---

**Table 4. Cumulative Incidence for Local Recurrence, With and Without Radiation, at 12, 24, and 60 Months Postoperative**

<table>
<thead>
<tr>
<th></th>
<th>12 months</th>
<th></th>
<th>24 months</th>
<th></th>
<th>60 months</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local recurrence (%)</td>
<td>95% CI</td>
<td>Local recurrence (%)</td>
<td>95% CI</td>
<td>Local recurrence (%)</td>
<td>95% CI</td>
</tr>
<tr>
<td>Radiation</td>
<td>1.19</td>
<td>0.10-5.80</td>
<td>2.71</td>
<td>0.50-8.58</td>
<td>6.79</td>
<td>2.06-15.49</td>
</tr>
</tbody>
</table>

**Figure 1. Kaplan-Meier Survival to recurrent Plot. Comparison of local recurrence rates in the entire cohort with and without adjuvant radiation within 6 months.**

**Figure 2. Kaplan-Meier Survival to recurrent Plot. Comparison of local recurrence rates in patients treated with radiation by Enneking margin categories of intralesional, marginal, and wide.**
were at a significantly higher risk of local recurrence when compared to those who had also received RT. This is consistent with prior studies and conventional understanding of radiation treatment, which has shown RT to reliably decrease local recurrence rates.1,3,5

Similarly, in the absence of RT, myxofibrosarcoma histology demonstrated an unacceptably increased rate of LR. However, it was notable that in both the RT and no-RT cohorts, patients with other histological diagnoses and a wider resection margin (>2 mm or no residual tumor on tumor bed re-excision), did not experience any local recurrences.

Our investigation revealed myxofibrosarcoma repeatedly and strongly associated with risk of local recurrence, consistently demonstrating higher recurrence rates than other histology types. The role of RT in treating myxofibrosarcoma is not absolutely clear, however, most studies have attributed reduced recurrence rates to the combination of RT and improved margins.16,17 Some suggest that the multinodular and infiltrative growth pattern of myxofibrosarcoma can cause extensive invasion of the neighboring tissue that may not be easily identified during excision.18-21 This results in difficulty of obtaining clear margins as the tumor commonly extends microscopically through subcutaneous fat and along fascial planes. Our study supports these prior observations and demonstrates dramatically that myxofibrosarcoma continues to have a relentless capacity for local recurrence in the modern treatment of sarcoma. Complicating matters further, is there remains much uncertainty on what a critical margin distance would be.

Margins were shown to have a significant association with recurrence under univariate and multivariate analyses. A prior cohort study22 and retrospective study23

<table>
<thead>
<tr>
<th></th>
<th>Full cohort</th>
<th>No radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=165</td>
<td>N=78</td>
</tr>
<tr>
<td>HR</td>
<td>95% CI</td>
<td>p value 95% CI</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;65</td>
<td>ref 0.2780</td>
<td>ref 0.2997</td>
</tr>
<tr>
<td>≥65</td>
<td>2.414 0.491-11.867</td>
<td>2.835 0.396-20.326</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1.111 0.306-4.040</td>
<td>1.638 0.309-8.677</td>
</tr>
<tr>
<td>Male</td>
<td>ref ref</td>
<td>ref ref</td>
</tr>
<tr>
<td>Histology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myxofibrosarcoma</td>
<td>5.538 1.988-15.430</td>
<td>0.0011 8.002 2.392-26.773</td>
</tr>
<tr>
<td>Other</td>
<td>ref ref</td>
<td>ref ref</td>
</tr>
<tr>
<td>Grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High (3/3)</td>
<td>3.001 0.715-12.593</td>
<td>0.1331 2.299 0.444-11.893</td>
</tr>
<tr>
<td>Int (2/3)</td>
<td>ref ref</td>
<td>ref ref</td>
</tr>
<tr>
<td>Size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5 cm</td>
<td>ref 0.0571</td>
<td>ref 0.0719</td>
</tr>
<tr>
<td>≥5 cm</td>
<td>6.454 0.945-44.072</td>
<td>8.317 0.802-86.260</td>
</tr>
<tr>
<td>Depth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superficial</td>
<td>ref 0.7487</td>
<td>ref ref</td>
</tr>
<tr>
<td>Deep</td>
<td>1.308 0.253-6.755</td>
<td>1.600 0.207-12.382</td>
</tr>
<tr>
<td>Tumor Bed Excision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2.451 0.643-9.344</td>
<td>0.1891 3.037 0.693-13.313</td>
</tr>
<tr>
<td>No</td>
<td>ref ref</td>
<td>ref ref</td>
</tr>
<tr>
<td>Radiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>ref 0.0032</td>
<td>ref ref</td>
</tr>
<tr>
<td>No</td>
<td>15.187 2.484-92.877</td>
<td>5.479 1.474-20.371</td>
</tr>
<tr>
<td>Margins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wide (&gt;1mm)</td>
<td>ref 0.0992</td>
<td>ref ref</td>
</tr>
</tbody>
</table>
Selective Radiation in Sarcoma

of patients with STS have similarly shown intralesional margins as a significant predictor of STS local recurrence and is a generally accepted concept.

We also found more limited associations with tumor bed re-excisions and superficial tumors. Prior research supports early referral to a sarcoma center for planned excision of STS tumors, and has shown that unplanned resections are associated with higher local recurrence; our results support this approach.

Our univariate data demonstrated a higher rate of local recurrence in superficial tumors. This is at odds with prior research that has shown that deep-seated tumors have an increased risk of local recurrence compared to superficial tumors. The association was not significant in a multivariate analysis, implying that other variables, such as a higher proportion of myxofibrosarcoma and fewer superficial tumors treated with RT, explain the differences noted on the univariate analysis. Specifically, seven out of the nine superficial tumors that recurred (only one received RT) were myxofibrosarcoma.

The clinical scenarios for patients who received postoperative RT tended to be more complex since our standard protocol is preoperative RT. Postoperative RT is known to have fewer long-term side effects of radiation but with the trade-off of increased perioperative wound complications. Our indications for postoperative RT in these 29 patients were high risk of wound complications (8), preference to have radiation delivered locally (4), unanticipated close or positive margins (4), prior incomplete excision (3), painful tumors with an anticipation that a treatment course of radiation would not be tolerable (3), presentation with diffuse metastatic disease (2), concern for pathologic fracture (2), unclear diagnosis (1), planned vascular repair (1), and presentation with an infected sarcoma after local incisional biopsy (1). Our four LR in the postoperative RT group were for indications of positive margins after amputation (2), desire for local RT (1), and unable to tolerate preoperative RT due to pain or functional limitations (1).

Overall, the local control rate for STS in our series without use of adjuvant RT was 83% at 24 months and 73.5% at 60 months. There is no question that RT effectively decreased the rate of local recurrence, with local control of 97% at 24 months and 93% at 60 months. However, it does come with increased cost, time commitment, risk of wound complications, and functional consequences. From an alternative perspective, 7 of 10 of patients who were not treated with radiation also did not experience a local recurrence within 60 months of resection. Our numbers are small and there is a selection bias, so these data should not be generalized. Yet it does imply that there is a population of patients who meet criteria for perioperative radiation but do not require

<table>
<thead>
<tr>
<th>Table 6. Multivariate Cox Proportional Hazards Model For Local Recurrence at 60 Months, With Competing Risk Of Death, For the Full Cohort and Patients Without Radiation Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>&lt;65</td>
</tr>
<tr>
<td>≥65</td>
</tr>
<tr>
<td>Sex</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Histology</td>
</tr>
<tr>
<td>Myxofibrosarcoma</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Grade</td>
</tr>
<tr>
<td>High (3/3)</td>
</tr>
<tr>
<td>Int (2/3)</td>
</tr>
<tr>
<td>Size</td>
</tr>
<tr>
<td>&lt;5 cm</td>
</tr>
<tr>
<td>≥5 cm</td>
</tr>
<tr>
<td>Depth</td>
</tr>
<tr>
<td>Superficial</td>
</tr>
<tr>
<td>Deep</td>
</tr>
<tr>
<td>Tumor Bed Excision</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Radiation</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Margins</td>
</tr>
<tr>
<td>Wide (&gt;1mm)</td>
</tr>
<tr>
<td>Not wide</td>
</tr>
</tbody>
</table>

Selective Radiation in Sarcoma

Volume 42 Issue 1  245
it for adequate local control (Table 7). Future clinical studies and prospective registry data will be helpful to determine which patients individually will benefit from radiation, and which would have a successful outcome with surgery alone.

In a detailed case review, we noted that the 15 cases not treated with RT that recurred were disproportionately myxofibrosarcoma (11/15, 73%). Viewed differently, 51/55 (93%) of non-myxofibrosarcoma patients did not have a local recurrence, and were better off for avoiding exposure to the cost and side-effects of RT. Margins were also consistently associated with LR in the no-RT cohort, and we did not note any local recurrences in non-myxofibrosarcoma histology with margins >2 mm or no

Table 7. Characteristics For Patients With Deep Soft Tissue Sarcoma That Did Not Receive Radiation Therapy and Did Not Experience Local Recurrence

<table>
<thead>
<tr>
<th>Pt</th>
<th>Sex</th>
<th>Age</th>
<th>Histology</th>
<th>Size (cm)</th>
<th>Grade</th>
<th>Margins (mm)</th>
<th>Metastasis (Y/N)</th>
<th>f/u (months)</th>
<th>Death (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>35</td>
<td>Alveolar Soft Part Sarcoma</td>
<td>17.1</td>
<td>High (G3)</td>
<td>1.0</td>
<td>Yes</td>
<td>3.50</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>35</td>
<td>Alveolar Soft Part Sarcoma</td>
<td>9.4</td>
<td>High (G3)</td>
<td>0.2</td>
<td>Yes</td>
<td>13.70</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>67</td>
<td>Angiosarcoma</td>
<td>3.1</td>
<td>High (G3)</td>
<td>2.8</td>
<td>Yes</td>
<td>6.13</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>49</td>
<td>Epithelioid Hemangioendothelioma</td>
<td>2.3</td>
<td>Intermediate (G2)</td>
<td>0.2</td>
<td>No</td>
<td>28.83</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>24</td>
<td>Epithelioid Sarcoma</td>
<td>4.5</td>
<td>High (G3)</td>
<td>0.1</td>
<td>Yes</td>
<td>0.83</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>85</td>
<td>Extraskeletal Osteosarcoma</td>
<td>18.1</td>
<td>High (G3)</td>
<td>0.7</td>
<td>No</td>
<td>2.20</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>49</td>
<td>Leiomyosarcoma</td>
<td>1.9</td>
<td>High (G3)</td>
<td>0.3</td>
<td>Yes</td>
<td>0.63</td>
<td>No</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>71</td>
<td>Liposarcoma</td>
<td>11.2</td>
<td>High (G3)</td>
<td>0.1</td>
<td>No</td>
<td>37.03</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>74</td>
<td>Liposarcoma</td>
<td>12.0</td>
<td>Intermediate (G2)</td>
<td>0.0</td>
<td>No</td>
<td>38.27</td>
<td>No</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>57</td>
<td>MPNT</td>
<td>5.8</td>
<td>High (G3)</td>
<td>0.1</td>
<td>Yes</td>
<td>6.97</td>
<td>Yes</td>
</tr>
<tr>
<td>11</td>
<td>F</td>
<td>24</td>
<td>MPNT</td>
<td>2.4</td>
<td>High (G3)</td>
<td>0.1</td>
<td>No</td>
<td>81.77</td>
<td>No</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>57</td>
<td>MPNT</td>
<td>11.2</td>
<td>High (G3)</td>
<td>0.0</td>
<td>No</td>
<td>0.63</td>
<td>No</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>37</td>
<td>Myxofibrosarcoma</td>
<td>6.5</td>
<td>Intermediate</td>
<td>0.2</td>
<td>No</td>
<td>1.60</td>
<td>No</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>48</td>
<td>Myxofibrosarcoma</td>
<td>6.5</td>
<td>Intermediate (G2)</td>
<td>No residual</td>
<td>No</td>
<td>21.37</td>
<td>No</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>66</td>
<td>Myxofibrosarcoma</td>
<td>4.9</td>
<td>High (G3)</td>
<td>0.1</td>
<td>No</td>
<td>36.40</td>
<td>No</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>47</td>
<td>Myxofibrosarcoma</td>
<td>13.8</td>
<td>Intermediate (G2)</td>
<td>0.3</td>
<td>No</td>
<td>59.23</td>
<td>No</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>62</td>
<td>Myxofibrosarcoma</td>
<td>9.3</td>
<td>High (G3)</td>
<td>0.6</td>
<td>No</td>
<td>0.90</td>
<td>No</td>
</tr>
<tr>
<td>18</td>
<td>F</td>
<td>32</td>
<td>Rhabdomyosarcoma</td>
<td>27</td>
<td>High (G3)</td>
<td>1.3</td>
<td>No</td>
<td>76.40</td>
<td>Yes</td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>30</td>
<td>Sarcoma, NOS</td>
<td>15.1</td>
<td>High (G3)</td>
<td>5.0</td>
<td>Yes</td>
<td>8.43</td>
<td>Yes</td>
</tr>
<tr>
<td>20</td>
<td>M</td>
<td>91</td>
<td>Sarcoma, NOS</td>
<td>7.4</td>
<td>High (G3)</td>
<td>0.1</td>
<td>No</td>
<td>31.37</td>
<td>Yes</td>
</tr>
<tr>
<td>21</td>
<td>F</td>
<td>81</td>
<td>Sarcoma, NOS</td>
<td>6.7</td>
<td>High (G3)</td>
<td>0.3</td>
<td>No</td>
<td>12.53</td>
<td>No</td>
</tr>
<tr>
<td>22</td>
<td>M</td>
<td>87</td>
<td>Sarcoma, NOS</td>
<td>3.0</td>
<td>High (G3)</td>
<td>9.3</td>
<td>No</td>
<td>48.33</td>
<td>No</td>
</tr>
<tr>
<td>23</td>
<td>M</td>
<td>42</td>
<td>Sclerosing Epithelioid Fibrosarcoma</td>
<td>10.4</td>
<td>Intermediate (G2)</td>
<td>0.2</td>
<td>Yes</td>
<td>57.13</td>
<td>Yes</td>
</tr>
<tr>
<td>24</td>
<td>M</td>
<td>38</td>
<td>Synovial Sarcoma</td>
<td>9.0</td>
<td>High (G3)</td>
<td>9.0</td>
<td>Yes</td>
<td>3.90</td>
<td>Yes</td>
</tr>
<tr>
<td>25</td>
<td>M</td>
<td>82</td>
<td>UPS</td>
<td>36.0</td>
<td>High (G3)</td>
<td>12.5</td>
<td>No</td>
<td>102.77</td>
<td>Yes</td>
</tr>
<tr>
<td>26</td>
<td>M</td>
<td>52</td>
<td>UPS</td>
<td>33.9</td>
<td>High (G3)</td>
<td>0.1</td>
<td>Yes</td>
<td>3.93</td>
<td>Yes</td>
</tr>
<tr>
<td>27</td>
<td>M</td>
<td>65</td>
<td>UPS</td>
<td>33.5</td>
<td>High (G3)</td>
<td>2.5</td>
<td>No</td>
<td>100.47</td>
<td>Yes</td>
</tr>
<tr>
<td>28</td>
<td>M</td>
<td>83</td>
<td>UPS</td>
<td>32.0</td>
<td>Intermediate (G2)</td>
<td>0.1</td>
<td>No</td>
<td>27.37</td>
<td>Yes</td>
</tr>
<tr>
<td>29</td>
<td>M</td>
<td>93</td>
<td>UPS</td>
<td>19.2</td>
<td>High (G3)</td>
<td>0.8</td>
<td>No</td>
<td>8.80</td>
<td>Yes</td>
</tr>
<tr>
<td>30</td>
<td>M</td>
<td>77</td>
<td>UPS</td>
<td>8.0</td>
<td>High (G3)</td>
<td>0.7</td>
<td>No</td>
<td>59.70</td>
<td>Yes</td>
</tr>
<tr>
<td>31</td>
<td>F</td>
<td>58</td>
<td>UPS</td>
<td>0.0</td>
<td>High (G3)</td>
<td>No residual</td>
<td>No</td>
<td>54.80</td>
<td>No</td>
</tr>
<tr>
<td>32</td>
<td>M</td>
<td>66</td>
<td>UPS</td>
<td>23.5</td>
<td>High (G3)</td>
<td>0.0</td>
<td>Yes</td>
<td>106.60</td>
<td>Yes</td>
</tr>
<tr>
<td>33</td>
<td>F</td>
<td>74</td>
<td>UPS</td>
<td>6.5</td>
<td>High (G3)</td>
<td>0.0</td>
<td>No</td>
<td>2.07</td>
<td>No</td>
</tr>
</tbody>
</table>

UPS: undifferentiated pleomorphic sarcoma, MPNT: malignant peripheral nerve sheath tumor, NOS: not otherwise specified.
residual tumor on re-excision. Thus, surgical resections widely free of tumor in non-myxofibrosarcoma histology can be acceptably managed with surgery alone when deemed clinically appropriate. Myxofibrosarcoma, consistent with prior literature, continues to be a significant challenge in the absence of RT, even in the setting of a perceived adequate resection. We treated ten myxofibrosarcomas with RT; one patient had a local recurrence.

There are a number of limitations to our investigation that warrant further discussion. First, as is common with many studies in orthopedic oncology, our numbers were small and the patient, tumor, and treatment details were heterogeneous. Specifically, there are so many histologic subtypes that we may not have identified rare tumors that demonstrate a higher than average likelihood for local recurrence. There was a clear selection bias in this retrospective case-control investigation, with proportionally fewer deep and large tumors managed without RT. We mitigated this with a multivariate analysis accounting for potentially confounding clinical factors. Next, there are other treatment factors that could impact local recurrence, such as systemic therapy. Our institution enrolls many patients on clinical trials, and the medications given were diverse throughout the study period, so it is difficult to assess the efficacy of any one approach to systemic therapy in preventing recurrence. Despite this, our findings are still meaningful as radiation treatment is the adjuvant intervention most effective at limiting local recurrence in soft tissue sarcoma. Finally, the median time to follow up for patients without an event (LR or death) was 37 months. Most local recurrences occur in the first 2 years, but there will likely be some patients who develop recurrences at longer periods of follow-up. We chose a time-based survival analysis to allow for censoring at the time of last follow-up, and to account for the competing risk of death, in order to present the most accurate prediction of local recurrence at specific timepoints postoperatively. Although we had a substantial portion of the cohort with less than 24 months of followup (61/165, 37%), only 14 of these patients were alive without LR. Our analysis strategy accounted for censoring of these patients and we do not believe this altered the integrity of our results or conclusions.

These results suggest that in certain situations surgery alone has potential to be adequate and may be presented as a treatment option, weighing the elevated risk of recurrence against the risks of RT (wound healing complications, pain, edema, fibrosis, and risk of secondary tumor) and patient commitment (cost, treatment time). However, in cases of myxofibrosarcoma or when wide margins are not possible or advised, providers should continue to use perioperative radiation routinely as an effective means to limit local recurrence.

REFERENCES
THE RELATIONSHIP BETWEEN LESION SIZE AND LOAD TO FAILURE AFTER STABILIZATION OF SIMULATED METASTATIC LESIONS OF THE PROXIMAL FEMUR

Arham Pasha, MD1; Jessica Goetz, PhD2; Marc Brouillette, PhD2; Palani Permeswaran, MS2; Trevor R. Gulbrandsen, MD2; Benjamin J. Miller, MD, MS2

ABSTRACT

Background: As overall cancer survival continues to improve, the incidence of metastatic lesions to the bone continues to increase. The subsequent skeletal related events that can occur with osseous metastasis can be debilitating. Complete and impending pathologic femur fractures are common with patients often requiring operative fixation. However, the efficacy of an intramedullary nail construct, on providing stability, continue to be debated. Therefore, the purpose of this study was to utilize a synthetic femur model to determine 1) how proximal femur defect size and cortical breach impact femur load to failure (strength) and stiffness, and 2) how the utilization of an IMN, in a prophylactic fashion, subsequently alters the overall strength and stiffness of the proximal femur.

Methods: A total of 21 synthetic femur models were divided into four groups: 1) intact (no defect), 2) 2 cm defect, 3) 2.5 cm defect, and 4) 4 cm defect. An IMN was inserted in half of the femur specimens that had a defect present. This procedure was performed using standard antegrade technique. Specimens were mechanically tested in offset torsion. Force-displacement curves were utilized to determine each constructs load to failure and overall torsional stiffness. The ultimate load to failure and construct stiffness of the synthetic femurs with defects were compared to the intact models with no defect and the 2 cm defect group (p=0.98, p=0.43). The 2.5 cm, and 4.5 cm defect groups demonstrated significant difference in both load to failure and overall stiffness when compared to intact models with results demonstrating 1313 N (95% CI: 874-1752 N; p<0.001) and 104 N/mm (95% CI: 98-110 N/mm; p=0.03) in the 2.5 cm defect models, and 512 N (95% CI: 390-634 N, p<0.001) and 21 N/mm (95% CI: 9-33 N/mm, p<0.001) in the models with a 4 cm defect. Compared to the groups with defects, the placement an IMN increased overall stiffness in the 2.5 cm defect group (125 N/mm; 95% CI:114-136 N/mm; p=0.003), but not load to failure (p=0.91). In the 4 cm defect group, there was a significant increase in load to failure (1067 N; 95% CI: 835-1300 N; p=0.002) and overall stiffness (57 N/mm; 95% CI:46-69 N/mm; p=0.001).

Conclusion: Prophylactic IMN fixation significantly improved failure load and overall stiffness in the group with the largest cortical defects, but still demonstrated a failure loads less than 50% of the intact model. This investigation suggests that a cortical breach causes a loss of strength that is not completely restored by intramedullary fixation.

Level of Evidence: II

Keywords: prophylactic intramedullary nail, pathologic fracture, metastases, musculoskeletal oncology

INTRODUCTION

The American Cancer Society estimated that 1,735,350 new cases of cancer would be diagnosed in 2018.1 Approximately, 50% will be one of the various carcinoma subtypes. Carcinoma is the most common cancer to metastasize to bone.2-4 Metastatic disease of bone (MDB) causes skeletal-related events (SRE) including pain, metabolic derangements, and pathologic fractures, requiring extensive and multi-modal healthcare resources.5-8 The most common presenting symptom of MDB is pain and increasing pain can an early indication of impending pathological fractures.7 Diseased bone is weaker than healthy bone and therefore requires less force for a fracture to occur.8
Historically, predictive scoring systems such as the Mirels’ criteria, are most commonly used to assist musculoskeletal oncologists in determining when there is a significant risk of pathologic fracture, and therefore prophylactic internal fixation is warranted. Newer methods, such as CT-based structural rigidity analysis, have proven to be more accurate in terms of sensitivity, specificity, positive predictive value, and negative predictive value. While these measures provide predictably high sensitivity and are helpful to guide surgical decision-making, there continues to be suboptimal specificity that likely results in overtreatment.

The most appropriate fixation method continues to be discussed when addressing both impending and complete pathologic fractures. The choice of reconstruction is ultimately left to the surgeon’s discretion based upon a multitude of clinical factors including histology, location, defect size, bone quality, and estimated overall survival. The femur is the most common location that undergoes MDB that is indicated operative intervention. The primary methods used to surgically correct or prevent pathologic fractures in the femur are intramedullary nailing (IMN) and endoprosthetic reconstruction (EPR). For femoral metastatic fractures, IMN offers many advantages such as reduced invasiveness, sufficient durability, preserved bone stock resulting in additional revision selections, and less cost as compared to EPR. However, more extensive bone destruction or more proximal lesion locations in the femur may test the limits of intramedullary stabilization and therefore patient outcome construct durability may be optimized by completely replacing the compromised bone, making EPR justifiable. However, the size of metastatic lesions that would correlate with risk for fracture as well as the size of the lesion correlated with construct failure is unknown.

The purpose of this study was to determine mechanical data that will guide future studies investigating the role of fracture prediction and fixation choices in MDB. The primary aim was to investigate the effect of the placement of a femoral IMN on failure load and torsional stiffness in femurs with different sized defects. We hypothesized that there would be no difference in decrease in failure load and torsional stiffness with the different sized defects after placement of an IMN.

METHODS

A total of 21 4th Generation composite Sawbone femurs, designed to mimic the properties of human bones (Model #3403, Sawbones Inc. Vashon, WA), were used. These models were randomly assigned into four groups: Group 1: no defect (n=3); Group 2: each model consisting of a 2 cm diameter calcar defect with an incomplete cortical breach (n=6); Group 3: each model consisting of a 2.5 cm diameter calcar defect with a complete cortical breach (n=6); Group 4: each model consisting of a 4 cm diameter calcar defect with a complete cortical breach and substantial cancellous involvement (n=6). The medial calcar region was chosen as it is known to be an area more sensitive to changes in strength as compared to other locations in the proximal femur. An alignment jig was utilized to position the Sawbones and all defects were centered on the same location consisting of the medial aspect of the calcar: 1 cm anterior to and at the level of the lesser trochanter (Fig. 1). The defects were created using a computer numerical control (CNC) mill (TM-1; HAAS Automation, Inc. Oxnard CA) to trace a circular cutting pattern with the specified diameter. The 2.5 cm diameter defect was selected to be similar in size to the 2 cm defect while including a cortical breach without moving the location of the defect.

After the establishment of the defects, half of the models in groups 2, 3, and 4 (n=3/group) had an 11.5 x 360 mm, 130-degree cephalomedullary nail with a 100 mm proximal lag screw and single distal locking screw (Smith and Nephew InterTAN, Watford, UK) placed by a board certified, musculoskeletal oncology fellowship trained orthopedic surgeon (BJM). To standardize the nailing technique among specimens, a series of drill guides made from polymethylmethacrylate (PMMA) molds of specific locations on the Sawbones geometry were secured around the defect during cephalomedullary screw insertion in order to prevent...
worsening of the defect prior to biomechanical testing. A total of 3 replicate models for each of the seven groups (intact, 2 cm, 2 cm with IMN, 2.5 cm, 2.5 cm with IMN, 4 cm, 4 cm with IMN) was prepared for mechanical testing.

The femoral models were mechanically tested in offset torsion. The distal 10 cm of each Sawbone femur was potted in a PMMA block with the axis of the femoral neck in an axial plane parallel to a flat edge of the box. Models were then rigidly clamped with the femoral shaft and femoral neck oriented horizontally, and the femoral head was positioned under the mechanical loading actuator of a servohydraulic mechanical testing machine (MTS Bionix, Eden Prairie, MN). To constrain wholebone bending during testing while leaving medial-lateral and anterior-posterior translations and all rotations at the proximal end free, a cylindrical horizontal support bar located 11 cm distal to the center of the femoral head was raised until it contacted the bone. A PMMA mold of the Sawbones femoral head geometry was mounted to the mechanical loading actuator on an x-y bearing for application of load to the anterior femoral head (Fig. 2). The loading plate was brought into contact with the femoral head using a compressive force of 50 N. Three preconditioning cycles, consisting of application and removal of 2 mm of femoral head displacement were performed with 30 second rests between cycles. Models were then loaded to failure at a displacement rate of 1 mm/s. Force and displacement data were collected simultaneously at 100 Hz.

The mode of failure was qualitatively assessed by documenting the location and direction of fracture propagation. Load of failure and overall torsional stiffness were calculated from the measured force-displacement curves. Failure was defined at the instant of maximum force prior to fracture. Failure was defined as a sudden deviation from the linear load versus the displacement curve. Stiffness was defined as the steepest slope of the linear portion of the force-displacement curve. One-way ANOVA with Tukey’s multiple comparisons were used to evaluate the significance of pairwise differences in failure load and stiffness associated with defect size. Two-way ANOVA with Tukey’s multiple comparisons was used to evaluate differences associated with defect size and the presence/absence of an intramedullary nail. All statistical analysis was performed in GraphPad Prism (v 8.4.3, GraphPad Software LLC, San Diego, CA) with significance defined by multiplicity adjusted p < 0.05.

RESULTS

Intact models (no defect; n=3) failed at an average load of 2701 N (95% CI: 2282-3120 N) with an overall stiffness of 122 N/mm (95% CI: 99-144 N/mm). Models with 2 cm defects, which did not perforate the cortex, demonstrated essentially equivalent loads to failure (2785 N; 95% CI: 2276-3295; p=0.98) and stiffness (112 N/mm; 95% CI: 89-135 N/mm; p=0.43) compared to intact models. The 2.5 cm defect group, which did perforate the cortex, had a load to failure that was 49% of the intact models (1313 N; 95% CI: 874-1752 N; p<0.001). Additionally, the overall stiffness was 85% of the intact models (104 N/mm; 95% CI: 98-110 N/mm; p=0.03). The 4 cm defect group had further reduction in failure load with a load to failure that was 19% of the intact models (512 N; 95% CI: 395-629 N; p=0.002).
N; 95% CI: 390-634 N; p<0.001) and an overall stiffness that was 17% of the intact models (21 N/mm; 95% CI: 9-33 N/mm; p<0.001). (Fig. 3)

Placement of an IMN in the 2 cm defect models did not have a significant increase in the overall failure load (3087 N; 95% CI: 2921-3253; p=0.10) or the overall stiffness when compared to previous non-IMN models (125 N/mm; 95% CI: 122-129; p=0.07). IMN fixation of the 2.5 cm defect models had a significant increase in stiffness (125 N/mm; 95% CI:114-136 N/mm) when compared to the non-IMN models (104 N/mm; 95% CI: 98-110 N/mm; p=0.003). However, there was no difference regarding load to failure between these groups (p=0.91). When compared to the non-IMN 4 cm defect models, placement of an IMN in the 4 cm defect models significantly increased both the load to failure (512 N; 95% CI: 390-634 N vs. 1067 N; 95% CI: 835-1300 N; p=0.002) and the overall stiffness (21 N/mm; 95% CI: 9-33 N/mm vs 57 N/mm; 95% CI:46-69 N/mm; p=0.001). However, despite these increases relative to the non-IMN models, placement of an IMN in the 4 cm models only achieved 40% of the average failure load and 47% of the average overall stiffness of an intact models. (Fig. 4)

**DISCUSSION**

The goal of this work was to investigate the biomechanical relationship between simulated metastatic lesion defects of various sizes, intramedullary fixation, and mechanical failure. Of the three defect sizes tested, only those that perforated the cortex (the 2.5 cm and 4 cm defects) clearly reduced the average failure load and stiffness. IMN fixation increased overall stiffness in the 2.5 cm group, as well as failure load and overall stiffness in the 4 cm defect group. However, failure load in both the IMN stabilized 2.5 cm and 4 cm defect groups remained less than 50% of the intact models. Our data suggest that cortical perforation is a critical event that causes substantial weakening of intact femurs, and fixation with an IMN only partially restores the strength and stiffness.

Lesions located at the calcar of the femur were selected as defects in this location have demonstrated to be more mechanically compromising in comparison to lesions in other locations. Additionally, enlarging lesion size has demonstrated to increase the risk of pathological fracture. The results of this biomechanical study demonstrated similar results with decreased load to failure with increasing lesion size located at the calcar of the proximal femur. We found a variable amount of restoration of strength and stiffness after IMN fixation relative to defect size. For the smallest defect, 2 cm (no cortical defect), the changes in load to failure and stiffness were insignificant compared to an intact bone model, both with and without an IMN. This supports the implication that bones lacking a cortical defect retain nearly equivalent mechanical strength of an intact specimen when exposed to this method of mechanical loading. This finding further poses the question whether lesions without cortical deficits need to be prophylactically stabilized.

The 2.5 cm defect models demonstrated an increase in stiffness after stabilization, but not failure load, and failed with a spiral fracture pattern predominantly by torsion with a smaller component of bending (Fig 5). This mechanism of failure would be expected clinically and provides qualitative assurance in our experimental
design. In the 4 cm defect model, the IMN significantly improved both strength and stiffness. Prophylactic fixation restored strength and stiffness nearly to the level of the 2.5 cm cortical defect, but not to the same level as the intact model. Overall, these findings suggest that strength and stiffness of simulated bone decrease substantially as lesion size and cortical destruction increase. Intramedullary stabilization can restore strength and failure resistance, but this study demonstrated not more than 50% of an intact model. These results do not allow for generalization into clinical treatment of MDB, however they do suggest that the mechanical properties of femurs with large lesions and cortical deficiencies may not be adequately restored with closed intramedullary nailing.

Prior studies have shown strength restoration to a greater extent than ours using simulated metastatic defects with alternate methods of experimental fixation. Kaneko et al. performed a study utilizing human cadavers with a femoral neck inferomedial defect.23 They subsequently filled the defect with bone cement and tested the specimens with single-limb stance-type loading, (rather than offset torsion). They reported at least 85% strength when compared to specimens with no defect. In a study of cadaveric canine femurs with 50% cortical defects, Leggon et al. described the greatest increase in strength came from the utilization of polymethylmethacrylate with a plate and bicortical screws. They demonstrated that this combination retained 56% strength of the intact specimens.24 The 2.5 cm and 4 cm defects in our investigation both demonstrated significant changes after IMN fixation, however the magnitudes differed substantially. The reasons for the limited improvements of strength are unclear, however are likely due to the combination of defect location and mechanical testing. This stresses the IMN construct in the direction of its most substantial deficiency. Specifically, the points of IMN fixation in the bone are limited to screws in the femoral head and distal shaft and does not directly support the defect. Further, our testing in offset torsion exposes the specimens to forces that the IMN is least designed to withstand, as IMN would perform better in axial loading and bending forces. These choices were made specifically to investigate conditions in which IMN fixation may not be mechanically adequate and are at highest risk of failure.

There were several limitations that should be discussed. First, the mechanical tests performed were in a controlled environment established for this work and do not directly translate to clinical practice. Like most biomechanical studies of metastatic lesions, the defects used in this study were created artificially with a regular geometry that by definition cannot replicate the tortuous shapes or encroachment of the lesion into the cortex from the intramedullary space.17,19,20 The Sawbones that we used replicate the mechanical properties of human femurs are designed for use in biomechanical research. This offers an advantage over cadaveric models used in similar experiments in terms of uniformity and reproducibility of the mechanical testing. However, Sawbones lack several potentially important features seen in patients with MDB, namely abnormal bone mineral density secondary to malnutrition or systemic agents and effects of external beam radiation. Another limitation was that defects investigated in this work were created mechanically, which will not fully replicate the often amorphous and asymmetric nature of invasive carcinoma. The offset torsion test was selected for this work to better simulate functional loading of the femur during high demand flexion activity; however, it does not specifically replicate any single physiological activity and does not reflect the only mechanism of fracture. Finally, the number of replicates (n=3) within each experimental group were extremely limited. While this did not facilitate robust statistical analysis, with our standardized procedures for lesion creation and IM nailing, the mechanical response was extremely similar within each group, and the mechanical differences among groups with a cortex perforation were dramatic (Figure 4). Within these limitations, our intent was not to perform an investigation that can directly be applied to clinical practice, but rather to explore the mechanical changes that occur with increasing metastatic lesion size, and the strength that can be recovered under ideal conditions with an intramedullary device.

In conclusion, this study demonstrated that cortical deficiencies, rather than simply lesion size, caused substantial losses in torsional strength. Additionally, IMN fixation did not completely restore the strength and stiffness to that of an intact bone model when loaded in offset torsion. IMN fixation alone does not address cortical breaches that may lead to compromised osseous integrity during activities of daily living that require torsional load of the femur. The clinical significance of incomplete restoration of strength after IMN nailing of proximal femoral defects remains unclear, but it does suggest that additional mechanical investigation to determine a mechanically optimal treatment strategy to definitively manage impending pathologic fractures with large cortical defects in high-stress areas of the proximal femur is warranted. Future investigations should attempt to find a threshold of defect size in which IMN is insufficient to adequately support all activities of daily living for patients with MDB.
REFERENCES
DETECTION OF FERRITIN EXPRESSION IN SOFT TISSUE SARCOMAS WITH MRI: POTENTIAL IMPLICATIONS FOR IRON METABOLIC THERAPY

Michael S. Petronek, MS; Ann M. Tomanek-Chalkley, BS; Varun Monga, MBBS; Mohammed M. Milhem, MBBS; Benjamin J. Miller, MD, MS; Vincent A. Magnotta, PhD; Bryan G. Allen, MD, PhD

ABSTRACT

Background: Cancer cells often have altered iron metabolism relative to non-malignant cells with increased transferrin receptor and ferritin expression. Targeting iron regulatory proteins as part of a cancer therapy regimen is currently being investigated in various malignancies. Anti-cancer therapies that exploit the differences in iron metabolism between malignant and non-malignant cells (e.g. pharmacological ascorbate and iron chelation therapy) have shown promise in various cancers, including glioblastoma, lung, and pancreas cancers. Non-invasive techniques that probe tissue iron metabolism may provide valuable information for the personalization of iron-based cancer therapies. T2* mapping is a clinically available MRI technique that assesses tissue iron content in the heart and liver. We aimed to investigate the capacity of T2* mapping to detect iron stores in soft tissue sarcomas (STS).

Methods: In this study, we evaluated T2* relaxation times ex vivo in five STS samples from subjects enrolled on a phase Ib/IIa clinical trial combining pharmacological ascorbate with neoadjuvant radiation therapy. Iron protein expression levels (ferritin, transferrin receptor, iron response protein 2) were evaluated by Western blot analysis. Bioinformatic data relating clinical outcomes in STS patients and iron protein expression levels were evaluated using the KMplotter database.

Results: There was a high level of inter-subject variability in the expression of iron protein and T2* relaxation times. We identified that T2* relaxation time is capable of accurately detecting ferritin-heavy chain expression (r = -0.96) in these samples. Bioinformatic data acquired from the KMplotter database revealed that transferrin receptor and iron-responsive protein 2 may be negative prognostic markers while ferritin expression may be a positive prognostic marker in the management of STS.

Conclusion: These data suggest that targeting iron regulatory proteins may provide a therapeutic approach to enhance STS management. Additionally, T2* mapping has the potential to be used a clinically accessible, non-invasive marker of STS iron regulatory protein expression and influence cancer therapy decisions that warrants further investigation.

Level of Evidence: IV

Keywords: T2* mapping, iron metabolism, soft tissue sarcoma

INTRODUCTION

Alterations in iron (Fe) metabolism between tumor and non-malignant tissue are a promising therapeutic target in cancer therapy. In gliomas, there is an association between tumor grade and transferrin receptor (TIR) and ferritin (Ft) expression. Both transferrin receptor (TIR) and ferritin (Ft) expression corresponded with decreased overall survival and progression free survival in glioblastoma tumors. TIR expression is an adverse prognostic indicator for breast cancer progression with a hazard ratio of 3.54. These reports support the theory that tumors have enhanced Fe availability to support their proliferative demands and maintain clonogenicity during disease progression. Thus, targeting the altered iron metabolic state in tumors (e.g. iron chelation therapy and pharmacological ascorbate) may significantly enhance
Fe chelation therapy using both deferoxamine and deferasirox kills cancer cells by binding Fe and preventing its utilization in cellular processes.7–12 Deferoxamine has shown promise in enhancing standard chemotherapy (e.g. carboplatin) in patients with advanced neuroblastoma.13 An alternative therapeutic approach is the chemical enrichment of redox-active Fe pools using pharmacological (high dose, intravenous) ascorbate. Ascorbate is a one electron reducing agent that can actively reduce and release Fe from proteins (e.g. aconitase) to increase the redox-active Fe content inside cells.14 Both non-small cell lung cancer and glioblastoma tumors have increased redox-active Fe relative to their adjacent non-malignant tissues which contributes to the tumor selective pharmacological ascorbate toxicity.14 Pre-clinical STS models demonstrate that pharmacological ascorbate increases the redox-active Fe fraction to enhance radiosensitivity and chemosensitivity to gemcitabine.15 These data suggest that Fe metabolism may also be an efficient therapeutic strategy to enhance the clinical management of STS. Currently, little is known regarding the Fe metabolic status of STS and its impact on patient outcomes. Thus, a better understanding and prediction of the Fe metabolic network in STS may provide an opportunity for improved clinical outcomes and allow for a more personalized treatment approach.

Magnetic resonance imaging (MRI) provides a rapidly translatable and non-invasive method of personalizing cancer therapy. T2* mapping is an Fe-sensitive MRI technique used to assess tissue Fe overload in the liver, heart, and brain.16–19 T2* mapping was shown to have prognostic potential in a small cohort of glioblastoma patients treated with pharmacological ascorbate.20 T2* relaxation times are sensitive to the paramagnetic properties of the tissue being measured and can thus detect changes in Fe oxidation state (ferric vs. ferrous Fe).10,20 Therefore, T2* mapping may provide a rapidly translatable approach for evaluating STS Fe metabolism non-invasively. The present study acquired tissue samples from five STS subjects enrolled on a phase Ib/II clinical trial (NCT03508726) combining pharmacological ascorbate (75 g infused three times per week) with concurrent fractionated radiation therapy (50 Gy in 25 fractions). This was followed by standard of care surgical resection of the primary tumor approximately four weeks after completion of radiation therapy (IRB# 201901810). A portion of the removed sarcoma tumor was collected and flash frozen immediately following surgical resection for analysis. Tumors were thawed on ice and MR imaged to acquire T2* maps immediately before further sample processing. STS tissue was then homogenized using mortar and pestle in RIPA buffer (Sigma-Aldrich; St. Louis, MO) containing protease inhibitor and spun down at maximum speed for 10 min to remove cell debris. Protein levels were quantified by the Lowry method.21

MRI parameters

T2* weighted images were collected using a gradient echo sequence (TR = 10 ms; TEs = 2.2, 8.2, 14.2, and 20.2 ms; Field of View= 2.0x2.0cm, matrix=256x256, signal averages = 2) on a 7T GE small animal scanner, a part of the Small Animal Imaging Core at the University of Iowa. T2* maps were generated by fitting each voxel to a mono-exponential curve across the four echoes acquired using an in-house python code. Images were imported to Slicer3D software where regions of interest (ROIs) were delineated and mean T2* values were calculated using the label statistics tool within Slicer3D.

Western blotting

Total protein (25μg) was electrophoresed on a 4–20% gradient gel (Bio-Rad) at 150 V for approximately 1.5 h. The separated proteins were transferred onto PVDF membranes (Millipore, Billerica, CA) and non-specific binding was blocked using 5% nonfat dry milk in PBS-Tween (0.2%) for 1 hr at room temperature. The membranes were incubated with primary antibodies (ferritin-heavy chain, 1:1000, iron responsive protein 2 1:1000, both antibodies from Abcam, Cambridge, MA, Transferrin receptor, 1:1000, Invitrogen, Camarillo, CA) at 4°C for 12 hours. Glyceraldehyde 3-phosphate dehydrogenase (GAPDH) served as a loading control (1:4,000; Sigma-Aldrich). Following three 5 min PBS-Tween washes, the membranes were probed with secondary antibodies (mouse anti-rabbit; 1:25,000; Sigma-Aldrich, St. Louis, MO) that were conjugated with horseradish peroxidase for 1 h. The washed membranes were incubated with Super Signal West Pico Chemiluminescent Substrate (Thermo Scientific, Rockford, IL) and exposed to CareStream BioMax MR Film (CareStream Health,
RESULTS

**T₂** relaxation times are variable across sarcoma subtypes

We imaged the resected STS tumors using a multi-echo gradient-echo MR sequence to generate quantitative T₂* maps (Figure 1A). We found that the tumor relaxation times across the five subjects were highly variable, ranging from 10.3 to 46.2 ms (Figure 1B). The following subjects had associated STS subtypes and T₂* relaxation times: 1. undifferentiated pleomorphic sarcoma = 29.3 ms, 2. extraskeletal osteosarcoma = 46.2 ms, 3. dedifferentiated liposarcoma = 10.3 ms, 4. myxoid liposarcoma = 16.2 ms, and 5. solitary fibrous tumor = 17.2 ms. Because T₂* relaxation times are predictive of tissue Fe content, these initial results suggest that sarcoma Fe content is also highly variable across STS subtypes.

**Fe metabolic parameters in STS tumors have high inter-subject variability**

Because T₂* relaxation is an accepted marker of Fe content, we examined the expression of STS Fe regulatory protein expression. TfR and FtH expression showed a high level of variability across the different STS subtypes (Figure 2A-C). Undifferentiated pleomorphic sarcoma and myxoid liposarcoma exhibited the highest levels of TfR expression, while dedifferentiated liposarcoma, myxoid liposarcoma, and solitary fibrous tumors had the greatest FtH expression. Interestingly, extraskeletal osteosarcoma had minimal TfR and no detectable FtH expression.

Both TfR and FtH are regulated by post-transcriptional modifications to their mRNA via iron response proteins 1 and 2 (IRP1 and IRP2). IRP1 and 2 respond to intracellular Fe levels to either stabilize or promote the degradation of TfR and FtH mRNAs. Under conditions of low Fe, IRP1 and 2 can bind to iron response elements (IREs) at the 3’ end of TfR mRNA to stabilize and promote translation. Meanwhile, IRP1 and 2 can bind at the 5’ end of FtH mRNA to repress translation. Alternatively, under conditions of increasing intracellular Fe, IRP1 and 2 will be released from the IREs leading to TfR mRNA degradation and activation of FtH translation. IRP2 itself is regulated via proteasomal degradation under Fe-replete conditions. Thus, IRP2 expression is directly related to its function. We found STS IRP2 expression to be detectable in pleomorphic sarcoma, extraskeletal osteosarcoma, dedifferentiated liposarcoma, and solitary fibrous tumor. IRP2 was not detectable in the myxoid liposarcoma sample (Figure 2D-E).

**T₂** relaxation times are inversely correlated with FtH expression

We assessed for correlation between the expression of Fe regulatory proteins and T₂* relaxation time using...
Pearson’s correlation coefficient (r) (Figure 3). Using this approach, we observed no correlation between T2* relaxation time and TfR expression (r = -0.02). There were mild, inverse correlations between FtH and IRP2 (r = -0.29) and TfR (r = -0.2). Moderate correlations (>0.4) were observed between IRP2 and TfR (r = -0.45), and T2* (r = 0.43). A significant correlation was observed between FtH expression and T2* relaxation time (r = -0.95, p < 0.05).

Expression of Fe metabolic enzymes are associated with differential outcomes in STS

Because we observed a significant correlation between T2* relaxation time and FtH expression, we evaluated the potential clinical relevance of these findings in the context of STS response. Using the KMplot database, we found that FtH gene expression in sarcoma subject tissue (n = 259) was a positive prognostic marker for patient overall survival with a hazard ratio (HR) of 0.57 (p = 0.0096; 95% CI = 0.37-0.88; Figure 4A). Subjects with high FtH expression (n = 107) have a median overall survival of 89.8 months compared to the low expression cohort (n = 152) who have a median overall survival of 57.4 months. Therefore, early, accurate, and non-invasive detection of FtH expression in sarcoma tumors with T2* mapping may have significant prognostic potential.

While T2* mapping failed to adequately correlate with TfR, or IRP2 expression, we evaluated their outcomes
because they may provide novel information into the clinical relevance of Fe metabolic perturbations in the management of STS. We found that TfR has a HR of 1.62 (p = 0.018; 95% CI = 1.08-2.43; Figure 4B) and IRP2 has a HR of 1.5 (p = 0.045; 95% CI = 1.01 – 2.24; Figure 4C) and thus can be thought of as negative prognostic markers of STS survival. Subjects with a high TfR expression profile (n = 135) have a median overall survival of 85.8 months compared to 55 months for those with low expression (n = 124). Similarly, subjects with high IRP2 expression (n = 120) show a median overall survival of 85.8 months compared to 61.5 months for the low expression cohort (n = 139).

**DISCUSSION**

The biological implication of intratumoral FtH and TfR expression in STS remains largely unknown. In osteosarcoma, TfR overexpression is observed in 43% of patients and is positively correlated with histologic grade, Enneking stage, distant metastasis, and shorter overall survival.33 This is consistent with other cancer types that tend to be more aggressive with increased TfR expression. In breast cancer, tumors with high TfR expression have significantly worse distant metastasis-free survival (HR = 3.54).2 Interestingly, this analysis showed that two of the three tumors with high FtH expression were liposarcomas. These data suggest that iron storage may be particularly relevant in these adipose-containing STS subtypes. This may not be surprising as increased serum ferritin levels have been reported to be associated with increased body fat.34-36 Additionally, a 2007 case report described an individual (82 year old male) with an abdominal myxoid liposarcoma who presented with hyperferritinemia (serum ferritin = 1542 ng mL-1).37 Ferritin can be secreted from tissue into circulation via a non-classical, multivesicular body-exosome pathway.38 Coalescing these ideas would support a hypothesis that high intratumoral ferritin expression would correlate with the hyperferritinemia frequently observed in cancer patients.39-42 However, there remains limited data regarding intracellular and/or circulating ferritin and its impact on STS which may warrant closer consideration.
in future studies.

Our bioinformatic approach suggests that FtH may serve as a positive prognostic marker (HR = 0.57) and that Fe availability may play a role in sarcoma progression. Additionally, IRP2 appears to be a negative prognostic marker (HR = 1.5). In a lung cancer model system, tumor growth was significantly enhanced by IRP2 expression. IRP2 expressing tumors exhibited increased c-Myc levels along with enhanced ERK1/2 phosphorylation. Biochemically, this supports the hypothesis that constitutive IRP2 activation gives rise to a preferential Fe accumulation phenotype culminating in more aggressive STS as IRP2 undergoes proteasomal degradation under Fe-replete conditions.

The high level of variability between different STS underscores the overwhelming complexity of the Fe regulatory network and the necessity of developing markers to personalize Fe metabolic therapies. For example, either IRP1 or 2 can regulate FtH and TIR protein expression independent of one another. While many consider the IRP-IRE system to be the primary regulatory mechanism of several Fe metabolic enzymes (e.g. FtH and TIR), the complexity increases because FtH and TIR expression can be regulated at the transcriptional level as well. FtH can be regulated by Nrf2 as its promoter region contains an antioxidant/xenobiotic response element. Similarly, TIR expression can be transcriptionally regulated by HIF1α, as its promoter region contains a hypoxia response element.

A significant limitation of this study is that every subject was treated with pharmacological ascorbate which can perturb the Fe metabolic system in STS. However, the impact of ascorbate on the expression of these proteins remains unclear. Additionally, the wide variety of STS subtypes evaluated limits our ability to differentiate subtypes based on Fe metabolic signatures. However, this type of information would be invaluable in the design of Fe metabolic therapies for STS.

Because we observed a significant inverse correlation between $T_2^*$ relaxation times and FtH expression, it suggests that $T_2^*$ mapping has the potential to detect FtH expression in vivo. The ability of $T_2^*$ relaxation to detect FtH expression is not uncommon. Considering the physics of $T_2^*$ relaxation where relaxation times are much shorter in regions of interest with highly paramagnetic material, the detection of FtH fits this model because it is the most paramagnetic material within a cell as it contains up to 4500 Fe3+ atoms when completely saturated. It was previously reported in brain tissue that grey matter with higher FtH expression levels have significantly lower $T_2^*$-relaxation times and has been proposed that FtH is a primary driver of Fe-dependent changes in $T_2^*$-relaxation. Therefore, despite the small sample size, these data suggest that $T_2^*$ relaxation may be a novel tool for the early detection of FtH expression in STS and warrants further investigation into the prediction of treatment response.

CONCLUSION

We have observed that $T_2^*$ mapping accurately reflects FtH expression in STS tissues and thus, may serve as a marker of its differential expression pattern in the management of STS. Additionally, we have observed high levels of STS tumor variability in critical Fe regulatory proteins. Our bioinformatic data suggests that protein expression patterns supporting increased tumor Fe uptake and availability are correlated with STS progression. Therapeutic approaches targeting Fe regulatory proteins in STS warrant further investigation and $T_2^*$ mapping may be a novel, non-invasive prognostic marker to facilitate treatment decisions.

ACKNOWLEDGEMENT

This research was funded by NIH grants P01 CA217797, T32 CA078586, the Gateway for Cancer Research Grant G-17-1500, and the University of Iowa Sarcoma MOG. Acknowledgements to the University of Iowa Department of Radiation Oncology, University of Iowa Department of Orthopedics, and the Carver College of Medicine. The content is solely the responsibility of the authors and does not represent views of the National Institutes of Health.

REFERENCES


ABSTRACT

Background: Pigmented villonodular synovitis (PVNS) and synovial chondromatosis (SC) of the hip are rare synovial diseases that can induce joint destruction without early diagnosis and treatment. The extent of surgical excision is critical given the high rates of recurrence. In the presented case, a 19-year-old female was referred to our institution with progressive left hip pain and radiologic evidence of an intra-articular mass that was consistent with PVNS versus SC. Her medical history was notable for a prior excision of a fibrous lesion at an outside hospital at age 13 with persistent pain. The patient underwent a surgical hip dislocation approach to obtain near-complete visualization of the femoroacetabular joint, ensuring complete evaluation and excision. The tumor was intraoperatively diagnosed as SC and excised accordingly, during an uneventful operation. Pathology confirmed the diagnosis. The essential diagnostic and surgical steps for the management of this pelvic tumor diagnostic dilemma are described.

Level of Evidence: V

Keywords: synovial chondromatosis, pigmented villonodular synovitis, surgical hip dislocation, diagnostic dilemma, pelvic tumor

INTRODUCTION

Pigmented villonodular synovitis (PVNS) and synovial chondromatosis (SC) of the hip are two rare and benign synovial diseases that can progress to joint destruction without early diagnosis and treatment. Treatment consists of open versus arthroscopic synovectomy with loose body removal. PVNS typically requires a more aggressive excision due to its higher rate of recurrence, which can be up to 55% following surgical excision.

This case report aims to discuss the diagnostic dilemma and surgical implications of a recurrent intra-articular tumor of the hip that required a surgical hip dislocation to obtain near-complete visualization of the femoroacetabular joint and permit oncologic resection with negative margins.

Case Report

A 19-year-old woman presented with gradually worsening left hip pain and restricted range of motion since age 13. At age 15, she underwent needle biopsy and hip arthroscopic synovectomy with mini-open excision of an intra-articular mass at an outside hospital. Pathology was consistent with a fibrous lesion, without evidence of PVNS or SC. Following surgery, her pain and stiffness persisted and progressively worsened to the point that she could no longer run or sit for prolonged periods of time despite physical therapy and NSAIDs. She was otherwise healthy, with an unremarkable rheumatologic workup.

The patient was subsequently referred to our institution. Radiographs and magnetic resonance imaging (MRI) of her left hip demonstrated a partially calcified mass in the inferior aspect of the hip near the neck and calcar region associated with mild erosive changes to the femoral neck. The mass appeared to be composed of calcified foci with associated dense tissue. Surgery was indicated due to worsening function and bony erosion concerning for an impending pathologic fracture. Given the lack of “classic” imaging findings of SC or PVNS, the recurrence of disease, and the concern for rapid chondral and bony erosion if subsequent surgeries were required, a surgical hip dislocation approach was recommended to ensure complete visualization and removal of the tumor.

A surgical hip dislocation approach was performed as described by Ganz et al. Following dislocation, a lesion that appeared osseous and cartilaginous in nature was identified at the inferior aspect of the hip near the neck and calcar region associated with mild erosive changes to the femoral neck. The lesion scalloped into the inferior femoral neck, with clear evidence of cortical erosion. The tumor and surrounding periosteum were sharply excised with a scalpel. Meticulous curettage of the tumor site ensured the removal of residual tumor. The tumor along with the surrounding synovium was sent for pathology. The patient was admit-
Pathologic examination showed coalescent rounded osteochondromatous structures with a central core of lamellar bone and a surface osteochondroma-like cartilaginous cap, confirming the diagnosis of synovial osteochondromatosis.

Eight months post excision, the patient complained only of mild groin pain with prolonged standing but was otherwise asymptomatic. She has no radiographic evidence of recurrence.

**DISCUSSION**

SC and PVNS rarely occur in the hip, but can lead to devastating functional complications. Both are characterized by persistent hip pain, swelling, and limited motion that can progress to joint destruction without early diagnosis and surgical excision. SC is thought to be caused by the formation of small intra-articular cartilaginous nodules that can detach from the synovial lining, ossify, and gradually degrade articular cartilage. In contrast, PVNS is an aggressive subtype of a tenosynovial giant cell tumor that penetrates bone and cartilage, resulting in diffuse joint destruction. The highest reported rate of recurrence for SC following surgical excision is 16.1%, while PVNS recurs in up to 55% of cases. A single case of concurrent SC and PVNS in the hip has been reported.

Achieving a diagnosis is critical, particularly in the setting of non-diagnostic imaging. This patient’s primary mass was pathologically not a tumor during index surgery, yet it recurred, and did so in a manner that was inconsistent with the classic radiographic findings of SC or PVNS. While the majority of intra-articular pathology is benign and erosive changes are not specific to malignancy, recurrent tumors—particularly within the developing patient—must be considered malignant until proven otherwise. The hip joint is no exception to this tenet. Asiri et al. report a case of a synovial sarcoma in a 17-year-old masquerading as a solitary intra-articular mass. While observation with short-term follow-up imaging may be considered in the asymptomatic patient, this option was not available to us in the present case because the patient’s tumor had eroded into her femoral neck. Surgery was therefore necessary; however, surgical approach merited careful consideration.

Our service chose to perform a surgical hip dislocation given the skillsets of the involved surgeons, recurrence after the primary procedure through a less extensile approach, and our preference to inspect the entire hip joint. However, no prior work to our knowledge has definitively shown that a hip dislocation yields superior visualization or oncologic quality to an arthroscopic approach. Arthroscopic excision of hip tumors is well documented, with a small case series demonstrating good functional recovery and minimal recurrences. However, no works have compared the outcomes of intra-articular hip tumors excised via open versus arthroscopic access. We suspect that the reason...
for this is the relative rarity of intra-articular hip pathology and the inconsistent availability of either technique. We therefore can justify our decision-making only based on the experience of the involved surgeons.

Obtaining a tissue diagnosis in the present case can also inform the need for long term surveillance and adjuvant therapies. Should this patient have had PVNS, we would have considered an adjunctive therapy given the recurrence of this tumor and the sensitive nature of the involved anatomy. Therapeutic options include adjuvant radiotherapy and monoclonal antibody and/or tyrosine kinase inhibitor therapy, all of which have been shown to reduce the high risk of tumor recurrence.6-8

In conclusion, we report the effective use of open surgical hip dislocation in the treatment of a recurrent intra-articular mass in a developing patient. If available, this technique should be considered a part of the orthopaedic oncologist’s armamentarium when dealing these challenging pathologies.

REFERENCES
THE EFFECTS OF FACE MASKS ON THE DOCTOR-PATIENT RELATIONSHIP IN ORTHOPAEDICS

Shivani Pandya, BS1; Anil B. Sedani, MD1,2; Alina Syros, MPH1; Ramakanth R. Yakkanti, MD1,2
Seth D. Dodds, MD1,2; Amiethab A. Aiyer, MD3

ABSTRACT

Background: Since the onset of the COVID-19 pandemic, the widespread use of face masks has grown exponentially. There is limited data highlighting the patient perception of face mask use during this pandemic, specifically in orthopaedic clinics. The purpose of this study was to determine the patient’s perception of the implementation of face masks in the orthopaedic clinic during a period of mask mandates and if this change impacted the success of their interactions with physicians. The secondary aim includes measures of patient satisfaction such as the ability to understand conversation and communicate effectively with the physician.

Methods: Participants were recruited on the day of their appointment at our institution’s orthopaedic clinic and provided with instructions via email. The online, anonymous survey included the CARE questionnaire - a tool to examine patient satisfaction by assessing perception of empathy and was conducted using Qualtrics.

Results: Does patient preference to have their physician wear a face mask impact the success of their interactions with physicians? Overall, the use of face masks by physicians did not negatively impact patient encounters. CARE scores for patients who preferred masks (37.2) were similar to those who preferred their physician did not wear a mask (37.5). Is patient satisfaction affected by the use of face masks in the orthopaedic clinic? Patients who preferred that their doctor wear a face mask stated that it had no negative impact on the effect of communication or conversation with the physician. Other factors such as how well the patients knew the physician and patient gender had a greater impact on the CARE score than masks did.

Conclusion: Our study determined that the preference of face masks by patients does not impact the success of their interactions with physicians using the CARE score. The findings of this study are valuable in informing orthopaedic physicians about patient attitudes towards mask use and could influence decision making for not only the COVID-19 pandemic, but also future infectious outbreaks that may arise.

Level of Evidence: III

Keywords: patient perception, COVID-19, face masks

INTRODUCTION

Since the onset of the Coronavirus (COVID-19) pandemic, the widespread use of facemasks has grown exponentially across the globe. Along with this abrupt change, came significant debate on the efficacy of face masks. The face mask discourse revealed, amongst many things, the discrepancies in the general public’s trust in healthcare and skepticism of adhering to medical advice. While the intention of its use was to reduce the spread of respiratory transmission, the impact of personal protective equipment (PPE) including face masks by physicians in the context of the current pandemic is a multifaceted discussion that has yet to be fully examined.

Recent literature supports that physician use of face masks has a significant impact on the verbal and nonverbal communication between the doctor and patient. In a 2013 study conducted in Hong Kong primary care clinics, a survey using the Consultation and Relational Empathy (CARE) measure revealed that when doctors wear masks during visits, patients perceive diminished empathy, which negatively affects the therapeutic relationship between patient and provider.1 The doctor-patient relationship is an essential cornerstone in healthcare that is built on trust and compassion and remains one of the most important factors in the long-term outcome of a patient’s health. Incorporation of PPE into this equation must be analyzed to ensure that the doctor-patient relationship is uncompromised and respected by both parties. Furthermore, a 2019 study interviewing patients to determine their understanding of the purpose of face masks.
masks revealed that patient acceptance was higher when he/she understood the importance of reducing disease transmission, and it highlighted patient complaints such as the reduced ability to hear doctors who wear masks. The behavioral inconveniences of face masks have been extensively reported including the discomfort with wearing them, the impediment to verbal communication (unclear conversation, quieter sound etc.), and the lack of important nonverbal cues such as facial expressions. A 2016 study during the peak season of Influenza in Hong Kong explored the sociocultural meanings of masks pre and post SARS outbreak. It was determined that the experiences of patients with providers who wore masks was critical in shaping patient attitudes toward the use of masks in the clinic during and after an infectious disease outbreak. Overall, there is limited data highlighting the patient perception of facemask use during the current pandemic, specifically in orthopaedic clinics.

We sought to ascertain patient attitudes towards the use of face masks and personal protective equipment (PPE) by orthopaedic surgeons in the clinic to help physicians balance reducing disease transmission and communicating with patients during the COVID-19 pandemic. The purpose of this study was to determine the patient’s perception of the implementation of face masks in the orthopaedic clinic during a period of mask mandates and if this change impacted the success of their interactions with physicians. The secondary aim includes measures of patient satisfaction such as the ability to understand conversation and communicate effectively with the physician. This information in the context of COVID-19 could provide a deeper understanding of how an orthopaedic surgeon’s use of facemasks affects the trust, empathy and communication needed to facilitate a successful patient encounter.

METHODS

Study Population

Participants were recruited from November 2020 – January 2021 on the day of their in-person appointment at our institution’s orthopaedic clinic. Participants were from an urban population. To be eligible for inclusion, patients had to have a current scheduled appointment with one of our orthopaedics physicians and be older than 18 years of age. Patients who met these inclusion criteria were sent a survey via email in December 2020 and again in January and February 2021. Patients were provided with instructions for the survey after their visit by a member of the research team and were given the opportunity to opt out of the survey if they no longer wanted to participate. Patients were excluded from study participation if they belonged to vulnerable populations such as minors, the cognitively incapacitated, and/or prisoners. This project was granted an exemption by the Institutional Review Board at our institution, as no identifiers or personal information were collected. The IRB determined that this study meets the criteria for exemption based on Federal Regulation 45 CFR 46.104.

Survey Design

The online survey (Table I) was composed of questions about demographics, the CARE questionnaire, measures of verbal/nonverbal communication and the general acceptance of masks. The surveys were conducted using the validated questionnaire tool Qualtrics (Provo, Utah), and responses were anonymous. The survey was designed to require only 2-5 minutes to complete. Participants assessed their doctor’s patient-related empathy using the CARE Measure, a tool developed in Glasgow and Edinburgh University that has successfully been used by healthcare professionals to assess empathy in the context of the doctor-patient relationship. Our specific survey consists of 10 questions ranking the patient’s perceived experience from 1 “poor” to 4 “excellent”. Each participant’s individual CARE score was calculated by taking the average of the 10 questions’ scores for a maximum score of 40. This method of calculating CARE scores has been used in multiple studies to assess patient satisfaction of perceived empathy and shown to be a valid and reliable measure.

Statistical Analysis

We conducted analyses of the characteristics of patients in the doctor-wearing (Mask) and non-mask wearing (No Mask) clinical consultations (Q18). The survey was emailed to 658 patients over the three-month timeline. 211 (32%) of patients consented to participate in the study. Of the 211 participants who submitted the electronic survey, 178 (84%) completed all the questions. Participants who did not complete all questions were excluded.

The primary outcome in this study was the CARE score, which measures the patient-related experience. The total CARE score for mask vs. no mask was calculated as the average score for each cohort. The results of the CARE score were then analyzed by question and significant patient characteristics.

All analyses were performed using Qualtrics Stats IQ and all statistical tests were performed using a significance level of 0.05. The patient characteristics included age, gender, education, familiarity with the doctor, and duration of consultation. Furthermore, three Chi-square tests were run to analyze patient satisfaction vs. perceived mask efficacy, perceived mask efficacy vs. preference for physician to wear masks/PPE and patient’s preference for physician to wear masks/PPE vs. patients’ comfort in asking for clarification/repetition. All three
### Table I. Patient Survey

<table>
<thead>
<tr>
<th>DEMOGRAPHICS</th>
<th>CARES QUESTIONNAIRE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AGE</strong></td>
<td><strong>How good was your physician at:</strong></td>
</tr>
<tr>
<td>18-20</td>
<td>Poor</td>
</tr>
<tr>
<td>20-30</td>
<td></td>
</tr>
<tr>
<td>30-40</td>
<td></td>
</tr>
<tr>
<td>40-50</td>
<td></td>
</tr>
<tr>
<td>50-60</td>
<td></td>
</tr>
<tr>
<td>60-70</td>
<td></td>
</tr>
<tr>
<td>70+</td>
<td></td>
</tr>
<tr>
<td><strong>GENDER</strong></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
</tr>
<tr>
<td><strong>EDUCATION</strong></td>
<td></td>
</tr>
<tr>
<td>Some High School</td>
<td></td>
</tr>
<tr>
<td>High School</td>
<td></td>
</tr>
<tr>
<td>Bachelor’s Degree</td>
<td></td>
</tr>
<tr>
<td>Master’s Degree</td>
<td></td>
</tr>
<tr>
<td>Ph.D. or Higher</td>
<td></td>
</tr>
<tr>
<td>Trade School</td>
<td></td>
</tr>
<tr>
<td>Prefer Not to Say</td>
<td></td>
</tr>
<tr>
<td><strong>GENERAL HEALTH OVER THE LAST FEW MONTHS:</strong></td>
<td></td>
</tr>
<tr>
<td>Very Bad</td>
<td></td>
</tr>
<tr>
<td>Bad</td>
<td></td>
</tr>
<tr>
<td>Fair</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Very Good</td>
<td></td>
</tr>
<tr>
<td><strong>HOW WELL DO YOU KNOW THE PHYSICIAN SAW YOU TODAY?</strong></td>
<td></td>
</tr>
<tr>
<td>Not Well</td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td></td>
</tr>
<tr>
<td>Well</td>
<td></td>
</tr>
<tr>
<td>Very Well</td>
<td></td>
</tr>
<tr>
<td><strong>NATURE OF THE PROBLEM:</strong></td>
<td></td>
</tr>
<tr>
<td>New (acute)</td>
<td></td>
</tr>
<tr>
<td>Old, ongoing (chronic)</td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
</tr>
<tr>
<td><strong>DURATION OF CONSULTATION:</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;15 minutes</td>
<td></td>
</tr>
<tr>
<td>15-30 minutes</td>
<td></td>
</tr>
<tr>
<td>30-45 minutes</td>
<td></td>
</tr>
<tr>
<td>45 minutes – 1 hour</td>
<td></td>
</tr>
<tr>
<td>&gt; 1 hour</td>
<td></td>
</tr>
</tbody>
</table>

1. Making you feel at ease (introducing him/herself, explaining his/her position, being friendly and warm towards you, treating you with respect; not cold or abrupt)

2. Letting you tell your “story” (giving you time to fully describe your condition in your own words; not interrupting, rushing, or diverting you)

3. Really listening (paying close attention to what you were saying, not looking at the notes or computer as you were talking)

4. Being interested in you as a whole person (asking/knowing relevant details about your life, your situation; not treating you as “just a number”)

5. Fully understanding your concerns (communicating that he/she had accurately understood your concerns and anxieties; not overlooking or dismissing anything)

6. Showing care and compassion (seeming genuinely concerned, connecting with you on a human level; not being indifferent or “detached”)

7. Being positive (having a positive approach and a positive attitude; being honest but not negative about your problems)

8. Explaining things clearly (fully answering your questions; explaining clearly, giving you adequate information; not being vague)

9. Helping you to take control (exploring with you what you can do to improve your health yourself; encouraging rather than “lecturing” you)

10. Making a plan of action with you (discussing the options, involving you in decisions as much as you want to be involved; not ignoring your views)

Comments: If you would like to add further comments on this consultation, please do so here.

### VERBAL & NONVERBAL COMMUNICATION

Do you believe that the use of facemasks and protective personal equipment has negatively affected your ability to understand your physician’s conversation?

- Greatly
- Moderately
- Not at all

If so, how?

- I am unable to hear the conversation properly
- I am unable to see my physician’s face and expressions
- I cannot understand my physician’s body language

Other: ____________
tests were statistically significant and were followed up with a Fisher’s exact test due to the small, expected cell counts. Ranked ANOVA tests were used to compare the average CARE score to each variable.

**RESULTS**

Descriptive statistics were produced for the entire sample of 178 patients. Of the 178 patients in our analysis, a majority (157/178, 88.2%) preferred that their physician wear a mask and PPE while only 11.8% (21/178) preferred no mask and PPE to be worn in the clinic (Table II). The categorical variables of education level, gender, and how well the patient knew the doctor are summarized in Table III with frequencies and percentages. Age and duration of visit are summarized in Table IV, which displays the sample size and percent for each variable. The mean CARE score for all patients (n=178) was 37.24, (standard deviation 4.79) with a minimum score of 16 and maximum score of 40 (Table V).

**Preference of Masks/PPE (Q18)**

The average CARE Score of participants who preferred their physicians to wear masks/PPE was 37.2, while the average CARE Score of participants who preferred their physicians to not wear masks/PPE was 37. There was not a statistically significant relationship between average CARE score and preference for physicians to wear a mask/PPE (p=0.692, Cohen’s F-statistic = 0.0569).
Belief in Reduction of Transmission of COVID-19 (Q19)

The average CARE Score of participants who think masks reduce transmission was 37.1, while the average CARE Score of participants who think masks do not reduce transmission was 37.3. There was not a statistically significant relationship between average CARE score and belief that wearing masks helps reduce the transmission of COVID-19 (p=0.969, Cohen’s F-statistic=0.0953).

In both analyses of the CARE measure, the groups who prefer the doctor not wear a mask and do not think masks help reduce transmission of COVID-19 had higher CARE scores.

How well patient knew the doctor (Q9)

Higher CARE scores were seen in patients who knew their physician better. (Table VI). (p<0.00001, Cohen’s F-statistic=0.436).

Gender

A chi-squared test was run between gender of the patient and average CARE Score. According to the CARE score measure, male patients felt significantly more at ease with their physician in comparison to female patients (p=0.00358). The male total score for feeling at ease was “excellent” (5 points) in comparison to the female score, which was distributed between “fair”, “very good” and “excellent” for a lower overall score on question 1 of the CARE measure. Overall, the average CARE score for men was 38.4 (CI 37.6-39.1) and for women it was 36.5 (CI 35.5-37.5) (Table VII). The difference in CARE scores between men and women was statistically significant (p=0.00358).

There was not a statistically significant relationship between age, education level, and duration of visit and average CARE score.

Patient Satisfaction Analysis

The majority of patients who believe masks are essential in preventing the spread of COVID-19 reported that the physician wearing a mask had no negative impact on their patient visit (n=129). In comparison, patients who do not believe masks are essential in preventing the spread of COVID-19 reported that the physician wearing a mask moderately impacted their visit (n=4). (p=0.000643)

Furthermore, the majority of the patients who believe masks are efficacious in preventing the spread of COVID-19 preferred for their physician to wear a mask and other appropriate PPE during the visit (n=152). On the contrary, patients who do not believe face masks help reduce the transmission of COVID-19 preferred that their physician not wear a mask or any other PPE (n=6, p<0.0001, 95% CI 13.8-50%).

Similarly, patients who prefer for their physician to wear a mask/PPE felt comfortable asking their physician for clarification or repeating advice (n=145), while patients who prefer for their physician to not wear PPE/mask did not feel comfortable asking their physician to repeat or clarify (n=7, p=0.0306, 95% CI 15.2-64.6%).

According to the CARE score measure, the majority of patients (n=117) felt that the use of face masks and PPE did not interfere with the physician’s ability to understand his/her concerns during their visit (p=0.00720). The average overall CARE score for this group was 38.17.

DISCUSSION

Effective communication is essential for a successful patient encounter and a vital foundation for improved patient outcomes. The widespread use of face masks in orthopaedic clinics during the COVID-19 pandemic has caused both patients and physicians to adapt to the changes required to reduce respiratory transmission, while maintaining the doctor-patient relationship. This study determined the patient perspective of the effects of face masks on doctor-patient interactions and patient satisfaction in orthopaedic clinics.

Does patient preference to have their physician wear a face mask impact the success of their interactions with physicians?

The CARE measure is a tool used to examine patient satisfaction by assessing patient perception of empathy during face-to-face interactions. Literature shows that CARE scores are valid and reliable measurements of assessing patient experiences of interpersonal skills during their physician encounter.5,6,7 The questionnaire has been carefully designed to include wording that is comprehensible to patients of all socio-economic backgrounds to produce a standardized score that is meaningful evaluation of empathy.4 Overall, the use of face masks by physicians did not negatively impact patient encounters. CARE scores for patients who preferred masks (37.2) were similar to those who preferred their physician did not wear a mask (37.5). Similarly, CARE scores for patients that do not believe face masks are efficacious in stopping the spread of COVID-19 (37.3) and those who do believe in the efficacy of face masks (37.1) were similar. Patients stated they felt comfortable asking for clarification or for the doctor to repeat himself or herself regardless of their preference of masks. The consistency of perceived empathy, trust, and compassion as seen in the almost identical CARE scores amongst patients who differ in their belief in the use and efficacy of face masks may be explained by physicians actively working to communicate with patients despite the mask/PPE barrier to nonverbal communication. Since the onset of the pandemic, recent literature has been continuously
promoting the preservation of effective conversation and delivery such as by physicians using transparent masks\(^9\) to allow for patients to see their facial expressions and using gestures and maintaining eye contact.\(^{10}\) Our finding that face masks do not have a significant effect on the perceived empathy and communication is consistent with previous studies analyzing the perception of face masks by patients.\(^{1,3,4}\)

**Is patient satisfaction affected by the use of face masks in the orthopaedic clinic?**

Patients who preferred that their doctor wear a face mask stated that it had no negative impact on the effect of communication or conversation with the physician. Other factors such as how well the patients knew the physician and patient gender had a greater impact on the CARE score than masks. Higher CARE scores were seen in patients who knew their physician better. Patients who stated that they did not know their physician well had significantly lower CARE scores (34.2) than those who stated that they knew their physician very well (39.3). Therefore, how well the patient knows the physician may be a confounder for the CARE score’s ability to measure the impact of masks on patient experience.

Gender of the patient was also a variable impacting the average CARE scores. Male patients felt significantly more at ease with their physician and had higher CARE scores in comparison to female patients. All physicians in our study were male, potentially contributing to gender being a confounding variable in the analysis.

**Limitations**

This study is limited by the small sample size of 178 patients who opted-in to participate and completed the entire survey. A large majority of patients preferred the use of masks/PPE with less responses of those who do not prefer masks and PPE. Further studies with more participants who question the use of masks would be needed to create a more accurate representation of this group. Participants who did not complete all questions

### Table V. CARE Scores - This Table Illustrates the Responses For Each Question of the CARE Survey and How Each Response Was Scored

<table>
<thead>
<tr>
<th>CARE Question</th>
<th>Poor (score =1) # responses</th>
<th>Fair (score =2) # responses</th>
<th>Very Good (score =3) # responses</th>
<th>Excellent (score =4) # responses</th>
<th>No Response # responses</th>
<th>Total # responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Making you feel at ease</td>
<td>0</td>
<td>1</td>
<td>17</td>
<td>157</td>
<td>3</td>
<td>178</td>
</tr>
<tr>
<td>2. Letting you tell your “story”</td>
<td>0</td>
<td>5</td>
<td>23</td>
<td>147</td>
<td>3</td>
<td>178</td>
</tr>
<tr>
<td>3. Really listening</td>
<td>0</td>
<td>3</td>
<td>23</td>
<td>151</td>
<td>1</td>
<td>178</td>
</tr>
<tr>
<td>4. Being interested in you as a whole person</td>
<td>0</td>
<td>9</td>
<td>29</td>
<td>136</td>
<td>4</td>
<td>178</td>
</tr>
<tr>
<td>5. Fully understanding your concerns</td>
<td>0</td>
<td>3</td>
<td>28</td>
<td>143</td>
<td>4</td>
<td>178</td>
</tr>
<tr>
<td>6. Showing care and compassion</td>
<td>2</td>
<td>4</td>
<td>26</td>
<td>141</td>
<td>5</td>
<td>178</td>
</tr>
<tr>
<td>7. Being positive</td>
<td>0</td>
<td>4</td>
<td>21</td>
<td>152</td>
<td>1</td>
<td>178</td>
</tr>
<tr>
<td>8. Explaining things clearly</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>147</td>
<td>1</td>
<td>178</td>
</tr>
<tr>
<td>9. Helping you take control</td>
<td>1</td>
<td>4</td>
<td>29</td>
<td>134</td>
<td>10</td>
<td>178</td>
</tr>
<tr>
<td>10. Making a plan of action with you</td>
<td>1</td>
<td>6</td>
<td>20</td>
<td>145</td>
<td>6</td>
<td>178</td>
</tr>
</tbody>
</table>

### Table VI. CARE Score and Knowing the Physician

<table>
<thead>
<tr>
<th>How Well Patient Knows Physician</th>
<th>Average CARE Score (std)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not well</td>
<td>34.2 (6.5)</td>
</tr>
<tr>
<td>Neutral</td>
<td>37.4 (4.6)</td>
</tr>
<tr>
<td>Well</td>
<td>38.2 (3.5)</td>
</tr>
<tr>
<td>Very well</td>
<td>39.3 (1.6)</td>
</tr>
</tbody>
</table>

### Table VII. CARE Score and Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>Count (n)</th>
<th>Average CARE Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>63</td>
<td>38.4</td>
</tr>
<tr>
<td>Female</td>
<td>111</td>
<td>36.5</td>
</tr>
</tbody>
</table>
were not included which also limited the responses used for statistical analysis.

Furthermore, the surveys were distributed from November 2020 - January 2021. Opinions from before and after COVID-19 or earlier in the pandemic such as in March of 2020 may differ than those collected in this survey due to the later acceptance and education on the topic of masks.

The CARE scores were higher in groups that prefer their physician not wear a mask/PPE and who do not believe masks help reduce the transmission of COVID-19. This data could be confounded by how well the patient knows the doctor. On average, the better the prior relationship between the physician and patient the higher the CARE score. Additionally, certain components of the CARE measure including “comfort” were significantly higher in males than females so gender could be another confounding factor.

**CONCLUSION**

Our study determined that the preference of face masks by patients does not impact the success of their interactions with physicians through the use of the CARE score to determine perceived empathy and communication. This elucidates patients’ attitudes and perceptions of the change towards the use of face masks and PPE in the orthopaedic clinic. The findings of this study are valuable in informing orthopaedic practitioners about patient attitudes about mask use and could inform decision making about preserving the doctor-patient relationship while using face masks and PPE for not only the current COVID-19 pandemic but also future infectious outbreaks that may arise.

**REFERENCES**


ABSTRACT

Background: Effective communication between the physician and the patient is crucial to quality healthcare. The orthopedic surgery clinic setting provides an environment for cultivating the physician-patient relationship, eliciting diagnostic data, and developing treatment strategies. However, little is known about the orthopedic surgeon perspective on communicating with patients. The purpose of the study was to identify patient communication and care issues faced in the orthopedic surgery clinic setting that physicians categorize as challenging.

Methods: All surgeons in the department of orthopedics in a large tertiary care center were invited to respond to an online survey on common communication challenges. Physicians were asked to rate 13 challenges identified by the literature and opinion leaders using a four-point Likert scale ranging from “Not at all challenging” to “Extremely challenging”. In addition, the survey included open ended questions regarding common challenges in communicating with patients and types of encounters, and thematic analysis was applied. Mean scores were calculated.

Results: Nineteen orthopedic surgeons completed the survey and were included in the analysis. Orthopedic surgeons identified misaligned expectations for surgical intervention for a nonsurgical diagnosis as the most challenging encounter in the clinic (16/19). Managing postoperative patient expectations (14/19) and communicating with patients who were dissatisfied with their surgical outcome (13/19) were also commonly rated as particularly challenging. Open ended responses echoed these ratings and additional difficulty facilitating patient understanding of complex information as common communication challenges.

Conclusion: Common challenges in the orthopedic clinic often surround managing patient expectations and providing effective explanations, particularly where physicians perceive a surgical intervention as inappropriate for addressing the patient complaint. Identifying these issues can guide training efforts to help orthopedic physicians in managing these and improving communication. These findings can also provide basis for collecting information about communication challenges from orthopedic surgeons across institutions.

Level of Evidence: IV

Keywords: health care barriers, physician-patient relationship, communication

INTRODUCTION

Effective communication between physician and patient is crucial to delivering quality healthcare. Public opinion surveys have demonstrated that 85% of patients identified communication skills as a critical feature of a good doctor. Effective communication is central to achieving patient-centered care that involves treating patients as partners, involves them in decision-making, and enlists their sense of responsibility for their care while respecting their individual values and concerns. Previous primary care-based literature has demonstrated that successful communication aids in information recall in patients, patient adherence, and patient satisfaction.

The orthopedic surgery outpatient clinic setting provides an environment for cultivating the physician-patient relationship, eliciting diagnostic data, and developing treatment strategies. A 2002 review by Herndon and Pollick described the orthopedic surgeon’s communication skills as “the single greatest factor influencing each [patient] encounter.” The complexity of surgical indication and intervention adds additional intricacy to the interaction between the surgeon and patient. Previous research suggests that in the surgical domain, effective communication is associated with fewer postoperative complications, decreased postoperative pain medication consumption, and shorter inpatient hospital stay. Prior studies have also shown an association between communication and malpractice.

Disclosures: One or more of the authors (C.C.) has received funding as a deputy editor of the Journal of Bone and Joint Surgery.

Sources of Funding: No sources of funding declared.
communication problems in 70% of malpractice claims included in the study.19

Lipkin, et al. previously described the necessary communication skills for gathering patient information, most notably “recognizing barriers to effective communication and adapting constructively to these barriers.”16,24 Historically, the literature has relied on patient opinion for evaluation of physician communication skills, often in the form of surveys or patient satisfaction scores.14,25 The barriers to effective communication in the orthopedic surgery clinic setting as defined by orthopedic surgeons themselves are currently poorly understood. The purpose of this study was to identify and describe the most common physician-identified challenges with patient communication in the clinical orthopedic setting.

METHODS

All orthopedic surgeons in the Department of Orthopedics at a large, tertiary care center were invited to respond to an anonymous online survey on common communication challenges. Surveys were dispersed and collected prior to provider participation in a mandatory communication skills session implemented hospital-wide. The survey was dispensed via departmental email using Qualtrics 2019 software (Qualtrics, Provo, UT). The survey contained 15 items: 13 discrete questions and two open-ended response questions. The open-ended queries were presented first to minimize bias of the narrative response that would have occurred with presenting the discrete categories initially.

The survey included open-ended questioning eliciting providers to explicitly identify their individual challenges in communicating with patients and difficult encounters. Two open-ended questions were used: 1) What common challenges do you encounter in communicating with patients? 2) What types of encounters or patients do you find challenging?

The narrative responses were categorized thematically based on 13 common patient interaction challenges identified by review of the existing literature (Table 1).2,14,16,26 If the open-ended response did not correlate with an established category, it was labeled as “other.” Physicians responses to the open-ended questions were not length restricted, and they were allowed to provide multiple answers, each of which were individually categorized.

Physicians were then asked to rate 13 common patient interaction challenges as previously identified using a four-point Likert scale ranging from “Not at all challenging” to “Extremely challenging.” Each physician was only allotted one answer for each category (A-M).

Descriptive statistics were calculated, including the mean score for each rated category, as well as the proportions of “challenging” and “very challenging” responses (scores of 3 or 4) for each of the 13 topics. Proportions of open-ended responses that fit the described encounters were also determined. External funding sources did not play a role in this study.

RESULTS

Overall Response

A total of 19 out of 26 orthopedic surgeon faculty completed the survey (73%). For each of the rating categories, each physician completed their one allotted response, with nineteen responses in each of the thirteen categories. Responders provided a total of 29 responses to the first open-ended question, and 32 responses to the second open-ended question. No questions were unanswered.

Discrete Rating

Orthopedic surgeons identified unrealistic expectations for surgical intervention for a nonsurgical diagnosis as the most challenging encounter in the clinic, with 16 describing the encounter as “challenging” or “extremely challenging” (Table 2). Nearly half of the physicians polled described the interaction as “extremely challenging.” Managing postoperative patient expectations and communicating with patients who were dissatisfied with their surgical outcome were also commonly scored highly, with upper-end score reported by 14/19 and 13/19 surgeons, respectively. Physicians reported less difficulty in identifying patient concerns

<table>
<thead>
<tr>
<th>Table 1. Common Patient Interaction Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Identifying patient concerns/agenda</td>
</tr>
<tr>
<td>B. Managing patients with multiple concerns</td>
</tr>
<tr>
<td>C. Responding to patients who are angry/frustrated</td>
</tr>
<tr>
<td>D. Responding to patients who become emotional during the encounter e.g. sadness</td>
</tr>
<tr>
<td>E. Efficient time management</td>
</tr>
<tr>
<td>F. Adjusting to different levels of health literacy</td>
</tr>
<tr>
<td>G. Addressing worker compensation issues</td>
</tr>
<tr>
<td>H. Managing pain medication requests for chronic pain complaints</td>
</tr>
<tr>
<td>I. Patients who are convinced a surgery is their best option when in reality it is not</td>
</tr>
<tr>
<td>J. Patients with multiple medical comorbidities that are not appropriate surgical candidates</td>
</tr>
<tr>
<td>K. Patient whose health behaviors (smoking, diet, etc.) impact their health and surgical eligibility</td>
</tr>
<tr>
<td>L. Patient disappointment with surgical outcomes</td>
</tr>
<tr>
<td>M. Patients with unrealistic expectations for surgical outcomes</td>
</tr>
</tbody>
</table>
or adjusting to differing health literacy, with 11 and seven surgeons describing the encounter as “not at all challenging,” respectively.

Open-Ended Responses

When asked to identify challenges in the outpatient clinic setting without prompting of the specific categories of the study, 17.2% of responses identified misaligned patient and provider expectations for surgical intervention as one of the most common and difficult patient interactions. Managing postoperative expectations of patients also proves difficult for 13.8% of orthopedic surgeons surveyed. Nearly 21% fell into the “other” category, with more than half referencing non-English speaking language barriers to eliciting clinical information from the patient.

In reference to specific encounters, physicians equally described three of the most commonly experienced difficult situations (each 15.6%): managing chronic pain patients, unrealistic surgical expectations for outcome, and patients expecting surgical intervention where physicians perceive a surgical intervention as inappropriate for addressing the patient complaint. The remaining categories were referenced at least once, with the exception of addressing worker compensation issues, as no physician mentioned worker’s compensation in their open response.

<table>
<thead>
<tr>
<th>Table 2. Physician Difficulty Rating of Communication Challenges Faced in the Orthopedic Surgery Clinical Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating [n, (%)]</td>
</tr>
<tr>
<td>Category</td>
</tr>
<tr>
<td>A. Identifying patient concerns/agenda</td>
</tr>
<tr>
<td>B. Managing patients with multiple concerns</td>
</tr>
<tr>
<td>C. Responding to patients who are angry/frustrated</td>
</tr>
<tr>
<td>D. Responding to patients who become emotional during the encounter e.g. sadness</td>
</tr>
<tr>
<td>E. Efficient time management</td>
</tr>
<tr>
<td>F. Adjusting to different levels of health literacy</td>
</tr>
<tr>
<td>G. Addressing worker compensation issues</td>
</tr>
<tr>
<td>H. Managing pain medication requests for chronic pain complaints</td>
</tr>
<tr>
<td>I. Patients who are convinced a surgery is their best option when in reality it is not</td>
</tr>
<tr>
<td>J. Patients with multiple medical comorbidities that are not appropriate surgical candidates</td>
</tr>
<tr>
<td>K. Patient whose health behaviors (smoking, diet, etc.) impact their health and surgical eligibility</td>
</tr>
<tr>
<td>L. Patient disappointment with surgical outcomes</td>
</tr>
<tr>
<td>M. Patients with unrealistic expectations for surgical outcomes</td>
</tr>
</tbody>
</table>

DISCUSSION

The purpose of the study was to explore physician-perceived challenges in communicating with patients in the orthopedic surgery clinical setting. This survey identified that physicians recognize common struggles in their clinical encounters, and regularly rate these as significantly difficult, even when unprompted by category.

Interestingly, surgeons described managing patients who expect surgical intervention for a complaint where physicians perceive a surgical intervention is inappropriate as the toughest communication interaction, with sixteen participants rating the encounter as “challenging” or “extremely challenging.” The same category was frequently mentioned in the open-ended responses as well. This seems paradoxical to the actionability of surgi-
cal training – the resolution of medical malady through direct surgical intervention. It reflects on perhaps the less publicly understood aspect of operative training – the knowledge of when surgery is indicated, and when it is not. This concept of effectively communicating indications for surgical intervention that contradict pre-existing patient expectations remains poorly understood and remains a significant clinical challenge.

Handling dissonant expectations between physician and patient and patient dissatisfaction with an operative outcome were both expressed as difficult without categorical prompting (15.6% and 9.4%, respectively) and scored as “challenging” or “extremely challenging” (14/19 and 13/19, respectively). The management of patient expectations for postoperative outcomes has been previously explored. Noble, et al. acknowledged the gap in understanding between patient expectations for a procedure and what the physician and procedure can realistically provide, and attributes this to a lack of proper informed consent in discussing outcomes. In addition, the study described how patient satisfaction with surgical outcome is significantly influenced by failure to meet preoperative expectations of postoperative activity level. The study also suggests incompatible definitions of “success” between patient and surgeon contributes to lack of patient satisfaction with results and suggests discussion of the patient’s personal goals in conjunction with the likelihood of those goals as an important tool to reduce postoperative dissatisfaction.

The reasoning for why orthopedic surgeons find these types of encounters particularly arduous is poorly understood in current peer-reviewed literature. Prior studies largely focused on the general content of surgical clinic visits. Levinson, et al. previously described conversation content of physician-patient communication in the orthopedic and general surgery clinic settings in a landmark study that identified differences in communication patterns between primary care and surgical specialties. The study demonstrated that surgeons spend close to 50% of total visit time on patient education and counseling, a significantly increased amount compared to primary care. This, in addition to the highly technical details of surgical intervention, poses unique challenges in communicating with patients. The study also highlighted the propensity for surgeons to discuss outcomes towards recovery, which is supported by the current study as a common difficulty in the orthopedic clinical encounter.

Of significant note, 17/19 surgeons surveyed reported adjusting to health literacy as “not at all” or “somewhat” challenging, making the category the lowest scoring in the entire study. A study by Rosenbaum, et al. found limited musculoskeletal literacy to be more prevalent than general health literacy. Multiple studies across orthopedics specialties have also found health literacy to be a significant barrier to the understanding of orthopedic injuries and procedures. The current study, however, is a subjective evaluation of physician opinion on health literacy and does not evaluate patient opinion. It also offers no objective data by which to measure the understanding of patients. While the current study stands in contrast to the literature, it is difficult to compare subjective views to the rigorous objective data in the current orthopedic literature.

We sought to identify the specific challenges to physician-patient communication in the orthopedic surgery clinical setting. Previous patient surveys have shown a dissonance in how patients perceive orthopedists, and how orthopedists perceive themselves and their colleagues. Patients placed value in both technical skill and compassion but scored orthopedic surgeons much lower in the latter. With the restatement of the importance of technical skill, and the propensity for surgeons to spend most of a visit on patient education, it makes sense that communication surrounding the action of surgery (indications, expectations, and outcomes) is perceived as particularly challenging. Noted differences in perspective between patient and surgeon may help to explain why surgeons in the current study did not identify health literacy as a barrier even though previous literature demonstrates this.

Furthermore, patient evaluation of the clinical encounter has become increasingly more critical to orthopedic practice in recent years. Recent literature in the hand surgery clinic setting also demonstrated physician empathy to be the most influential factor in patient satisfaction. With a shift towards physician compensation based on patient experience, clinical encounter ratings are used to evaluate the quality of care, and in turn, how much physicians are reimbursed. Tools such as the Press-Ganey questionnaire are often used to score physicians for the care provided and determine their compensation. Specifically, the Press-Ganey questionnaire incorporates an assessment of physician communication within its scoring matrix. While the extent to which the physician communication aspect of Press-Ganey affects overall scores has not been previously explored in the literature, the mere existence of the topic within the survey presents a potential avenue for improving the patient experience.

Additionally, previous review of graduate medical school education have shown a deficiency in communication education in their curricula. The identification of this reveals a need to develop effective training tools to improve physician communication overall. The results of the current study suggest a potential need for further
education for orthopedists in the identified weak areas. Communication training specifically targeting negotiating patient expectations for surgery, expected postoperative outcomes, and dissatisfaction with postoperative results may help to combat the difficulty of these interactions in the clinic setting. This could enhance patient comprehension as well as improve health care delivery.

Improving physician-patient communication in orthopedics is a continuous effort and has taken many forms over the years. A 2005 instructional course given by the American Association of Orthopaedic Surgeons (AAOS) comprehensively detailed several strategies for enhancing the physician-patient relationship. The review detailed the importance of both written educational materials as well as interactive workshops in order to facilitate skillful improvement. Methods for effective communication include open-ended questioning, eliciting patient perspectives and expectations early, allowing patients to answer without interruption, reflective listening, frequent empathic statements checking for patient comprehension, and using direct clear statements when delivering bad news. Table 3 provides additional communication strategies that may be particularly helpful in exploring and addressing the primary challenges highlighted by survey respondents in this study.

Limitations
There are several limitations to the current study. The study reports subjective physician perceived patient interaction difficulties and relies on recall of individual experience, and there is no objective data to reconcile with these opinions. Further large-scale investigations are needed to quantify the specific frequency of each of these encounter categories. The thirteen described communication challenges may also exhibit some overlap in certain patient populations or clinical scenarios.

<table>
<thead>
<tr>
<th>General skill set</th>
<th>Specific strategies (relevant example phrases in italics)</th>
<th>Relevance to common challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skill Set 1</strong></td>
<td><strong>Create Rapport</strong></td>
<td></td>
</tr>
<tr>
<td>Warm greeting</td>
<td>&quot;Nice to meet you&quot;</td>
<td>Demonstrates attention and interest in patient</td>
</tr>
<tr>
<td>Small talk before big talk</td>
<td>&quot;Where did you drive from today?&quot;</td>
<td>Conveys full attention/time for patient</td>
</tr>
<tr>
<td>Sitting, eye contact</td>
<td></td>
<td>Early empathy for patient discomfort or language barriers</td>
</tr>
<tr>
<td><strong>Skill Set 2</strong></td>
<td><strong>Patient-centered History Building</strong></td>
<td></td>
</tr>
<tr>
<td>Open ended questions</td>
<td>&quot;Tell me about your knee pain&quot;</td>
<td>Allow patient to describe condition in their own words</td>
</tr>
<tr>
<td>Active, reflective listening</td>
<td>&quot;So just to summarize.....&quot;</td>
<td>Conveys to patient they are being heard</td>
</tr>
<tr>
<td><strong>Skill Set 3</strong></td>
<td><strong>Educate, Counsel and Plan</strong></td>
<td></td>
</tr>
<tr>
<td>Assess patient starting point</td>
<td>&quot;What have you heard/read about carpal tunnel syndrome?&quot;</td>
<td>Clarifies patient understanding of condition and expectations for treatment</td>
</tr>
<tr>
<td>Frame explanation using patient perspective/goals</td>
<td>&quot;I know your hope is surgery could help your pain, unfortunately surgery won’t improve the cause of this pain&quot;</td>
<td>Aligns discussion with patient ideas, concerns, expectations</td>
</tr>
<tr>
<td>Provide explanation in understandable chunks with room for questions/perceptions</td>
<td>&quot;Physical therapy is useful for this condition, what questions do you have about it?&quot;</td>
<td>Gives patient room to process and express ongoing concerns/questions</td>
</tr>
<tr>
<td>Respond with empathy (acknowledgement, support, etc.) throughout</td>
<td>&quot;I know you are disappointed&quot;, &quot;I wish surgery could help your pain&quot;, &quot;We’ll work together to help you manage this.&quot;</td>
<td>Acknowledges patient suffering, disappointment and goals, conveys partnership</td>
</tr>
<tr>
<td><strong>Assessing Understanding</strong></td>
<td></td>
<td>Increases retention of key components of discussion, allows for correction of misconceptions</td>
</tr>
</tbody>
</table>

Table 3. Evidence Based Strategies For Addressing Challenging Communication in Orthopedics
Given the extraordinary breadth of orthopedic maladies as well as the patient population, it would be difficult to isolate these to determine their effects, even within a subspecialty. Additionally, this survey was limited to one academic institution and its staff physicians. Although the number of employed faculty at our institution is relatively small, our response rate was 73%. A more complete survey participation may have yielded slightly different results. As previously mentioned, the overall number of survey participants is low and is a weakness of the study. As such, sub-analysis by specialty would compromise anonymity in this study. Replication of the survey on a national scale in both academic and private practice settings would provide a more comprehensive view of the surgeon-identified challenges and perhaps reveal patterns related to geographic region, practice setting, or level of care. Further sub-grouping by orthopedic subspecialty may also demonstrate differences in perception but would again require a much larger survey population.

**CONCLUSION**

Common challenges in the orthopedic clinic often surround managing patient expectations and providing effective explanations, particularly involving patients for where surgical intervention is not perceived as appropriate. Identifying these issues can guide training efforts to aid orthopedic surgeons in improving their clinical communication skills. These findings can also provide basis for further work examining communication challenges from orthopedic surgeons across institutions.

**REFERENCES**


A LARGE NUMBER OF REVIEWS ON PHYSICIAN RATING WEBSITES MAY REFLECT REPUTATION MANAGEMENT

Shyam Ramachandran, BSA¹; David Ring, MD, PhD¹; David Langerhuizen, MD¹; Gregg Vagner, MD¹

ABSTRACT
Background: Physicians with a large number of reviews and a high rating may be employing reputation management strategies. Specialists may be more likely than non-specialists to employ such strategies. This should be apparent in a study of online physician reviews on physician rating websites (PRW).

Methods: Using one physician rating website, we gathered orthopedic surgeon and family physician reviews. We measured Spearman correlations between the number of reviews and average numerical rating and used chi-squared to test threshold relationships.

Results: There were very small negative Spearman correlations between the number of online reviews and the average numerical rating for orthopedic surgeons (p= -0.097, p-value=<0.001) family medicine physicians (p= -0.170, p-value=<0.001; Figure 2). Physicians with more than 100 reviews had a greater average numerical rating than physicians with fewer than 50 reviews. Orthopedic surgeons are more likely than family medicine physicians to have a large number of reviews and average numerical rating greater than 3.

Conclusion: The small fraction of physicians with a high number of reviews may be utilizing reputation management strategies, and this seems relatively specific to specialists rather than non-specialists.

Level of Evidence: III
Keywords: family medicine, bias, online ratings, reputation management, orthopedics, online reviews

INTRODUCTION
Websites where patients can post reviews of physicians are intended to help people choose a physician. The percentage of people who use such websites to help make a choice is low, but the people who do use them indicate that they find the information helpful. It has been reported that patients who are highly educated, younger, women, and those with a long-term or permanent disease are more likely to review physician-rating websites (PRW) when selecting a physician.

Reputation management services have emerged as a way to help physicians defend their online reputation. These services request favorable reviews and highlight positive messaging however are costly. An alternative to reputation management services is for physicians to encourage satisfied patients to write online reviews. Most physicians tend to have a small number of online reviews making their average rating relatively susceptible to one or two bad ratings. One study in 2017 reported a median of 7 total online reviews per physician and in 2018 it was between 8-10 reviews. Much larger numbers of reviews might reflect a physician’s attempt to manage their reputation. However, anecdotally, it seems unusual for a physician to have more than 100 reviews when they are not performing some form of reputation management. Additionally, referral specialty practices seem more likely to invest in reputation management.

Online reviews were studied to address the following questions: (1) Is there a correlation between the number of online reviews about individual surgeons and their average numerical rating? (2) Is there a correlation between the number of online reviews for a family medicine physician and their average numerical rating? (3) Do physicians with an average numerical rating of 3 or below have a relatively low number of reviews (less than 50) or a relatively high number of reviews (greater than 100)? (4) Do orthopedic surgeons or family medicine physicians have an average numerical rating of 3 or below?

METHODS
This study is exempt from institutional review board approval as it uses open source data from anonymous online users.

On Vitals.com, orthopedic surgeons and family medicine physicians in the 20 most populated cities in the United States were evaluated. The Spearman correlation coefficient between the number of reviews and average numerical rating for each physician was calculated. A chi-squared test was used to test for threshold relationships. The level of evidence was assigned as III.

¹Department of Surgery and Perioperative Care, Dell Medical School, The University of Texas at Austin, Austin, TX, USA
Corresponding Author: David Ring, MD, PhD, david.ring@austin.utexas.edu
Disclosures: The authors report no potential conflicts of interest related to this study.
Sources of Funding: No sources of funding declared.
United States were searched. Orthopedic surgeons and family medicine physicians were selected because we wanted to contrast specialty and non-specialty care. The number of reviews for internal medicine physicians is too large for the version of the software that was utilized to collect the text from the website. The following cities were included in the study: New York City, Los Angeles, Chicago, Houston, Phoenix, San Antonio, Philadelphia, San Diego, Dallas, San Jose, Austin, Jacksonville, Fort Worth, San Francisco, Charlotte, Columbus, Indianapolis, Seattle, Denver, and Washington DC. These cities were chosen as an accurate representation of the US population due to their geographic distribution and population size. The terms “orthopedic surgeon” and “family medicine” were entered into the search bar as we found these terms resulted in the highest number of reviews. Scrapestorm® was used to collect the specialty, location, average numerical rating, and number of reviews for each physician. Extracted data was exported and stored in Excel. This resulted in 6597 family medicine physician reviews and 6607 orthopedic surgeon reviews.

A Spearman rank correlation coefficient was used to determine whether there is a correlation in the number of reviews for individual orthopedic surgeons and their average numerical rating. This was performed for family medicine physicians as well. A chi-square test was used to compare: 1) the proportion of physicians with an average numerical rating of 3 or below between physicians with more than 100 reviews and physicians with 50 or fewer reviews; and 2) the proportion of physicians with an average numerical rating of 3 or below between orthopedic surgeons and family medicine physicians.

**RESULTS**

There was a very small negative Spearman correlation between the number of online reviews for an orthopedic surgeon and the average numerical rating ($p=-0.097$, $p$-value=$<0.001$) that we felt was likely spurious given the scatter plot (Figure 1). A histogram shows that a few surgeons have a very high number of reviews (Figure 3). There was a small negative Spearman correlation between the number of online reviews for a family medicine physician and the average numerical rating.

| Table 1. Difference in Average Numerical Rating Between Physicians With More Than 100 Reviews and Physicians with 50 or Fewer Reviews |
|---------------------------------|-----------------|-----------------|-----------------|
| ≤3                               | >3              | P-value         |
| Physicians with 50 or fewer reviews | 1546            | 10768           | <0.001          |
| Physicians with more than 100 reviews | 2              | 190             |                 |

We found a difference in average numerical rating of 3 or below between physicians with more than 100 reviews and people with 50 or fewer.
Many Reviews May be Reputation Management

We found a significant difference in the average numerical rating of 3 or below between orthopedic surgeons and family physicians.

Figure 4. Histogram of number of online reviews for family physicians. 

Figure 5. Histogram of average ratings for orthopedic surgeons.

Figure 6. Histogram of average ratings for family physicians.

Table 2. Difference in average Numerical Rating Between Orthopedic Surgeons and Family Physicians

<table>
<thead>
<tr>
<th></th>
<th>≤3</th>
<th>≤3</th>
<th>Totals</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthopedic Surgeons</td>
<td>545</td>
<td>6062</td>
<td>6607</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Family Physicians</td>
<td>1020</td>
<td>5577</td>
<td>6597</td>
<td></td>
</tr>
</tbody>
</table>

We found a significant difference in the average numerical rating of 3 or below between orthopedic surgeons and family physicians.

DISCUSSION

Physicians can manage their reputation on physician rating websites by either using reputation management services or by encouraging reviews from satisfied patients. Prior studies found that most physicians have a small number of online reviews. We speculated that physicians with a very high number of reviews were using reputation management resulting in a relatively high mean rating. Overall, this study demonstrated signs of reputation management and non-specialists received more negative reviews than specialists.

There were limitations within this study. First, the software for retrieving data for numerous doctors is only usable with one rating site (Vitals.com). On the other hand, the ratings sites seem to have similar data and consistent number and character of reviews. Second, we had a limited version of ScrapeStorm® that limited the amount of data that could be exported. The number of family practitioners was easier to manage than the number of internal medicine doctors. The findings may be different if this study compared to internal medicine physicians.

The finding of a very small negative Spearman’s rank correlation coefficient between number of physician reviews and average numerical rating for both orthopedic surgeons and family medicine physicians is difficult to interpret and may be unauthentic. The correlation was so small and the sample so large that it’s probably best to interpret this as showing no correlation over the continuum of number of ratings. On the other hand, it may be that, when people do not participate in reputation management, a single bad rating is more likely to have an effect on the average numerical rating. According to
one study, physicians making sound medical decisions that are discordant with the patient can lead patients to express their anger through a bad rating.\(^5\)

The finding that both surgeons and family practitioners with a large number of reviews (100+) have a more favorable rating almost certainly represents a concerted effort at reputation management. The histograms show that the vast majority of both orthopedic surgeons and family practitioners have fewer than 25 reviews (Figures 3 and 4). And most raters give favorable reviews. A 5-star rating, the highest rating possible, was the most popular rating for both family medicine physicians and orthopedic surgeons (Figures 5 and 6). We believe that the very small fraction of surgeons with more than 100 reviews are using reputation management strategies.

The finding that orthopedic surgeons are more likely to have a higher rating suggests that orthopedic surgeons may be employing reputation management strategies more often than family physicians. Out of the 13204 reviews collected there were 192 physicians with more than 100 reviews, 178 of these reviews belonged to orthopedic surgeons and only 14 belonged to family medicine physicians. This confirms our previous finding that physicians with a large number of reviews (100+) may be utilizing reputation management.

Patients using physician rating websites to choose a physician can use the total number of reviews as a marker of reputation management. Our data shows that having more than 100 reviews is unusual and may suggest reputation management. Reputation management seems more common for specialists than non-specialists. This information can help people make more informed use of these websites.

**REFERENCES**


