JUNE 2022
VOLUME 42
ISSUE 2

THE IOWA ORTHOPEDIC JOURNAL

2022

Published by the residents and faculty of the University of Iowa Department of Orthopedics and Rehabilitation

UNIVERSITY OF IOWA HEALTH CARE

THE IOWA ORTHOPEDIC JOURNAL

2022 • Volume 42 • Issue 2

THE IMPORTANCE OF MENTORSHIP AND INTEREST GROUP INVOLVEMENT FOR THE ORTHOPEDIC SURGERY APPLICANT

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ABSTRACT

Background: Mentorship in medical education is important for students' professional development career planning. Orthopedic Surgery Interest Groups (OSIG) exist as formal organizations and serve as a conduit for undergraduate mentorship, though the role of mentorship via OSIGs within orthopedic medicine has not been thoroughly evaluated. Similarly, OSIGs within institutions are not standardized nor well defined. We sought to answer: (1) What offerings does OSIG provide for students interested in orthopaedic surgery? (2) How does OSIG involvement impact the orthopaedic surgery residency applicant? (3) Does OSIG involvement increase match rates for orthopaedic surgery residency applicants?

Methods: An online survey was distributed to faculty advisors at all allopathic US medical schools with available contact information. Results were analyzed using SPSS.

Results: Of the 28 respondent organizations, the majority (53.6%) have between 1-25 student members. On average, OSIGS offer 3.64 + 1.59 (mode = 4) executive positions. The most important initiative for OSIG groups was clinical/surgical shadowing, followed by faculty mentorship, and guidance for the residency application. OSIG involvement does impact the applicant, as all faculty mentors believed this to be an important component of the residency application. Leadership positions within OSIG was not perceived as being equally important. OSIG involvement did increase match rates; the match rate for all students at the schools surveyed (n=17) was 81.21% while the match rate for students within OSIG (n=17) was 82.39% ($p<0.05$). Of all students who applied to orthopedic surgery residency programs, 98.9% were members of OSIG, and of all students who successfully matched into orthopedic surgery residency programs in the 2019-2020 cycle, 100% ($p<0.05$) of students (n=17) were involved in OSIG.

Conclusion: This study indicates the importance of involvement in OSIG as a conduit for clinical exposure and mentorship throughout medical education, and is especially relevant for applicants given the impact of the COVID-19 pandemic on the residency application process. Data suggests that participation in an OSIG is a valuable experience for the medical student interested in orthopedics and that students involved in OSIGs are more likely to match into orthopedic residency programs.

Level of Evidence: V

Keywords: OSIG, mentorship, match, ummsm

INTRODUCTION

Mentorship in undergraduate medical education is important for professional development and career planning. Orthopedic Surgery Interest Groups (OSIG) exist as formal organizations within medical schools across the country and often serve as a conduit for formal undergraduate mentorship. Several publications in medical literature have highlighted the importance of mentorship, however, the role of OSIGs as a conduit for formal mentorship within orthopedic medicine has not been thoroughly studied. OSIGs are not standardized nor well defined, leaving a level of heterogeneity when considering student opportunities at medical institutions across the country.

Orthopedic surgery is an increasingly competitive specialty and has a demanding residency application process. Medical students must develop a multi-dimensional application with an extensive array of strengths and high-ranking metrics in order to set themselves apart from their peers. Success in matching into competitive

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

Sources of Funding: No sources of funding declared.

Work Performance: The was performed at the University of Miami with contributions from Dr. Cannada from the Hughston Clinic. All data collection, analysis, and writing was performed at University of Miami Miller School of Medicine.

residency programs is in part attributed by students to their prior mentorship, as mentors help students navigate the application process.[16] To display the benefit of organized student groups, students who participated in a Professional Student Mentored Research Fellowship reported a significantly higher average score on the United States Medical Licensing Exam (USMLE) Step 1 as well as a significantly higher match rate into highly ranked residency programs.[2] Similarly, students interested in the field of Neurology showed greater productivity, increased publications, and significantly higher interest in the field after the implementation of a student interest group.[19]

Among the existing literature regarding OSIG and orthopedic mentorship, the potential role of mentorship for medical students has been identified in various ways. Personal mentor-mentee relationships are an established positive predictor of retaining trainee interest in orthopedics. One study determined that focused mentorship is the strongest modifiable factor particularly for female students pursuing a career in orthopedics.[3] Additionally, when identifying driving factors for pursuing orthopedic medicine, female orthopedic residents are more likely to be positively influenced by mentorship and clinical exposures during medical school than their male counterparts.[12] These findings reinforce the belief that interest group involvement and formal mentorship are integral components for student interest, particularly diverse student interest, in orthopedic surgery. Despite its clear value, undergraduate mentorship in orthopedics has not been discretely defined, nor has it been extensively studied in order to stratify the impact of varying levels of mentorship on parameters of student success.[11] A thorough understanding of the latter is necessary to allow for improvements in the realm of mentorship in medical education. Therefore, this pilot study aims to utilize survey methods to answer the following: (1) What standard offerings does the typical OSIG provide for medical students interested in orthopedic surgery? (2) How does OSIG involvement impact the orthopedic surgery residency applicant? (3) Does OSIG involvement increase match rates for orthopedic surgery residency applicants?

The authors of this study aim to use these findings to establish the role of formal mentorship and student interest group involvement when considering the development of a competitive residency applicant. We hypothesized that there will be a higher match rate among students involved with OSIG when compared to the national average. We also hypothesized mentorship will be a significant factor for improving match rates of students applying to orthopedic surgery residency.

METHODS

We utilized survey methods in order to (1) define the characteristics of the Orthopedic Surgery Interest Group (OSIG), and (2) identify the importance of mentorship and OSIG involvement on the residency application process. The survey was sent to faculty advisors at all allopathic US medical schools with publicly available contact information. All responses were anonymous and were included for final data analysis. The individuals were informed that participation was strictly voluntary and that no compensation would be provided. Exclusion criteria included all schools with no available contact information of faculty leaders of OSIG or student body/government.

Upon IRB approval, faculty leaders were invited to participate in the study via an email sent by the investigators. The email contained a brief study description and a link to an anonymous electronic survey conducted via Qualtrics. Follow-up emails were sent two and four weeks after initial communication to encourage participation. The survey was available for completion for a total of eight weeks.

Data was collected in Qualtrics anonymously with no identifying information included or coded. Statistical analyses were completed using the Independent T-Test and Chi Square function of SPSS Version 26.0 for Macintosh (IBM Corp., Armonk, N.Y., USA).

RESULTS

A total of 28 responses were recorded. Of the subjects who responded, 12 (42.8%) were faculty advisors for their orthopedic student interest group, 7 (25%) were program directors or associate program directors, 7 (25%) were professors or faculty members, and 2 (7.1%) held unspecified positions within their programs. The representatives for each respective orthopedic surgery student organization then answered a series of questions regarding the membership, activities, executive positions, and residency applicants within their programs.

One of the goals of this survey was to identify and compare the demographics and structure of each organization. Of the 28 respondent organizations, 15 (53.6%) have between 1-25 student members, 7 (25%) have 26-50 student members, 5 (17.9%) have 51-75 student members, and 1 (3.6%) have 76-100 student members. On average, the student organizations have 3.64 + 1.59 (mode = 4) executive board positions available for their members and have 3.83 + 1.63 (mode = 3.5) members holding executive positions, including co-positions. Across all organizations, the most commonly offered executive positions were president (96.4%, n=27), vice president (78.6%, n=22), secretary (64.3%, n=18), treasurer (57.1%, n=16), and events coordinator (25%, n=7).

Table 1. Evaluation of Overall Importance of OSIG Initiatives Based on a Scale of 1-13 (1= most important, 13=least important)

Field	Minimum	Maximum	Mean	Std Deviation	Variance
Clinical/Surgical Shadowing	1	11	3.05	2.36	5.55
Faculty Mentorship	1	10	3.55	2.22	4.95
Residency Application Guidance	1	12	4.5	3.09	9.55
Resident Panels/Information Sessions	1	9	4.55	2.31	5.35
Research Involvement	1	10	4.75	2.49	6.19
Surgical Techniques/Training Sessions	1	10	5.05	2.22	4.95
Peer Mentorship	1	11	5.95	2.62	6.85
Anatomy Assistance/Tutoring	2	12	7.9	2.51	6.29
Post-Match Panels	4	10	8.4	1.74	3.04
USMLE Step 1 Preparation	7	12	9.35	1.24	1.53
Combined meetings with other interest groups (i.e neurosurgery for spine)	5	12	10.55	2.13	4.55
Athlete Physicals	2	13	10.6	2.35	5.54
Other	10	13	12.8	0.68	0.46

Research coordinator was offered as a position in only 10.7% (n=3) of organizations. Other positions including shadowing coordinator, mentorship coordinator, and class representative which were offered in less than 10% of organizations surveyed.

In assessing the activities and initiatives of each organization, results show that executive boards meet 2.81 + 1.42 times per academic semester, and each organization holds 3.84 + 2.19 events for OSIG members per semester. Representatives from each organization were asked to rank in order of importance the initiatives which their organizations focus on (1 = most important, 13 = least important). The most important initiative for OSIG groups was found to be clinical/surgical shadowing, with an average rank of 3.05 + 2.36 (range = 1-11). Faculty mentorship was found to be the second most important initiative, with an average rank of 3.55 + 2.22 (range =1-10), and residency application guidance ranked as the third most important, averaging 4.5 + 3.09 (range = 1-12) (Table 1).

Follow up questions were targeted toward assessing national initiatives outside of the realm of their respective medical schools. Of the follow up 19 responses recorded, 16 (84.21%) organizations do not participate in national initiatives, and only 3 (15.79%) do. Of those who do, the specified initiatives included the Perry Initiative, Nth Dimensions, and the Ruth Jackson Orthopedic Society. These initiatives have been successful in helping recruitment of diverse groups.[7,8,17]

The primary goal of this survey was to determine the role that faculty mentorship and student involvement in OSIGs may or may not have in determining the match rates of students applying to orthopedic surgery residency programs. Each faculty member was asked about their individual perception on the importance of involvement in OSIG as a component of the residency application. Of 20 responses recorded for this specific question, 8 (40%) believe involvement in OSIG to be extremely important, 2 (10%) feel that involvement in OSIG is very important, 7 (35%) feel that involvement in OSIG is moderately important, and 3 (15%) feel that it is slightly important. All advisors believed OSIG involvement to hold some level of importance in students' match success (Figure 1.1). With regards to the importance of holding executive positions within OSIG, only 1 (5%) of

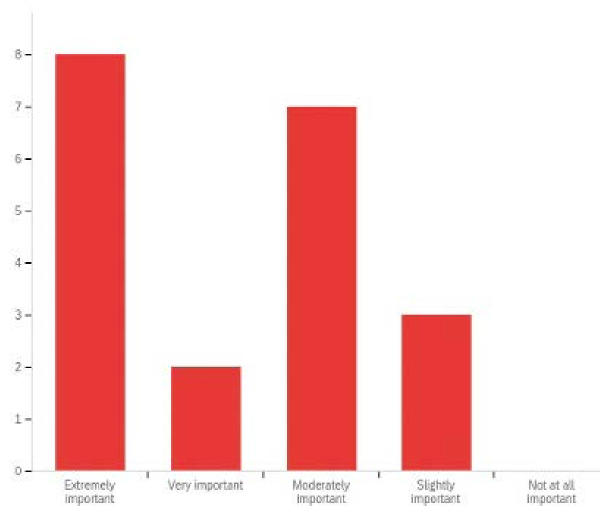

Figure 1.1. Importance of membership in OSIG as a component of the residency application, reported as the number of faculty advisors who selected each answer.
Importance of membership on executive board as a component of residency application.

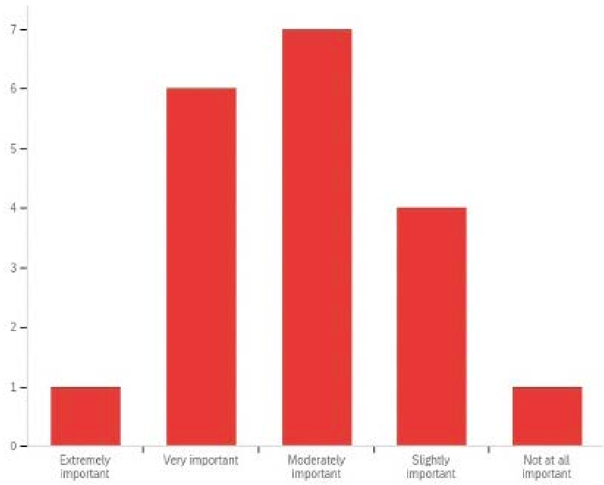

Figure 1.2. Importance of OSIG executive position membership component of the residency application, reports as the number of faculty advisors who selected each answer.
Importance of membership on executive board as a component of residency application.

19 advisors who responded believe this to be extremely important, while 6 (32%) deem this very important, 7 (37%) deem this moderately important, 4 (21%) believe this to be slightly important, and 1 (5%) believes this to be not at all important (Figure 1.2). With regards to mentorship, 20 advisor responses were recorded, with 12 (57.9%) reporting that students within their OSIG group are paired directly with faculty mentors, with 3 (27%) of schools pairing their students in the 1st year of medical school, 5 (45%) pairing in the 2nd year, and 3 (27%) pairing in the 3rd year.

In assessing the application and match rates within each program, there were 17 responses total. On average, the schools surveyed had 5.41 + 2.53 students from the class of 2020 apply to orthopedic surgery residency programs during the 2019-2020 application cycle (Table 2). There were 4.76+2.82 from each school who successfully matched into orthopedic residency programs in the 2019-2020 application cycle (Table 2). Specifically within OSIG, faculty advisors reported an average of 5.35+2.58 students who applied to orthopedic surgery residency, with an average of 4.76+ 2.82 students within OSIG successfully matching into orthopedic residency programs in the 2019-2020 application cycle (Table 2). When comparing rates between overall student applications and OSIG applications, the match rate for all students at the schools surveyed (n=17) was determined to be 81.21% (sd = 27.041) while the match rate for all students within OSIG was slightly higher at 82.39% (sd = 27.471, $p<0.05$) (Table 3). Importantly, there was insufficient representation of applicants who were not involved in their school's OSIG; only one student who applied to orthopedic residency with no involvement in their OSIG program failed to match into orthopedic surgery residency.

Table 2. T-Test Statistics Evaluating the Number of Applications and Matches Among Each Program, As Well as Each Individual OSIG

	N	Mean	Std. Deviation	Std. Error Mean
Number Applied	17	5.41	2.526	.613
Number Matched	17	4.76	2.818	.683
Number in OSIG who Applied	17	5.35	2.548	.618
Number in OSIG who Matched	17	4.76	2.818	.683

Of all the students who applied to orthopedic surgery residency programs across all schools surveyed, 98.9% (sd = 4.851) were members of orthopedic surgery interest groups, and of all the students who successfully matched into orthopedic surgery residency programs in the 2019-2020 cycle, 100% ($p<0.05$) of students were involved in OSIG (Table 3). Among the OSIG groups that paired students with faculty mentors, the match rate was found to be 88.93%. The match rate among those groups that did not pair students with faculty mentors was found to be 88.0%. There was no statistically significant difference between the two ($p=0.55$).

DISCUSSION

The authors of this study set out to establish the role that faculty mentorship and involvement in OSIG may play in the orthopedic surgery residency application process, and evaluate OSIG as an avenue for providing formal mentorship to students. In doing so, we ascertained a general understanding of the structure and initiatives of OSIGs across various allopathic and osteopathic

Table 3. T-Test Statistics Evaluating the Match Rate (%) Among Each School, Each OSIG Program, As Well as the Percentage of Applicants and Percentage of Successfully Matched Students Who Were Involved With Their School's OSIG

	N	Mean	Std. Deviation	Std. Error Mean
School Match Rate	17	81.21	27.041	6.558
OSIG Match Rate	17	82.39	27.417	6.650
Percentage Applied and involved in OSIG	17	98.82	4.851	1.176
Percentage Matched and Inolved in OSIG	17	100.00	.000a	.000

a. t cannot be computed because the standard deviation is 0 medical programs in the United States. The majority of groups consist of less than 25 student members, with relatively small executive boards setting up numerous OSIG events and initiatives. Clinical/surgical shadowing, faculty mentorship, and residency application guidance proved to be the most commonly emphasized initiatives, suggesting that faculty members and students within OSIG believe these to be the vital components of meaningful undergraduate medical education. Alpha Omega Alpha (AOA) status, USMLE step 2 CK score, and Step 1 score are known to be criteria most strongly associated with receiving interview offers for students applying to orthopedic surgery residency.[14] On the surface, this may suggest some limitation in the role that an OSIG can play in determining a student's success as an applicant. However, this could also suggest that OSIG groups use a targeted approach in order to maximize students' ability to achieve success; namely, by improving clinical skills and knowledge via shadowing and mentorship initiatives.

The results of this study suggest that faculty mentors believe student involvement in OSIG is an important component of the residency application and a successful match. Leadership positions within OSIG, however, are not perceived as being equally important. While involvement within OSIG may not be a heavily emphasized component for program directors assessing applications, the leadership experience and knowledge gained may indirectly provide benefit to a student's application. One study of medical students involved with an OSIG reported that OSIG members had increased interest in musculoskeletal medicine, confidence in their ability to perform orthopedic related exams, and better relationships with residents and attendings after joining the group.[9] The latter may contribute to a student's ability to successfully rotate as a third year medical student, collect strong letters of recommendation, and leave a positive impression during away rotations. Data has shown that spending time on an away rotation improves a student's chance of matching into that program by a factor of 1.5.[5] While the results of our study demonstrate faculty advisors believe involvement in OSIG to be an important component of the application process, this is likely related to the skills and knowledge that a student can gain from the initiatives set forth by OSIG more so than just the reporting of the involvement alone. With COVID-19, there are universal rules regarding no away rotations for 2020 applicants and consideration for only one away rotation for the 2021 applicant. Thus, the importance of meaningful clinical exposure through OSIG is increasingly important.

Regarding mentorship, 57.9% of the organizations surveyed directly pair their students with faculty mentors for guidance throughout undergraduate medical education. This seems to align well with established research. Prior studies have shown that orthopedic surgery residents believe mentorship to be superior to online resources for navigating the application process, and that they achieved highest satisfaction with their mentor-mentee experience when there was a formal program in place.[6,18] Although only 50% of orthopedic surgeons reported formal mentorship in their undergraduate medical education, 84.2% believed that their mentor played an integral role in determining their subspecialty.[4] The importance of mentorship has even been found to extend beyond the undergraduate level; strong mentorship is one of the most important factors in an applicant's decision when picking a residency program.[15] Another study proves that mentorship is important for trainees in multiple specialties, as the majority of internal medicine residents described their experience with mentorship as having a meaningful impact on their professional development.[13]

This in mind, using OSIG as a conduit for formal mentorship programs can maximize student satisfaction throughout the application process and help students find success during their years as a resident. Our findings within this OSIG survey suggest that mentorship is a highly emphasized initiative but that formal mentorship is only utilized by slightly above 50% of OSIG programs we surveyed. This would be an important initiative to develop. Furthermore, there was no statistically significant difference between the match rates of students in OSIG who were paired with a mentor and students who were not paired with a mentor. As a result, we fail to accept our hypothesis that mentorship would significantly improve a student's chances of matching into orthopedic surgery residency programs. The lack of significance may be attributed to this pilot study's small sample size. Despite this, it is still worth considering the implementation of formal mentorship programs within OSIGs in order to maximize student satisfaction and success throughout the application process.

With regards to overall match rates, our findings suggest the benefit of OSIGs within medical school extracurricular offerings. Specifically, the match rate among students within OSIGs was significantly higher than the national average, suggesting an important benefit of OSIG membership. According to the National Resident Matching Program (NRMP), the 2020 national match rate for orthopedic surgery residency was 70.8% compared to 82.4% for the students involved in OSIG reported by our study.[10] Though this is striking, our study only found a 1% difference in match rates between students involved in OSIG and those who were not. The small difference found is likely due to the present study's small sample size, however, this study still indicates that OSIG involvement has value. Another interesting point is the comparison between OSIG match rates and that of interest groups for other subspecialties within medicine. For example, 75% of neurosurgery student interest group (NSIG) members matched into neurosurgery residency.[1] While these two fields are inherently different, it is worth noting the relatively higher match rate among students within OSIG vs NSIG. This could indicate a greater impact on student interest group involvement within the field of orthopedics compared to other subspecialties or could be a result of uniquely strong mentorship in orthopedics. Another intriguing finding is that 100% of students in our study who matched into orthopedic residency programs during the 2019-2020 application cycle were involved in their schools orthopedic surgery interest group. This further adds to the suggestion that involvement within OSIG does play a role in students' success in the residency application process.

There were several limitations to this study. First, the study's survey design likely limited the final sample size. This survey was sent to over 140 medical programs across the country and received 28 responses. Of those responses, some short-answer questions were unanswered. The sample size must be taken into account when considering the generalizability of the study's findings. However, we cannot confirm the existence of OSIG at each institution or that the survey was received by an individual who could answer the questions. Furthermore, several of the survey questions did not offer an option for 0 (zero) or a numerical option greater than 10 (ten), thus some values may be slightly skewed due to lack of applicable options.

Further studies may utilize this study's results to broaden the range of knowledge to a greater number of schools. This also suggests a potential for comparison between undergraduate student interest groups within different subspecialties of medicine. Studies can investigate match rates among groups, as well as other metrics of successful matching into one's desired subspecialty.

CONCLUSION

In review, this pilot study indicates the importance of student involvement in OSIG as a conduit for clinical exposure and formal mentorship throughout their undergraduate medical education. Despite a small sample size, the data suggests that students are more likely to match into orthopedic residency programs when involved in OSIG. This can be used to increase the integration of mentorship programs within medical schools throughout the United States with the hopes of improving student preparedness throughout the application process. It can also improve the initiatives that OSIGs emphasize to create a targeted approach that maximizes their members' chances of becoming a competitive residency applicant.

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EDUCATIONAL FACTORS AND FINANCIAL IMPLICATIONS OF MEDICAL STUDENTS CHOOSING AND MATCHING INTO ORTHOPEDIC SURGERY

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ABSTRACT

Background: Mentorship and research have been shown to be important decision factors influencing medical students to pursue a particular specialty. The cost of applying to orthopedic surgery residency is at an all-time high. The purpose of this study is to identify the factors which increase the likelihood of medical students matching into orthopedic surgery, identify the timing and strength of impact these factors have on medical students' career choices, determine how many students have chosen orthopedic surgery prior to beginning medical school, and compare the financial impact of applying to orthopedics.

Methods: 608 medical students were surveyed 5 times during medical school (at the start of M1, M2, M3, M4 year and after the match process) to identify ongoing factors that influence their career choice and ultimately matching in orthopedic surgery. Unadjusted odds ratios and cost analysis were used to determine the factors influencing specialty choice. Level of evidence: III

Results: Students who matched into orthopedic surgery were more likely to be mentored by an orthopedic surgeon at all 5 survey points (M1 OR=30.93, M2 OR=12.38, M3 OR=17.96, M4 OR=65.2, Match OR=215.45) and involved in orthopedic surgery research at the last 4 survey points (M2 OR=20.05, M3 OR=14.00, M4 OR=12.00, Match OR=1566.60) compared to students who did not match into orthopedic surgery. 10 out of 19 students (52.6%) who matched into orthopedic surgery listed the specialty as their preference in the M1 survey. Students who matched into orthopedic surgery spent $8,838.80 on applications and interviews, while students applied to and matched into other specialties spent an average of $6,173.4 (p-value=0.007).

Conclusion: Many students have a predetermined plan to enter orthopedic surgery prior to medical school. Mentorship and research are important factors increasing students' interest in orthopedic surgery and ultimately leading to a successful match process. Going through the orthopedic surgery match process is significantly more expensive than other specialties.

Level of Evidence: IV

Keywords: residency, education, financial

INTRODUCTION

Orthopedic surgery is one of the more competitive specialties[1] therefore, it's important to identify the factors which may influence a student's decision to pursue orthopedic surgery and then successfully match into their desired specialty. Many studies have looked to identify the factors influencing specialty choice, however most are single, cross-sectional studies with limited conclusions.[10,12,26,29] There are a few studies looking at specialty groups, such as primary care[26] and surgery,[7,27] and these studies all identified that mentorship within their specialty had a positive correlation in pursuing their specialty. Berger et al. found research to be a key factor for entering into surgical specialties.[7] This study is a continuation of that previous work and includes a few of the same participants. However, that paper analyzed all surgical specialties and only included one medical school class which was still in their third year. In an orthopedic surgery specific study, Johnson et al. found many students know they want to specialize in orthopedic surgery before entering medical school and role models were influential for specialty choice. They also suggested there may be differences between men and women, and the timeframe they become interested in orthopedic surgery.[18]

Applying for residency through the ERAS process is very expensive; the average student who matched into orthopedic surgery in 2015 spent a total of $5414.54 on applications and travel expenses,[9] mainly due to an increase in applications. In 2006, the average number of programs matched orthopedic applicants applied to was

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

Sources of Funding: No sources of funding declared.

48.4, rising to 83.1 by 2017.[19] Applicants who see themselves as weaker applicants are applying to significantly more programs and doing more away rotations,[19] thus increasing expenses for the applicant and the number of applications each program receives. Therefore, it benefits both program directors and applicants to be aware of the factors influencing students to pursue a career in orthopedic surgery. The significant costs for students applying to numerous orthopedic surgery programs has been well described, however, it has not been compared to students applying to other specialties. During the 2020-2021 residency interview season the AAMC recommended all interviews to be held virtually.[5] Since then, many proposed changes for future cycles have been proposed including, interview[24] and application caps,[15] offering virtual and in person interviews. Therefore, a robust cost analysis of the traditional in person model is imperative for future decision making on how to best conduct residency interviews as many recent papers cite decreased expenditures as a reason to continue virtual interviews but none include a thorough analysis of the decreased cost[5,11,30,31] and only one included data comparing the cost of in-person and virtual interviews for a small cohort of applicants during the COVID-19 pandemic.[6]

Rationale

The first reasons for conducting this study is the fact that there are limited studies on the influential factors for a medical student's decision to pursue orthopedic surgery and ultimately matching into an orthopedic surgery residency, all of which are single cross-sectional observational studies.[8,18,28] These studies begin to identify common themes yet leave a lot of room for further investigation on the key factors and when they are important. Secondly, it is necessary to identify when students are becoming interested in orthopedic surgery thus allowing potential interventions to increase interest to be effective. Finally, with the recent change to virtual residency interviews due to COVID-19 it is necessary to have a robust evaluation of the financial impact that the traditional in person model had on applicants allowing future decision to be made. The first aim of this study is to evaluate students who have successfully matched into orthopedic surgery to identify the factors that influenced them to choose orthopedic surgery, as well as the identify the timing and strength of impact for these factors compared to their peers who did not match into orthopedic surgery. The second aim of this study is to demonstrate the financial impact of matching into orthopedic surgery compared to other specialties.

METHODS

Using a retrospective cohort method as follow up to preliminary findings from by Berger et al.,[7] this study was granted exception status by our Institutional Review Board. There was no source of funding for this study. All medical students (608) who matriculated at our institution between 2013 and 2016 and thus graduated between 2017-2020 were eligible to participate (152 per class). 5 surveys were distributed to each study participant. The M1 survey was administered during orientation week at the start of medical school. Subsequent surveys (M2, M3, M4) were administered to students at the beginning of each school year. The final survey was administered at graduation. The surveys were based on year in medical school (M1 = first year, M2 = second year, M3 = third year, M4 = fourth year, post-match = graduation). Data

Table 1. Demographic Information For All Study Participants That Completed M1 Surveys Separated by Case Control Groups at Matriculation

Study Demographics	All Students (%)	Orthopedics Matches (%)	Students interested in orthopedics but match another specialty	All Student who matched into a specialty other that orthopedics
Age at matriculation	23.6	23.7	22.55	23.57
Male	299 (55.9)	15 (78.9)	36 (72.0)	284 (54.9)
White	373 (75.4)	16 (88.9)	37 (77.1)	357 (69.1)
Married	78 (14.6)	2 (10.5)	8 (15.7)	76 (14.7)
No Children	517 (96.4)	10 (89.5)	49 (96.0)	500 (96.7)
Family in Medicine	113 (21.1)	5 (26.3)	12 (23.5)	108 (20.9)
Family in Orthopedics	38 (7.1)	2 (10.5)	2 (22.96)	5 (0.97)
Total in Cohort	536	19	51	517

Table 2. Survey Responses For Experimental Variables For Students That Matched Into Orthopedic Surgery

Orthopedic Matches Demographics (Group A)	M1 (%)	M2 (%)	M3 (%)	M4 (%)	Match (%)
Mentor	2 (12.5)	10 (62.5)	10 (66.7)	7 (77.8)	18 (85.7)
Mentor in Orthopedics	2 (12.5)	5 (31.3)	5 (33.3)	6 (66.7)	18 (85.7)
Research	6 (31.6)	14 (87.5)	12 (80.0)	5 (62.5)	14 (93.3)
Research in Orthopedics	2 (10.5)	8 (50.0)	7 (46.7)	3 (37.5)	13 (86.7)
Yes, debt from undergrad	6 (31.6)				
Yes, debt from med school	14 (73.7)	10 (62.5)	10 (66.7)	8 (72.7)	12 (85.7)
Yes, debt impact on choice	7 (38.9)	7 (43.8)	6 (40.0)	3 (33.3)	9 (69.2)
Selected orthopedics for that survey	10 (52.6)	11 (68.8)	8 (53.3)	8 (88.9)	22 (100.0)
Total Responses	19	16	15	11	22

collection began in 2013 and includes the matriculating classes of 2013, 2014, 2015, and 2016. The questions on the survey were derived from information collected during discussions with medical students and residents, regarding the factors they felt influenced specialty preference, as well as a literature review of similar surveys.[10,17,18,26,27] The surveys included a list of specialty choices, along with questions regarding demographics, finances, debt levels, academic history, extracurricular activities, history of physician shadowing, previous or current mentorship, and a personal and lifestyle preferences Likert scale. Each survey was compared to the student's previous responses, allowing for a longitudinal analysis.

Descriptive statistics, such as age, marital status, family, and debt status, for the study population, were calculated. Participants were then stratified into students who matched into orthopedic surgery (Group A-Table 2), students who stated they planned to enter orthopedic surgery at any point during medical school but matched into another specialty (Group B-Table 3), and students who matched into a specialty other than orthopedic surgery (Group C-Table 3). Group C includes all students in group B, as well as all students who never stated they wanted to pursue orthopedic surgery. Odds ratios were calculated to determine the likelihood of a student matching into orthopedic surgery or another specialty (Group A compared to Group C). Odds ratios were also calculated for students who matched into orthopedic surgery, compared to students who indicated plans to pursue orthopedic surgery, but then matched into another specialty (Group A compared with Group B). The number of programs applied to, number of interviews received, and interviews attended were compared between the students who matched into orthopedic surgery and the students who matched into other specialties. These were compared using two-tailed t tests (Group A compared to Group C). These results were then used to calculate the

Table 3. Survey Responses for Experimental Variables for Students That Were Stated They Were Pursuing Orthopedic Surgery at Some Point During Medical School But Matched Into Another Specialty

Non-orthopedic Matches that were interested in orthopedic in medical school Demographics (Group B)	M1 (%)	M2 (%)	M3 (%)	M4 (%)	Match (%)
Mentor	4 (8.89)	24 (53.3)	21 (56.8)	23 (67.6)	25
Mentor in Orthopedics	0 (0.00)	10 (22.2)	11 (29.7)	8 (23.5)	0 (0.00)
Research	33 (64.7)	28 (62.2)	28 (75.7)	11 (64.7)	18
Research in Orthopedics	12 (23.5)	13 (28.9)	15 (40.5)	5 (28.4)	1
Yes, debt from undergrad	14 (27.5)				
Yes, debt from med school	43 (84.3)	35 (77.8)	27 (73.0)	22 (68.7)	21 (87.5)
Yes, debt impact on choice	20 (40.0)	20 (44.4)	13 (39.4)	9 (30.0)	7 (41.2)
Selected orthopedics for that survey	29 (56.9)	27 (60.0)	18 (48.6)	9 (25.0)	0 (0.00)
Total Responses	51	45	37	36	37

Table 4. Survey Responses For Experimental Variables For All Students That Matched Into a Specialty That Was Not Orthopedic Surgery

All non-orthopedic matches demographics (Group C)	M1 (%)	M2 (%)	M3 (%)	M4 (%)	Match (%)
Mentor	72 (17.2)	199 (42.9)	182 (44.8)	195 (57.9)	257 (70.0)
Mentor in Orthopedics	2 (0.46)	17 (3.54)	11 (2.7)	10 (3.0)	0 (0.00)
Research	314 (60.7)	266 (57.5)	200 (49.0)	82 (39.0)	169 (69.8)
Research in Orthopedics	24 (4.60)	22 (4.75)	24 (5.9)	10 (4.8)	1 (0.41)
Yes, debt from undergrad	199 (38.5)				
Yes, debt from med school	437 (84.5)	398 (83.3)	341 (84.0)	284 (85.0)	227 (76.9)
Yes, debt impact on choice	184 (35.6)	183 (38.4)	154 (38.2)	112 (34.1)	105 (44.1)
Selected orthopedics for that survey	29 (5.6)	27 (5.83)	18 (4.4)	9 (2.7)	0 (0.00)
Total Responses	517	482	411	339	411

Table 5. Unadjusted Odds Ratios Comparing the Students That Matched Into Orthopedic Surgery Compared to the Students Who Matched Into Another Specialty

Orthopedics matches vs. non-orthopedics matches	M1 OR (95% CI)	M2 OR (95% CI)	M3 OR (95% CI)	M4 OR (95% CI)	Match OR (95% CI)
Male	**3.06 (1.01-9.36)**				
White	2.68 (0.61-3.52)				
Family in medicine	1.35 (0.48-3.84)				
Family in Orthopedics	**12.0 (2.20-66.58)**				
Married	0.68 (0.15-3.01)	0.69 (0.24-2.02)	1.28 (0.40-4.11)	2.73 (0.67-11.17)	0.61 (0.20-1.87)
Children	3.46 (0.74-16.19)	1.87 (0.41-8.70)	2.37 (0.51-11.08)	3.64 (0.72-18.51)	0.79 (0.17-3.69)
Mentor	0.69 (0.15-3.10)	2.22 (0.79-6.21)	2.46 (0.83-7.33)	2.55 (0.52-12.45)	2.94 (0.83-10.30)
Mentor in Orthopedics	**30.93 (4.06-235.72)**	**12.38 (3.87-39.60)**	**17.95 (5.25-61.39)**	**65.2 (14.23-298.73)**	**215.45 (55.23-840.48)**
Research	0.29 (0.11-0.89)	**5.18 (1.16-23.07)**	4.16 (1.16-14.96)	2.60 (0.61-11.18)	6.04 (0.78-46.84)
Research in Orthopedics	2.41 (0.53-11.07)	**20.05 (6.89-58.41)**	**14.00 (4.68-41.85)**	**12.00 (2.51-57.45)**	**1566.5 (133.23-18418.61)**
Debt from undergrad	0.73 (0.28-1.97)				
Debt from medical school	0.51 (0.18-1.46)	0.33 (0.12-0.95)	0.38 (0.13-1.15)	0.47 (0.12-1.83)	1.80 (0.39-8.22)
Debt affects specialty choice	1.12 (0.43-2.95)	1.25 (0.46-3.41)	1.03 (0.36-2.97)	0.69 (0.18-2.65)	2.85 (0.85-9.51)

Bolded values denotes statistical significance of $p < 0.05$

Table 6. Unadjusted Odds Ratios Comparing the Students That Matched Into Orthopedic Surgery Compared to the Students Who Did Not Match Into Orthopedic Surgery But Stated at Some Point During Medical School That They Were Pursuing Orthopedic Surgery

Orthopedics matches vs. non-orthopedics matches that were interested in Orthopedics in medical school	M1 OR (95% CI)	M2 OR (95% CI)	M3 OR (95% CI)	M4 OR (95% CI)	Match OR (95% CI)
Male	1.45 (0.41-5.16)				
White	2.37 (0.47-11.98)				
Family in medicine	1.16 (0.35-3.89)				
Family in Orthopedics	5.88 (0.50-69.04)				
Married	0.63 (0.12-3.29)	0.36 (0.11-1.22)	0.67 (0.18-2.54)	2.45 (0.52-11.60)	**1.00 (0.25-4.08)**
Children	2.88 (0.37-22.08)	1.71 (0.28-10.50)	1.26 (0.21-7.79)	3.33 (0.47-23.78)	1.38 (0.17-11.15)
Mentor	1.47 (0.24-8.89)	1.46 (0.45-4.70)	1.52 (0.43-5.35)	1.67 (0.29-9.42)	2.64 (0.64-36.00)
Mentor in Orthopedics	6.43 (0.54-76.33)	1.59 (0.45-5.66)	1.18 (0.32-4.27)	**6.50 (1.32-32.08)**	227.50 (18.98-2726.11)
Research	0.25 (0.08-0.76)	4.25 (0.86-21.04)	1.28 (0.38-4.30)	0.91 (0.16-5.20)	6.22 (0.69-55.77)
Research in Orthopedics	0.38 (0.08-1.90)	2.46 (0.76-7.96)	1.28 (0.38-4.30)	1.44 (0.30-9.42)	**227.5 (18.99-2726.11)**
Debt from undergrad	1.22 (0.39-3.84)				
Debt from medical school	0.52 (0.15-1.85)	0.48 (0.14-1.63)	0.74 (0.20-2.71)	1.21 (0.26-5.56)	0.86 (0.13-5.88)
Debt affects specialty choice	0.95 (0.32-2.88)	0.97 (0.31-3.07)	1.03 (0.29-3.57)	0.88 (0.19-4.09)	5.46 (1.26-23.77)

Bolded values denotes statistical significance of $p < 0.05$

estimated cost of applications, interviews, and total expenses. All calculations were done using SPSS software version 23.0 (IBM-SPAA, New York, USA).

RESULTS

608 students were eligible to participate from 4 separate graduating classes. The number of responses and response rates for the M1, M2, M3, M4, and match surveys were 536 (88.2%), 482 (79.3%), 425 (70.0%), 348 (57.2%), 433 (71.2%) respectively (Appendix Table A). During this time frame 580 students went through the NRMP match process,[20-23] thus adjusting the match response rate to 74.7%. There were 28 students who matched into orthopedic surgery from the eligible study participants.[20-23] Of these 28, 19 completed all five surveys (64%) as demonstrated in Table 1 and 2, 2 did not complete the M1 survey but completed the subsequent surveys (Table 2), and one student only completed the match survey, bringing the total to 22 completed match surveys (response rate=79%) as demonstrated in Match Column of Table 2.

Factors Influencing Choosing and Matching into Orthopedics

Significant factors associated with students more likely to match into orthopedic surgery, as compared to their classmates who did not match into orthopedic surgery, were male gender (OR=3.06, 95% CI=1.01-9.36), family in orthopedic surgery, (OR=12.05, 95% CI=2.18-66.58), performing research in any specialty during M2 and M3 year (M2 OR=5.18, 95% CI 1.6-23.07, M3 OR=4.16, 95% CI=1.16-14.96), performing orthopedic surgery research during M2, M3, M4 and Match surveys (M2 OR=20.05, 95% CI=6.88-58.41, M3 OR=14.00, 95% CI=4.68-41.85, M4 OR=12.00, 95% CI= 2.51-57.45, Match OR=1566.60, 95% CI=133.23-18419.00), and having an orthopedic surgery mentor was significant during M1, M2, M3, M4, and Match surveys (M1 OR=30.93, 95% CI=4.06-235.72,

Table 7. Unadjusted Odds Ratios Comparing the Students That Matched Into Orthopedic Surgery But Initially Reported an Interest in Another Specialty Compared to the Students Who Did Not Match Into Orthopedic Surgery

Orthopedics matches that developed interest in orthopedics during medical school vs. non-orthopedics matches	M1 OR (95% CI)	M2 OR (95% CI)	M3 OR (95% CI)	M4 OR (95% CI)	Match OR (95% CI)
Male	1.02 (0.27-3.85)				
White	1.34 (0.28-6.42)				
Family in medicine	0.20 (0.011-3.44)				
Family in Orthopedics	4.90 (0.25-95.16)				
Married	0.73 (0.090-5.88)	0.75 (0.14-4.19)	1.41 (0.27-7.37)	4.09 (0.67-24.95)	0.92 (0.20-4.25)
Children	3.68 (0..44-31.07)	**5.63 (1.00-31.75)**	2.57 (0.30-22.15)	2.55 (0.29-22.71)	0.86 (0.010-7.37)
Mentor	1.60 (0.32-8.12)	2.66 (0.48-14.69)	3.08 (0.59-16.05)	9.48 (0.53-169.58)	1.49 (0.30-7.30)
Mentor in Orthopedics	**61.86 (7.60-503.85)**	5.45 (0.60-49.21)	**14.36 (2.51-82.32)**	**163.00 (17.40-1527.1)**	**125.68 (23.38-675.59)**
Research	5.17 (0.64-41.67)	3.70 (0.43-31.95)	6.24 (0.74-52.29)	3.12 (0.28-34.98)	2.58 (0.30-21.80)
Research in Orthopedics	2.93 (0.35-24.82)	**10.02 (1.74-57.71)**	**12.00 (2.54-56.69)**	5.00 (0.51-48.96)	**1446 (80.54-25961)**
Debt from undergrad	1.27 (0.34-4.82)				
Debt from medical school	1.46 (0.18-11.87)	1.00 (0.12-8.72)	0.48 (0.091-2.51)	0.70 (0.077-6.42)	2.71 (0.14-50.97)
Debt affects specialty choice	1.41 (0.37-5.33)	3.21 (0.58-17.72)	1.16 (0.26-5.27)	2.76 (0.45-16.76)	3.80 (0.39-37.06)

Bolded values denotes statistical significance of $p < 0.05$

M2 OR=12.38, 95% CI=3.87-39.60, M3 OR=17.96, 95% CI=5.25-61.39, M4 OR=65.2, 95% CI=14.23-298.73, Match OR=215.45 95% CI=55.23-840.48) (Table 5). Notable variables that were not significantly different between the students who matched into orthopedic surgery and those who matched into another specialty were; marital status, children, debt from undergrad or medical school, or if debt influenced specialty choice (Table 5). All survey results are available in attached appendix. Students who were interested in orthopedics, but matched into a specialty other than orthopedic surgery, were more likely to have performed non-orthopedic surgery research before medical school (OR=0.25, 95% CI=0.08-0.78) (Table 3). During the M4 and match surveys, the group that matched into orthopedic surgery were more likely to have an orthopedic mentor (M4 OR=6.50, 95% CI=1.32-32.08, Match OR=2370.0, 95% CI=234.78-23,924) (Table 3). The group that matched into orthopedic surgery was more likely to be doing orthopedic research at the time of the match survey (Match OR=227.5, 95% CI=18.99-2726.1) and also stated that debt affected specialty choice (Match OR=5.46, 95% CI=1.26-23.78) (Table 6).

Developing an Interest in Orthopedics

10 out of 19 students (52.6%) who matched into orthopedic surgery and completed both the M1 survey and the Match survey, listed the specialty as their preference in the M1 survey. 8 out of those 10 students (80%) never indicated an interest in another specialty on any survey completed. The other two students initially indicated in interest in orthopedic surgery, then switched to another specialty, but then ultimately matched into orthopedic surgery. 9 out of the 19 (47.3%) switched from pursuing another specialty into orthopedic surgery. There were two additional students who only completed the match survey without completing any prior surveys.

Table 8. Number of Programs Applied to, Interview Invites Received, Interviews Attended, Rank List and the Cost Associated With Them For Orthopedic Surgery Matches Compared to Non-Orthopedic Matches Students

	Orthopedics Match (std dev) Cost ($) N=16	Non-orthopedics Match (std dev) Cost N=277	P-value
Programs applications	**82.3 (17.0) $1818.80**	**36.9 (20.7) $638.40**	**<0.001** **<0.001**
Interviews received	**23.2 (8.6)** -	**16.4 (8.0)** -	**0.009**
Interviews attended	**15.6 (3.6) $7,020.00**	**12.3 (4.7) $5,535.00**	**0.003** **0.009**
Total Cost	**$8,838.80**	**$6,173.40**	**0.007**

Bolded values denotes statistical significance of p <0.05

The cohort of 9 students who developed an interest in orthopedic surgery during medical school and matched into an orthopedic surgery were associated with having mentors in orthopedics in the M1, M3, M4, and match surveys (Mentor in orthopedics M1 OR=61.86, 95% CI=7.60-503.85, M3 OR=14.36, 95% CI=2.51-82.32, M4 OR=163.00, 95% CI=17.40-1527.1, Match OR=125.68 95% CI=23.38-675.59) as well as doing research within orthopedics during M2, M3, and Match surveys (Research in orthopedics M2 OR=10.02, 95% CI=1.74-57.71, M3 OR=12.00, 95% CI=2.54-56.69, Match OR=1446, 95% CI=80.54-25961) (Table 7).

Cost of Matching into Orthopedics

The total programs applied to, interview invites received, and interviews attended was significantly higher for matched orthopedic applicants, as compared to other specialties with 82.3, 23.2 and 15.6 compared to 36.9, 16.4, 12.3 (p-values=<0.001, 0.009, and 0.003) (Table 8). The average cost for application fees, interview expenses, and total cost for a matched orthopedic surgery applicant was significantly higher than other specialties (Table 8); $1,818.80, $7,020, and $8,838.80 compared to $638.50, $5,535.00, and $6,173.40 (p-values= <0.01, 0.009, and 0.007) (Table 8).

DISCUSSION

Consistent with current literature mentorship and research,[7,25] the impact factors which correlated most with choosing and matching into orthopedic surgery as a specialty are research and mentorship. This study is continuation of a 2017 paper by Berger et al. evaluating trends factors for interest in surgical specialties, but that paper had a small sample size and did not follow the participants until the match process and graduation. Therefore, the current manuscript specifically looks at orthopedic surgery applicants compared to their peers that have all gone through the match process and includes four times the number of study participants. The current study revealed that students who successfully match into orthopedic surgery are involved in research, particularly in their second and third years of medical school. Interestingly, the research does not seem to necessarily be within the field of orthopedic surgery, as students who matched into orthopedic surgery were more likely doing research in any specialty. However, there was a significantly higher likelihood of students who match into orthopedic surgery doing orthopedic surgery research during their M2, M3, M4 years and continuing through the match process. These students also tended to have orthopedic mentors all throughout medical school. Factors unrelated to pursuing orthopedic surgery on any of the surveys were marital status or having children. Consistent with published literature,[18] the first 4 surveys showed burden of debt from undergrad or medical school did not influence students to pursue orthopedic surgery, nor did being married or having children. However, at the match survey, students who matched into orthopedic surgery stated the debt from medical school did influence their decision. Their debt level may have been affected by the cost of applying to the orthopedic surgery match.

Many students decide early on, possibly even before medical school, they want to pursue orthopedic surgery.[18] We found many students knew they wanted to pursue orthopedics prior to medical school, but the majority (52.4%) who matched into orthopedic surgery became interested during medical school. Even though interest in a specialty has been shown to be associated with the clerkship experience in that specialty,[27] many schools do not require students to complete an orthopedic surgery rotation.[8] However, in 2005 the AAMC issued requirements for musculoskeletal education such as disease processes and physical exam be incorporated in the curriculum, but they did not mandate a clinical clerkship in orthopedic surgery. Therefore, opportunities for students to be involved with research and mentorship must be available to all students, starting at the beginning of medical school in order to get exposure to the specialty. These factors may be even more evident for female students, as they were the only demographic significantly under-represented in the group who matched into orthopedic surgery and have been shown to be more influenced by clerkship experiences, rather than experiences before medical school.[18]

There are only minor differences between students who were interested in orthopedic surgery in medical school, yet matched into another specialty, and the ones who matched into orthopedic surgery. Students who do not match into orthopedic surgery were more likely to have performed research in fields other than orthopedic surgery before medical school. They were also less likely to have an orthopedic surgery mentor during the M4 and match survey and were less likely to be doing research at the time of the match survey (Table 3). This further supports the hypotheses that many students have predetermined their specialty choice, prior to starting medical school. Subsequently, this highlights the importance of any early exposure to orthopedics, prior to medical school. One potential, confounder in these results is students that applied to and were unsuccessful in matching into an orthopedic surgery residency program. We are unable to make conclusions on this possible occurrence since the survey only asked what specialty they matched into and if they applied to multiple specialties but did not specifically ask which specialties they applied to, if it was multiple.

Conversely and more likely importantly, the students who initially did not report an interest in orthopedics on their M1 surveys but ultimately matched into it were associated with mentorship by an orthopedic surgeon during the M1, M3, M4, and Match time points and research in orthopedics during the M2, M3, and Match surveys Table 7). These further highlight importance of early exposure to orthopedic surgery through mentorship and providing research opportunities even to students who may not appear to have an initial interest in orthopedics. We are unable to definitively conclude how much affect the specialty of a mentor has on the student. However, these findings support the notion that a mentor's specialty likely affects the future career choice of the students they are mentoring to some degree. Alternatively, it is certainly possible that the students are searching out mentors and research project on their own. However, during the M1, and M2 surveys students have not completed any clinical rotations including rotations in orthopedic surgery to allow them to get to know and to work with orthopedic surgeons. Therefore, we suggest that the specialty of mentors has some effect on students' future career choice, but the exact amount is unknown and likely depends on each mentor and student. It has been demonstrated by Anderson et al. that exposure to surgical fields early in medical school increases interest and likelihood of matching into surgical specialtie,[4] but there is currently no literature evaluating the effect that mentors have on students' career choice.

The number of orthopedic surgery residency programs applicants are applying to has consistently increased over the past few decades,[13] leading to increased costs, as application fees are $99 for 1-10 programs, then $16 for each program between 11-20, then $20 for each program between 21-30, and then each application beyond 30 costs $26 each.[3] This fee schedule is designed to deter applicants from applying to more programs than necessary. However, it does not seem to be effective, as we found orthopedic applicants are applying to 82.3 programs. Compare this to their classmates entering other medical specialties, who are applying to a mean of 36.9 programs. In other words, it costs the average applicant who matches into orthopedics surgery $1,818.80 to apply for residency, while applications for matching to other specialties cost an average of $638.40. More applications lead to more interviews being offered and more interviews being attended, thus further increasing the cost of matching into orthopedic surgery. These numbers are excellent reference points in the light of recent concerns for further increases of applications by applicants due to less time constraints to conduct virtual interviews due to COVID-19 pandemic in the 2020-2021 interview season. With the potential continuation of this model this paper may become a reference for determining how to proceed.[15] Matched orthopedic surgery applicants in this study received an average of 23.2 interview invites, of which they attended 15.6. While applicants entering other specialties, received 16.4 interview invites and attended 12.3. Therefore, using the mean cost estimate for attending a single interview of $450,[14] the average orthopedic surgery applicant spent $7,020.00 on interview expenses compared to $5,535.00 for applicants of other specialties. Bringing the total cost of matching into an orthopedic surgery residency position to $8,838.80, compared to $6,173.40 for other applicants. A recent study found that it costed their interviewees $0 participate in their virtual interview during the COVID-19 pandemic.[6] With proposed continuation of virtual interviews[31] the data presented in this manuscript is an invaluable resource for program directors and coordinators to be able to evaluate the effects of any changes they are considering to their application and interview process as well as governing bodies when determining the future recommendations.

The effort to combat increased expenses of applying for orthopedic surgery residency is two-fold, students can and should get involved in research and mentorship in medical school. As it has been shown that less competitive applicants apply to more programs and do more costly away rotations.[13] Additionally, programs can be more transparent on with their historical averages for grades, scores, and research involvement, thus allowing applicants to be more selective and only apply to programs where they are competitive. This will decrease the application burden on program directors and will allow for a more thorough review of each application.[19] This is imperative as the USMLE step 1 exam moves to pass/fail,[2] thus removing one variable used for interview selection. A majority of program directors in neurosurgery report that making USMLE Step 1 pass/fail will make objective evaluation of residency candidates more difficult and will increase the weight put on USMLE Step 2 and medical school reputation.[16] Consequently, the best way to decrease application expenses is to decrease the number of unnecessary applications, thus allowing residency programs a more thorough and careful selection process to match their program's mission.

There are some minor limitations with this paper. Due to the fact that this study was conducted with the graduating classes of 2017-2020 with conclusion of data collection in May 2020 we are unable to evaluate the impact of COVID-19 on the residency application and interview process, however since the data collected was not altered by the pandemic it serves as an excellent resource for future research and planning of upcoming cycles. Also, due to the observational design of the study, we cannot definitively conclude causality with this study, such as students who perform research in orthopedic surgery are more likely to be interested in orthopedic surgery versus students who are interested in orthopedic surgery are more likely to perform research in orthopedic surgery. Any data discrepancies are due to participants choosing not to answer certain survey questions. There is potential sampling bias, due to only surveying students in one medical school and the overall small number of students matching into orthopedic surgery. This was minimized by surveying multiple classes and pooling the results. This study does not identify students who applied for but did not match into orthopedic surgery. Those students were counted with the specialty they ultimately matched into or positions obtained using the SOAP process. Therefore, we are unable to compare students who applied to and matched orthopedic surgery and those that applied for and were not successful in matching into orthopedic surgery. Despite the significant findings from this study, minimal differences between the students who matched into orthopedic surgery and the students who were planning to specialize in orthopedic surgery but matched into a different specialty suggest there are other variables, such as grades and USMLE scores, determining whether students pursue and match into orthopedic surgery. A future area of study would be to evaluate students that successfully matched into orthopedic surgery compared to those that applied but did not match as this would allow us to identify characteristics and experiences that influence a successful match. As this study did not explicitly ask what other specialties a student had applied to.

This study provides longitudinal insight into medical students pursuing a career in orthopedic surgery. Although many students who match into orthopedic surgery know they are interested in the specialty prior to medical school, a significant number of students still become interested during these formative years. Despite these differences, the students who matched into orthopedic surgery are doing research and have mentors within the specialty at multiple time points throughout medical school, particularly early on. Building on these factors and increasing the transparency of the residency match process can help reverse the trend of increasing application and interview numbers in light of possible continuation of virtual interviews. This would aid both applicants and programs, alike, streamlining the match process and decreasing the financial strain.

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APPENDIX

Table A. Survey Responses For All Study Participants

Study demographics	M1 (%)	M2 (%)	M3 (%)	M4 (%)	MATCH (%)
Age at matriculation	23.62 STD DEV=2.34				
Male	299 (55.9)				
Female	236 (44.1)				
Ethnicity is White	373 (75.4)				
Ethnicity is Non-White	122 (24.6)				
Ethnicity is African American	14 (2.83)				
Ethnicity is Asian	81 (16.4)				
Ethnicity is Hispanic	27 (5.45)				
Married	78 (14.6)	190 (39.4)	77 (21.1)	81 (27.5)	98 (44.3)
Not married	458 (85.4)	292 (60.6)	288 (78.9)	214 (72.5)	123 (55.7)
No children	517 (96.4)	440 (91.7)	343 (94.0)	314 (92.3)	163 (83.6)
At least 1 child	19 (3.54)	40 (8.3)	21 (6.0)	26 (7.6)	32 (16.4)
1 Child	12 (63.2)	31 (77.5)	12 (57.1)	10 (38.4)	17 (53.1)
2 Children	6 (31.6)	8 (19.0)	7 (33.3)	14 (53.8)	14 (43.8)
Greater than 2 children	1 (5.26)	1 (2.38)	2 (9.52)	2 (7.7)	1 (3.1)
Family in medicine	113 (21.1)				
No family in medicine	423 (78.9)				
Family in Orthopedics	38 (7.09)				
No family in Orthopedics	498 (92.9)				
Mentor	74 (17.0)	209 (43.5)	192 (45.6)	202 (58.4)	275 (70.9)
No mentor	361 (83.0)	271 (56.5)	229 (54.4)	144 (41.6)	113 (29.1)
Mentor in Orthopedics	2 (0.460)	17 (3.54)	16 (3.8)	16 (4.7)	18 (4.63)
No mentor in Orthopedics	433 (99.5)	462 (96.5)	405 (96.2)	328 (95.3)	370 (95.4)
Research	330 (61.6)	280 (58.5)	212	87 (39.9)	183 (71.2)
No research	206 (38.4)	199 (41.6)	211	131 (60.1)	74 (28.8)
Research in Orthopedics	31 (5.78)	30 (6.9)	31 (8.0)	13 (6.0)	14 (5.44)
No research in Orthopedics	498 (92.9)	446 (93.1)	389 (92.0)	202 (94.0)	243 (94.6)
Yes, debt from undergrad	205 (38.2)	154 (37.8)	155 (37.0)	101 (38.0)	104 (50.0)
No, debt from undergrad	331 (61.8)	253 (62.2)	264 (63.0)	165 (62.0)	104 (50.0)
Yes, debt from med school	451 (84.1)	342 (84.2)	351 (83.4)	292 (84.6)	239 (77.3)
No, debt from med school	85 (15.9)	64 (15.8)	70 (16.6)	53 (15.4)	70 (22.7)
Yes, debt impact on choice	191 (36.2)	152 (37.5)	160 (39.2)	125 (36.9)	114 (45.4)
No, debt impact on choice	336 (63.8)	253 (62.2)	248 (60.9)	214 (63.1)	137 (54.6)
Selected Orthopedics for that survey	39 (7.28)	38 (7.93)	26 (6.13)	17 (4.9)	22 (5.08)
Did not select Orthopedics for that survey	497 (92.7)	441 (92.1)	398 (93.6)	331 (95.1)	411 (94.9)
Total responses	536	482	425	348	433

Table B. Survey Responses For All Students That Matched Into Orthopedics

Orthopedic Matches Demographics	M1 (%)	M2 (%)	M3 (%)	M4 (%)	MATCH (%)
Age at Matriculation (Std dev)	23.73 (2.80)				
Male	15 (78.9)				
Female	4 (21.1)				
Ethnicity is White	16 (88.9)				
Ethnicity is Non-White	2 (11.1)				
Ethnicity is African American	0 (0.0)				
Ethnicity is Asian	1 (50.0)				
Ethnicity is Hispanic	1 (50.0)				
Married	2 (10.5)	5 (31.2)	4 (26.7)	4 (50.0)	5 (33.3)
Not Married	17(89.5)	11 (68.8)	11 (73.3)	4 (50.0)	10 (66.7)
No children	17 (89.5)	12 (75.0)	13 (86.7)	7 (77.8)	13(86.7)
At least 1 child	2 (10.5)	2 (12.5)	2 (13.3)	2 (22.2)	2 (13.3)
1 child	0 (0.0)	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.00)
2 children	2 (100.0)	1 (50.0)	2 (100.0)	2 (100.0)	1 (50.0)
Greater than 2 children	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (50.0)
Family in medicine	5 (26.3)				
No family in medicine	14 (73.7)				
Family in orthopedics	2 (10.5)				
No family in orthopedics	17 (89.4)				
Mentor	2 (12.5)	10 (62.5)	10 (66.7)	7 (77.8)	18 (85.7)
No mentor	14 (87.5)	6 (37.5)	5 (33.3)	2 (22.2)	3 (14.3)
Mentor in Orthopedics	2 (12.5)	5 (31.3)	5 (33.3)	6 (66.7)	18 (85.7)
No Mentor in Orthopedics	14 (87.5)	11 (68.8)	10 (66.7)	3 (33.3)	3 (14.3)
Research	6 (31.6)	14 (87.5)	12 (80.0)	5 (62.5)	14 (93.3)
No Research	13 (68.4)	2 (1.25)	3 (20.0)	3 (37.5)	1 (6.67)
Research in Orthopedics	2 (10.5)	8 (50.0)	7 (46.7)	3 (37.5)	13 (86.7)
No Research in Orthopedics	17 (89.5)	8 (50.0)	8 (53.3)	5 (62.5)	2 (13.3)
Yes, debt from undergrad	6 (31.6)				
No, debt from undergrad	13 (68.4)				
Yes, debt from med school	14 (73.7)	10 (62.5)	10 (66.7)	8 (72.7)	12 (85.7)
No, debt from med school	5 (26.3)	6 (37.5)	5 (33.3)	3 (33.3)	2 (14.3)
Yes, debt impact on choice	7 (38.9)	7 (43.8)	6 (40.0)	3 (33.3)	9 (69.2)
No, debt impact on choice	11 (61.1)	9 (56.3)	9 (60.0)	8 (72.7)	4 (30.8)
Selected orthopedics for that survey	10 (52.6)	11 (68.8)	8 (53.3)	8 (88.9)	22 (100.0)
Did not select Orthopedics for that survey	9 (47.4)	5 (31.25)	7 (46.7)	1 (11.1)	0 (0.00)
Total Responses	19	16	15	11	22

Table C. Survey Responses For All Students That Were Stated They Were Pursuing Orthopedics at Some Point During Medical School But Matched Into Another Specialty

Non-orthopedic Matches that were interested in orthopedic in medical school Demographics	M1 (%)	M2 (%)	M3 (%)	M4 (%)	MATCH (%)
Age at Matriculation	23.55 (std dev=2.28)				
Male	36 (72.0)				
Female	14 (28.0)				
Ethnicity is White	37 (77.1)				
Ethnicity is Non-White	11 (22.9)				
Ethnicity is African American	1 (9.1)				
Ethnicity is Asian	6 (54.5)				
Ethnicity is Hispanic	4 (36.3)				
Married	8 (15.7)	25 (55.6)	13 (35.1)	11 (28.9)	7 (33.3)
Not Married	43 (84.3)	20 (44.4)	24 (64.9)	27 (71.1)	14 (66.7)
No children	49 (96.0)	41 (91.1)	33 (89.2)	35 (92.1)	18 (90.0)
At least 1 child	2 (4.00)	4 (8.90)	4 10.8)	3 (7.9)	2 (10.0)
1 child	2 (100.0)	3 (75.0)	2 (50.0)	0 (0.0)	1 (50.0)
2 children	0 (0.00)	1 (25.0)	2 (50.0)	3 (100.0)	1 (50.0)
Greater than 2 children	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.0)	0 (0.00)
Family in medicine	12 (23.5)				
No family in medicine	39 (76.5)				
Family in orthopedics	1 (1.96)				
No family in orthopedics	50 (98.0)				
Mentor	4 (8.89)	24 (53.3)	21 (56.8)	23 (67.6)	25
No Mentor	41 (91.1)	21 (46.7)	16 (43.2)	11(32.4)	11
Mentor in Orthopedics	0 (0.00)	10 (22.2)	11 (29.7)	8 (23.5)	0 (0.00)
No Mentor in Orthopedics	45 (100.0)	35 (77.8)	26 (70.2)	26 (76.5)	36 (100.0)
Research	33 (64.7)	28 (62.2)	28 (75.7)	11 (64.7)	18
No Research	18 (35.3)	17 (37.8)	9 (24.3)	6 (35.3)	8
Research in Orthopedics	12 (23.5)	13 (28.9)	15 (40.5)	5 (28.4)	1
No Research in Orthopedics	39 (76.5)	32 (71.1)	22 (59.5)	12 (70.6)	35
Yes, debt from undergrad	14 (27.5)				
No, debt from undergrad	37 (72.5)				
Yes, debt from med school	43 (84.3)	35 (77.8)	27 (73.0)	22 (68.7)	21 (87.5)
No, debt from med school	8 (15.7)	10 (22.2)	10 (27.0)	10 (31.3)	3 (12.5)
Yes, debt impact on choice	20 (40.0)	20 (44.4)	13 (39.4)	9 (30.0)	7 (41.2)
No, debt impact on choice	30 (60.0)	25 (55.6)	20 (60.6)	21 (70.0)	17 (70.8)
Selected orthopedics for that survey	29 (56.9)	27 (60.0)	18 (48.6)	9 (25.0)	0 (0.00)
Did not select Orthopedics for that survey	22 (43.1)	18 (40.0)	(51.4)	27 (75.0)	37 (100.0)
Total Responses	51	45	37	36	37

Table D. Survey Responses For Students That Matched Into a Specialty That Was Not Orthopedics

All non-orthopedic matches demographics	M1 (%)	M2 (%)	M3 (%)	M4 (%)	MATCH (%)
Age at Matriculation	23.57 (std dev=2.50)				
Male	284 (54.9)				
Female	232 (44.9)				
Ethnicity is White	357 (69.1)				
Ethnicity is Non-White	120 (23.2)				
Ethnicity is African American	14 (11.7)				
Ethnicity is Asian	80 (66.7)				
Ethnicity is Hispanic	26 (21.7)				
Married	76 (14.7)	185 (39.7)	91 (22.1)	77 (26.8)	93 (44.5)
Not Married	441 (85.3)	281 (60.3)	320 (77.9)	210 (73.2)	115 (55.5)
No children	500 (96.7)	428 (91.8)	385 (93.9)	306 (92.7)	154 (83.7)
At least 1 child	17 (3.3)	38 (8.15)	25 (6.1)	24 (7.3)	30 (16.3)
1 child	11 (64.7)	33 (86.8)	12 (57.1)	10 (41.7)	15 (50.0)
2 children	4 (23.5)	5 (13.2)	11 (91.8)	12 (50.0)	11 (36.7)
Greater than 2 children	2 (11.8)	0 (0.00)	1 (8.2)	2 (8.3)	4 (13.3)
Family in medicine	108				
No family in medicine	409				
Family in orthopedics	5 (0.97)				
No family in orthopedics	512 (99.0)				
Mentor	72 (17.2)	199 (42.9)	182 (44.8)	195 (57.9)	257 (70.0)
No mentor	347 (83.2)	265 (57.1)	224 (55.2)	142 (42.1)	110 (30.0)
Mentor in Orthopedics	2 (0.46)	17 (3.54)	11 (2.7)	10 (3.0)	0 (0.00)
No mentor in Orthopedics	433 (99.5)	463 (96.5)	395 (97.3)	326 (97.0)	367 (100.0)
Research	314 (60.7)	266 (57.5)	200 (49.0)	82 (39.0)	169 (69.8)
No Research	203 (39.3)	197 (62.5)	208 (51.0)	128 (61.0)	73 (30.2)
Research in Orthopedics	24 (4.60)	22 (4.75)	24 (5.9)	10 (4.8)	1 (0.41)
No Research in Orthopedics	493 (95.4)	441 (95.2)	384 (94.1)	200 (95.2)	241 (99.6)
Yes, debt from undergrad	199 (38.5)				
No, debt from undergrad	318 (41.5)				
Yes, debt from med school	437 (84.5)	398 (83.3)	341 (84.0)	284 (85.0)	227 (76.9)
No, debt from med school	80 (15.5)	80 (16.7)	65 (16.0)	50 (15.0)	68 (23.1)
Yes, debt impact on choice	184 (35.6)	183 (38.4)	154 (38.2)	112 (34.1)	105 (44.1)
No, debt impact on choice	325 (62.9)	294 (61.6)	239 (60.8)	206 (65.9)	133 (55.9)
Selected orthopedics for that survey	29 (5.6)	27 (5.83)	18 (4.4)	9 (2.7)	0 (0.00)
Did not select Orthopedics for that survey	488 (94.4)	436 (94.2)	391 (5.6)	330 (97.3)	411 (100.0)
Total Responses	517	482	411	339	411

DOES IRRIGATING WHILE DRILLING DECREASE BONE DAMAGE?

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ABSTRACT

Background: Heat generated during bone drilling may be associated with thermal necrosis and direct damage, leading to complications after surgery. This preclinical study evaluates the in vivo effects of saline irrigation, drilling device type, and device sharpness on heat generation and bone damage in viable cortical bone.

Methods: Bicortical drilling of each tibial diaphysis from anesthetized research dogs was performed to evaluate temperature and bone damage using five different devices with or without saline irrigation.

Results: Saline irrigation and sharp drill bits were associated with smaller temperature increases and less acute osteonecrosis. Conventional trocar tip Kirschner wires were associated with the largest temperature increase and the most acute osteonecrosis changes.

Conclusion: The use of saline irrigation during bone drilling reduces temperature change and osteonecrosis. Furthermore, we recommend that the use of dull drill bits or standard tip Kirschner wires be avoided. Lastly, drill bit design can directly contribute to bone damage during drilling.

Clinical Relevance: This study provides in vivo data from a preclinical model to validate the benefits of saline irrigation and sharp drill bits during bone drilling to regulate increases in temperature and decrease associated osteonecrosis. Risk for early implant loosening and poor surgical outcome is influenced by thermal osteonecrosis of bone such that consistent use of saline irrigation, sharp drill bits, and optimized designs may have important clinical advantages.

Level of Evidence: II

Keywords: fracture surgery; osteonecrosis; bone drilling; saline irrigation; heat generation

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Disclosures: Brett D. Crist, MD, is both an unpaid design consultant for Osteocentric Technologies and a paid consultant for DePuy Synthes. The University of Missouri's Animal Care and Use Committee gave approval for the use of dogs in this study (#9167).

Sources of Funding: This study was partially internal funded by the University of Missouri Department of Orthopaedic Surgery, in-kind support from DePuy Synthes, and research funding and in-kind support from Osteocentric Technologies.

INTRODUCTION

Bone drilling is fundamental to the practice of orthopaedic fracture surgery. Drilling into bone generates frictional heat that may contribute to thermal osteonecrosis. Heat-induced osteonecrosis occurs when bone sustains a temperature of 47° Celsius (C) for a period longer than 60 seconds or 50°C for 30 seconds.[1,2] The threshold temperature for immediate bone death due to applied heat is 70°C.[3] Cortical bone will reach temperatures beyond 100°C in the surgical setting if no heat-counteracting measures are applied.[4] Cortical bone injury and necrosis can lead to bony resorption around the screw with the formation of fibrous tissue and subsequent loss of implant and bone interface.[5-7] The effects of bone injury that occur with specific temperature thresholds have been reported in association with oromaxillofacial implants.[8]

Fracture plating construct stability relies on screw purchase into the bone. The sufficient purchase of a screw translates into bone-plate stability by producing adequate friction between a bone and the applied plate or by providing a stable interface to resist torsional or axial load in an intramedullary nail or locking plate. Loss of the bone-screw interface in non-locking plates decreases screw pullout strength and implant stability.[9] Unstable orthopaedic implants predispose to premature implant failure, fractures, delayed union or nonunion, and increases the risk for infection.[10] Therefore, any cause for decreased screw-bone interface may contribute to significant surgical complications and minimizing the risk of bone necrosis during screw placement is important.

Regulating heat production is routinely practiced in orthopaedic surgical settings. In order to minimize heat production, it is recommended to use smaller diameter and sharp drill bits, avoid the use of blunted drill bits, drill with decreased rotational acceleration rates, use low-frequency vibration-drilling, alter the angle of screw insertion, and irrigate during active drilling.[11-14]

Related studies insist that irrigation while drilling is the superior method for temperature regulation.[2,3] Irrigation reduces drill site temperature by heat conduction—i.e., irrigation acts as a coolant to provide lubrication to decrease friction and facilitate the removal of bony debris that may obstruct drill flutes and decrease heat dissipation. When drill sites were irrigated externally with normal saline at a rate of 500 mL per minute, the local temperature never increased beyond threshold temperatures of 50 °C.[5]

Previous reports examining the effects of drilling on bone have focused primarily on cadaveric and tissue explant models, which do not account for the influences of live cells and blood supply on resultant damage.[2,3,9,12] Therefore, the purpose of the present study was to evaluate the effects of saline irrigation on regulating temperature increase and acute bone damage using different drill bits and Kirschner wire devices commonly used in fracture surgery in a live translational model. The study was designed to test the hypothesis that temperature change and initial cortical bone damage will each be significantly ($P < 0.05$) different based on the type of drill bit or wire used for bone drilling and that saline irrigation will effectively mitigate temperature change and damage.

METHODS

With approval from our institutional animal care and use committee, skeletally mature purpose-bred research dogs (n = 5) were premedicated, anesthetized, and prepared for aseptic surgery of both hindlimbs as part of an unrelated terminal procedure. Rectal temperature was measured during the procedure. For each canine, both tibias (n = 10) were treated as matched pairs to allow for drill bit type and irrigation assignments as described. A medial approach to expose the tibial diaphysis was performed, and hemorrhage was controlled with electrosurgery. Five diaphyseal drill sites were marked on the medial tibial diaphysis each 2 cm apart (Fig. 1A). Each drill site was assigned to one of the five drilling devices to be tested, and right and left tibias were alternated to receive or not receive saline irrigation during drilling, creating 10 treatment groups for comparison (n = 5 per treatment group) with the following:

- New (sharp) 2.5 mm drill bit (DePuy Synthes, West Chester, PA, USA)
  - o With saline irrigation (SDB+)
  - o Without saline irrigation (SDB-)
- Dulled 2.5 mm drill bit (DePuy Synthes) – dulled by performing 10 bicortical drill tunnels in femoral cortical bone
  - o With saline irrigation (DDB+)
  - o Without saline irrigation (DDB-)
- New 2.5 mm drill bit (Osteocentric Technologies, Inc, Austin, TX, USA)
  - o With saline irrigation (ODB+)
  - o Without saline irrigation (ODB-)
- New drill-tip 1.6 mm Kirschner wire (DePuy Synthes)
  - o With saline irrigation (DKW+)
  - o Without saline irrigation (DKW-)
- New spade-tip 1.6 mm Kirschner wire (DePuy Synthes)
  - o With saline irrigation (SKW+)
  - o Without saline irrigation (SKW-)

Drill devices were rotated among drill site locations for each dog so that each device was assigned to each location and order of drilling in equal numbers. Immediately prior to drilling, the temperature (°C) of the tip of the drilling device was measured at the cis[15] (near) cortex using a calibrated infrared thermometer gun (Fisherbrand, Thermo Fisher Scientific, Waltham, MA, USA) (Fig. 1B). High-speed (910 rpm) single-pass bicortical drilling of each site was performed using standard surgical power equipment (Arthrex 600 System, Arthrex, Inc., Naples, FL, USA) and the assigned drilling device with or without saline irrigation. A single board-certified veterinary orthopaedic surgeon with more than 20 years of experience performing open reduction internal fixation procedures performed the bone drilling for this experiment. Drilling was performed using a standard surgical technique with consistent pressure based on tactile response according to the manufacturer's instructions. Based on flute design, Osteocentric drill bits (ODB) bits were advanced with relatively less pressure during drilling. Per the manufacturer, OsteoGuard drill bits (Osteocentric Technologies, Inc.) are designed with a unique cutting tip, longer flutes with uniform volume, and no side cutting to remove less bone more efficiently with less damage.

Drill sleeves were used during the drilling process.

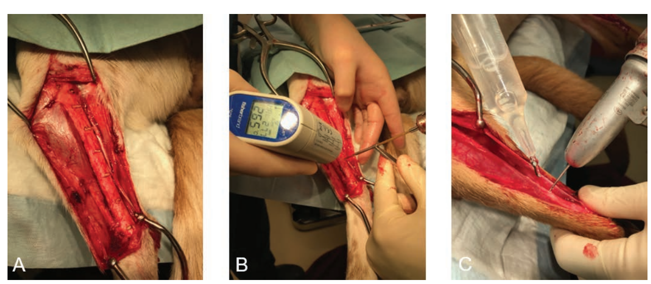

Figure 1. (A) Tibial diaphysis shown with drill sites spaced 2 cm apart. (B) Traceable® Infrared Thermometer Gun measuring drill bit temperature immediately upon cessation of drilling. C. 60-cc bulb syringe applying irrigation at drill bit tip during active drilling of cortical bone.

Saline irrigation was performed using room-temperature sterile isotonic saline via 60 ml bulb syringe delivered in standard clinical fashion (Fig. 1C). Immediately after drilling, the temperature (°C) of the tip of the drilling device was measured at the cis cortex using a calibrated infrared thermometer gun.[16]

Immediately after the completion of drilling, dogs were humanely euthanized while still under anesthesia. Histological examination of bone necrosis tends to occur in a pattern. Eriksson and Albrektsson described thermal osteonecrosis as occurring over several weeks.[1] Pathologists note the earliest signs of bone ischemia are seen by day two in the marrow spaces with loss of nuclear staining of marrow cells, osteocyte depletion, and the appearance of large round, ovoid spaces filled with fat. By day 15, osteocytic lacunae are empty and trabecular surfaces are devoid of cells while capillaries, fibroblasts, and foamy histiocytes may be appreciated at the border of the necrotic zone.[7]

The tibias were immediately disarticulated and dissected free from all soft tissues. Each drill site with 1 cm of surrounding bone circumferentially was collected and processed. The cis (near) and trans (opposite) cortices were separated and analyzed individually. Half of the samples were processed for scanning electron microscopy (SEM),[17] and the other half were processed for histology.

Samples destined for SEM were fixed in 2% paraformaldehyde, 2% glutaraldehyde in 100 mM sodium cacodylate buffer pH = 7.35. All specimen preparation was performed at our university's electron microscopy core facility. Fixed tissues were rinsed with 100 mM sodium cacodylate buffer, pH 7.35 containing 130 mM sucrose. Secondary fixation was performed using 1% osmium tetroxide (Ted Pella, Inc., Redding, CA, USA) in cacodylate buffer using a Pelco Biowave (Ted Pella, Inc.) operated at 100 Watts for 1 min. Specimens were then incubated at 4 °C for 1 hour, initially rinsed with cacodylate buffer, and further rinsed with distilled water. Using the Pelco Biowave, a graded dehydration series (per exchange, 100 Watts for 40s) was performed using ethanol. Samples were dried using the Tousimis Autosamdri 815 (Tousimis, Rockville, MD, USA), and samples were sputter-coated with 20 nm of platinum using the EMS 150T-ES Sputter Coater. Images of the drill site and surrounding bone were acquired with a FEI Quanta 600F scanning electron microscope (FEI, ThermoFisher Scientific, Hillsboro, OR, USA) using a high-vacuum secondary electron (Everhart-Thornley) detector at 25X to 25,000X magnification, a voltage of 5 or 20kV and spot of 3 or 8.

Samples destined for histology were fixed in 10% neutral buffered formalin fixative. Once properly fixed, the bone specimens were demineralized with 10% ethylenediaminetetraacetic acid (EDTA) in PBS, sectioned in two at the drill site when sufficiently softened, and processed for H&E staining.

An in-house scoring system was created to evaluate severity/extent of four histologic changes at the drill site (total out of 12 points) for both H&E staining and SEM:

1. loss of osteocytes from lacunae/bone necrosis (out of 3 points),
2. bone coagulation (thermal injury) (out of 3 points),
3. soft tissue coagulation (out of 3 points), and
4. debris in/neighboring the drill site (out of 3 points)

The highest score represents the most severe pathology. Histologic scoring of the drill sites was performed by two board-certified veterinary pathologists blinded to treatments. Both pathologists scored all sites and their mean scores were used for statistical analyses based on strong inter-observer agreement ($r^2 = 0.91$).

Statistical Analysis

Each continuous outcome measure (Δheat, structural damage, zone of necrosis) was compared among groups for cis or trans cortices using one-way ANOVA with multiple pairwise comparisons with corrections. Within-group comparisons were made for cis versus trans cortices and irrigation versus no irrigation using paired t-tests. Differences were considered statistically significant at $P < 0.05$. Correlations between change in temperature and bone damage or necrosis were assessed using Pearson Product Moment Correlations with $r > 0.7$ considered strong.

RESULTS

Rectal temperature was consistent among dogs at a mean of 37.8 °C (range, 36.1-38.3). Immediately prior to drilling, the temperature of the tip of the drilling device was consistent among dogs at a mean of 25.4 °C (range, 22-28.6).

Heat Generation

Saline irrigation while drilling resulted in smaller temperature increases than drilling without saline irrigation for all groups except for 1.6 mm spade-tip Kirschner wires (SKW- = 4.7 °C ± 2.9; SKW+ = 2.9 °C ± 1.3) (Fig. 2). The effects of saline irrigation on change in temperature did not reach statistical significance for any drilling device tested ($P > 0.1$). Sharp 2.5 mm drill bits with saline were associated with the smallest increase in temperature after drilling (SDB+ = 0.2 °C ± 0.7). Overall, SKW- reached the highest temperature change of 7.6 °C and SDB+ achieved the lowest temperature change of -0.1 °C. One-way ANOVA with pairwise comparisons

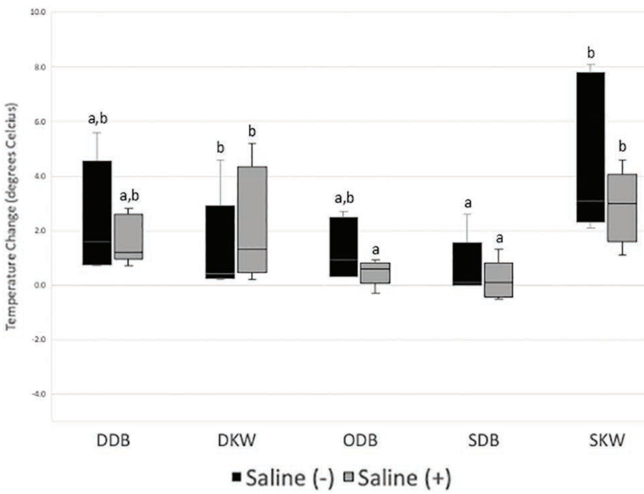

Figure 2. Mean ± standard deviation of change in temperature of drill sites before and after drilling using 10 drilling techniques. These box-and whiskers plot for median, interquartile range, minimum, and maximum values for temperature change for each drilling device tested. Note: different letters above plot indicate statistically significant differences (P < 0.05) among groups with "a" representing the smallest change in temperature.

produced the following statistically significant differences: SDB-, SDB+, and ODB+ had significantly smaller temperature increases compared to DKW- and DKW+ ($P < 0.03$). SDB-, SDB+, and ODB+ also had significantly smaller temperature increases than SKW- and SKW+ ($P < 0.042$). Surprisingly, dull drill bits did not show any statistically significant differences to other groups for change in temperature.

Bone Damage

H&E

One-way ANOVA comparison among groups showed significant findings. SKW- and SKW+ had significantly higher total histopathologic scores than all other groups ($P < 0.05$) (Table 1). ODB+ had a significantly lower histopathologic score than both DDB-, DDB+, DKW-, and SDB- ($P < 0.05$) (Table 1). There were no other statistically significant findings.

Saline irrigation while drilling was associated with lower histopathology scores compared to drilling without irrigation across all drilling techniques (Table 1). Further, subcategory analyses showed that SKW+ and SKW- had significantly higher osteocyte loss/bone necrosis and bone coagulation (thermal injury) scores at drill sites than all other groups with or without saline ($P < 0.05$). This finding is characterized by large numbers of empty bone lacunae and prominent basophilia of the disrupted bone matrix at/extending out from the drill site, respectively (Fig. 3 A and B). In contrast, the drill sites created with ODB were less disrupted with only small numbers of empty bone lacunae and

Table 1. Mean ± Standard Deviation of Total Histopathologic Scores

Saline Irrigation	SDB	DDB	ODB	DKW	SKW
Yes	5.6 + 0.8	5.8 + 1	4.6 + 1.5	5.3 + 1.9	8.5 + 1.4
No	6.0 + 2.2	6.3 + 2.6	5.2 + 1.1	6.2 + 1.2	9.1 + 1.5

Note: In-house scoring system attributes up to 3 points (1=mild, 2=moderate, 3=marked) for four different attributes: osteocyte loss/bone necrosis, bone coagulation, soft tissue coagulation, and debris at neighboring drill site. The maximum score possible is 12. A higher score equals more damage.

Key: SDB=sharp drill bit, DDB=dulled drill bit, ODB=Osteocentric drill bit, DKW=drill-tip Kirschner wire, SKW=spade-tip Kirschner wire.

small quantities of basophilia of the bone matrix immediately neighboring the drill site (Fig. 3 C and D). Other treatment groups (for example, SDB+ in Fig. 3 E and F) occasionally showed moderate disruption of bone at the drill site associated with moderate quantities of empty bone lacunae and basophilia of the bone matrix (but not as extensive as the spade tip 1.6 mm Kirschner wire group).

SEM

Similar to the histology findings, SEM showed that drill sites created by SKW had more surface and drill site microfractures and structural disarray of organic scaffolding. ODB created the least damage when compared to the other drilling devices (Fig. 4).

DISCUSSION

This novel preclinical study examined the in vivo effects that saline irrigation, drilling device type, and device sharpness have on heat generation and bone damage in viable cortical bone. Five different drill bits and wires commonly used for orthopaedic surgery were compared using temperature measurements, histologic assessments, and scanning electron microscopy (SEM). The results of this study confirm that saline irrigation provides a counterregulatory effect on heat generation produced by drilling into the bone. As a result, concomitant saline irrigation was associated with less disruption of cortical bone secondary to osteonecrosis as represented by histopathology scores and SEM imaging assessments.

There were also notable differences between drilling instruments. Compared to their dulled counterparts, sharper drill bits were associated with smaller temperature increases with or without saline irrigation. Importantly, standard trocar tip 1.6 mm Kirschner wires (SKW) were associated with the highest temperature increase and most severe histopathologic changes in

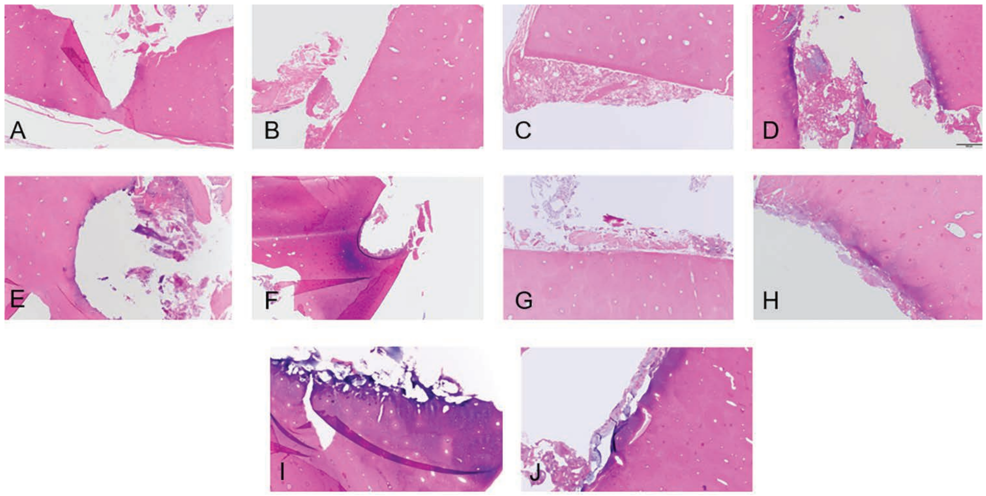

Figure 3. Representative H&E images of drill sites in tibial cortices with increasing severity of bone coagulation (thermal damage) and osteocyte loss/bone necrosis for selected drill types. Bone necrosis is characterized by empty osteocytic lacunae (osteocyte loss) within areas of bone coagulation (basophilia) neighboring or surrounding the drill site. Bone and cellular debris is commonly seen within drill sites. Left column (A, C, E, G, I) represent drill bits and K-wires without saline irrigation. Right column (B, D, F, H, J) represent drill bits and K-wires with saline irrigation. In-house pathology scores (out of 3) for the following images are based on bone coagulation, and osteocyte loss/osteonecrosis:

A. ODB- scores (1,1)
B. ODB+ scores (1,1)
C. DDB- scores (1,1)
D. DDB+ scores (2,3)
E. DKW- scores (2,1)
F. DKW+ scores (1,2)
G. SDB- scores (1,1)
H. SDB+ scores (2,2)
I. SKW- scores (3,3)
J. SKW+ scores (2,2)

B, C, E, G, H, I, J (10x magnification; scale bar = 200 μm). A, D, F (4x magnification; scale bar = 500 μm).

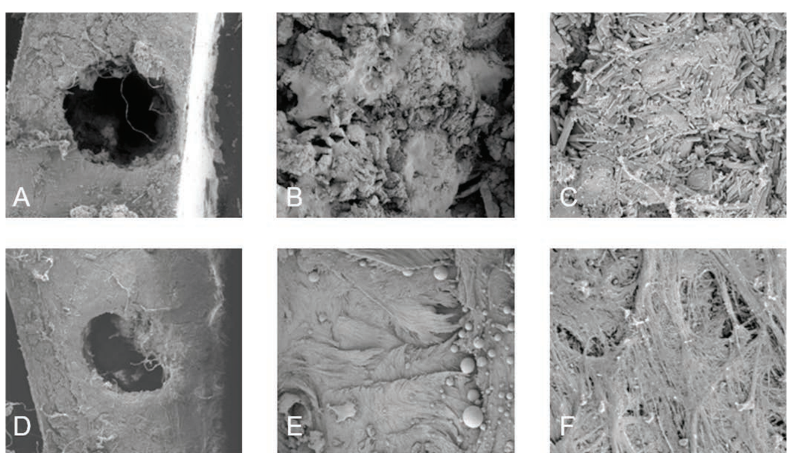

Figure 4. (A-E). Representative scanning electron microscopy (SEM) images visualizing varying degree of bony damage, debris, and necrosis of drill sites produced by osteocentric drill bits with saline (ODB+) and without saline (ODB-). Left column (A-C) represents drill sites subjected to drilling without saline. All images of the left column taken from the cis (near) cortex of the tibial specimen. Right column (D-F) shown to represent drill sites subjected to drilling with saline. All images of the left column taken from the trans (far) cortex of the tibial specimen. Magnification across rows is held constant. Top row (A,D) is shown at 25x magnification (scale bar = 2 mm); middle row (B,E) is shown at 280x magnification (scale bar = 200 μm); bottom row is shown at 4,000x magnification (scale bar = 10 μm). Comparative observation of either column shows that drill sites created by Osteocentric drill bits (ODB) in the presence of saline had less structural disarray of organic scaffolding than DePuy Synthes drill sites (SDB) created without saline.

the presence of saline irrigation and without. In contrast, the Osteocentric drill bits (ODB) performed the best in terms of limiting bony damage, drill site debris, and osteonecrosis as seen on H&E and SEM. Interestingly, though ODB outperformed all other drill bits from H&E and SEM standpoints, sharp DePuy Synthes drill bits (SDB) performed the best in terms of limiting temperature increases. The clinical significance of this trend may suggest that variables inherent to each drill bit other than their ability to regulate temperature increase in the presence of saline irrigation could influence drilling-related bone damage such that multiple factors, including saline irrigation, sharpness, and design, should be considered for optimizing bone drilling for subsequent implant placement.

Much of the recent literature involves oromaxillofacial surgery.[18-20] Other current studies involve either cadaveric human, bovine, rabbit, or porcine models.[1-4] One study by Lundskog et al.[21] from 1972 did use living human bone to evaluate thermal properties. Of the animal models, canine and porcine bone has been shown to be the most representative of human cortical bone.[22] Our study is unique in that we used live canine models with drilling taking place at baseline physiologic temperatures during general anesthesia to show the effects on perfused bone and surrounding tissue. In essence, we were able to evaluate the effects of drilling on live tissue using valid and applicable basic science outcome measures.

Drilling into bone in one form or another is ubiquitous in orthopaedic surgery. The friction generated with drilling produces heat that may reach temperatures above physiologic levels. The poor thermal conductivity of bone inhibits heat dissipation. Therefore, if no countermeasures are applied while drilling, local drill site temperatures reach threshold measurements associated with deleterious bony effects including necrosis.[2-5,23,24]

Why does this matter? Circumferential osteonecrosis at a drill site can lead to poor outcomes.[7] If osteonecrosis occurs, less viable bone remains to produce a compressive force to support bone purchase with screws.[8] Implants with unsatisfactory purchase are associated with early loosening and poor surgical outcomes such as higher rates of infection, implant instability, and reoperation.[25,26]

Bone changes occur at set temperatures with instant osteonecrosis occurring at temperatures at or above 70°C or above 47°C for 1 min. Temperatures can exceed 100°C if counterregulatory measures to heat production are not employed.[1-4] Therefore, careful application of these compensatory measures should be practiced by orthopaedic surgeons to manage heat production. Heat-reducing measures include, but are not limited to, decreasing the drill bit diameter, slowing rotational drilling speeds, avoiding the use of blunt drill tips, and irrigating during drilling to facilitate heat-dissipation.[9-12]

Limitations of the study must be considered when interpreting and applying these data. Temperature measurement was performed using a non-contact infrared instrument to determine drill device tip temperature. While this method is accurate and was standardized for the experiment, it does not provide a measure of bone temperature. As such, comparisons among drilling devices must be limited to the relative change in temperature as presented. However, the associated bone damage relative to temperature change does provide direct clinically applicable data, especially based on the use of live bone in a surgically-based animal model. Saline irrigation was performed at a constant rate by hand, which is representative of the standard practice in the operating room. As such, the exact rate of irrigation was not measured. One study suggests that irrigation at 500 mL/min successfully limited drill site temperatures to below 50°C.[4] Our goal was to recreate what occurs in surgery to determine if irrigating makes a practical difference.

Future studies may seek to clarify what factors are responsible for how individual drill bits or wires influence osteonecrosis in the setting of controlled temperature over the long term. For example, a future study may include another animal model in the context of induced osteotomies followed by the use of a standard plating technique with drilling occurring with or without saline irrigation to compare rates of implant loosening and failure, infection, and reoperation. Admittedly, the question may arise whether this is clinically relevant and if it affects patient outcomes. Although this may be challenging to verify, the authors feel strongly enough that they have incorporated this into their clinical practice and wanted to evaluate this in a controlled basic science model.

The use of saline irrigation during bone drilling reduces temperature change and bone necrosis. Furthermore, we do not recommend using dull drill bits or standard tip Kirschner wires if trying to minimize heat generation and osteonecrosis. Lastly, drill bit design can directly contribute to bone damage during drilling. Taken together, these results provide in vivo data from a preclinical model to validate the benefits of saline irrigation and sharp drill bits during bone drilling to regulate increases in temperature and decrease associated osteonecrosis. Risk for early implant loosening and poor surgical outcome is influenced by thermal osteonecrosis of bone such that consistent use of saline irrigation, sharp drill bits, and optimized drill device designs may have important clinical advantages.

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DOES ANTERIOR IMPACTION AFFECT RADIOGRAPHIC OUTCOMES OF PILON FRACTURES?

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ABSTRACT

Background: The outcomes of pilon fractures are multifactorial. Anterior articular impaction requires sagittal plane correction (anterior distal tibia angle (ADTA)) with articular reduction. However, there is a risk of avascular necrosis of the articular fragments and postoperative tibiotalar arthritis. The purpose of this study was to determine if the presence of anterior impaction affects radiographic alignment after definitive fixation.

Methods: Retrospective cohort study of patients who underwent operative management for pilon fractures at two academic, level 1 trauma centers between September 2005-September 2016. Fractures were categorized as having anterior impaction or no anterior impaction after review of preoperative radiographic and computer tomography imaging. Patient demographics and postoperative time to union was recorded. Quality of reduction was measured using (ADTA) (degrees), lateral distal tibia angle (LDTA) (degrees), and lateral talar station (LTS) (millimeters) from postoperative radiographs. Statistical analysis compared fracture patterns with anterior impaction to those without.

Results: 208 patients met inclusion criteria. 132 fractures (63.4%) were determined to have anterior impaction. Cohorts were similar in demographics and medical comorbidities (p>0.05). Mean ADTA, LTDA, and LTS for the anterior impaction group 83.5°, 89.7°, and 2.4mm versus 84.6°, 89.9°, and 2.0mm in the group without anterior impaction. Cohorts significantly differed in ADTA(p=0.01), but not LDTA(p=0.12) or LTS(p=0.44). No significant differences were found between cohorts with infection (>0.05), nonunion(p=0.76), unplanned reoperation(p=0.56), or amputation(p=0.34).

Conclusion: This study demonstrated no significant differences in the coronal or sagittal plane alignment when comparing definitively fixed pilon fractures with and without anterior impaction. Additional studies are needed to evaluate the long-term clinical impact of failing to restore ADTA.

Level of Evidence: III

Keywords: anterior impaction, pilon, sagittal alignment, complications

INTRODUCTION

Pilon fractures are commonly associated with articular comminution, soft tissue injury and neurovascular injury.[1-5] The known injury mechanism consisting of axial compression of the talus into the tibial plafond often results in significant articular impaction.[6] Mechanism of injury, severity of the associated soft tissue injury and fracture characteristics determine operative strategy as well as prognosis.[6]

As with all articular fractures, anatomical reconstruction of the articular surface and overall restoration of the mechanical axes of the distal tibia should be the goal. Postoperative malalignment contributes to accelerated post-traumatic osteoarthritis of the tibiotalar joint.[6-8] Sagittal plane deformities alter biomechanics and joint forces to a greater degree than coronal plane deformities.[5,9,10] However, there is not a current consensus on gold-standard radiographic parameters used to assess postoperative reduction in pilon fractures. This is largely due to the significant variability in baseline anatomy of patients, variability in radiographic positioning of injured limb, training level of evaluators, as well as poor inter- and intra-rater reliability.[1,2,7,11-18] Furthermore, secondary radiographic parameters that are more difficult to measure, including the presence of anterior impaction, create a unique challenge for surgeons regarding attaining anatomical reduction.

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

Sources of Funding: No sources of funding declared.

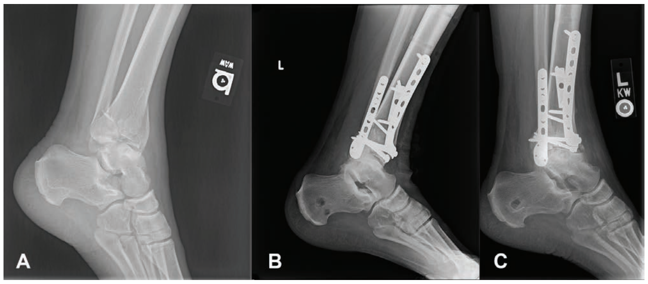

Figure 1. (A) A lateral radiograph showing left pilon fracture with anterior impaction, (B) An immediate postoperative lateral radiograph showing anterolateral primary plate and accessory anterior rim plate; (C) A two-year postoperative lateral radiograph showing anterior talar subluxation, anterior plafond avascular necrosis and post-traumatic tibiotalar arthrosis.

While previous studies have investigated the impact of soft tissue injury and fracture patterns on outcomes,[6-8] associated anterior impaction has not been emphasized. Incidence of avascular necrosis has been reported up to 25% after injury and post-traumatic arthritis up to 31% depending on initial fracture severity and length of follow-up.[38] Anterior articular impaction makes both sagittal plane correction and obtaining and maintaining articular reduction difficult. Initial fracture reduction of the comminuted anterior articular surface and postoperative fragment resorption due to avascular necrosis can create problems with joint containment that increases the chance of postoperative tibiotalar arthritis. This is exacerbated when there is limited ankle motion that continues to stress the anterior tibiotalar joint (Figure 1). The purpose of this study was to determine if the presence of anterior impaction affects radiographic alignment outcomes of pilon fracture after undergoing open reduction internal fixation (ORIF). We hypothesize that the presence of anterior impaction will result in worse radiographic alignment when compared to fracture patterns without anterior impaction.

METHODS

After Institutional Review Board (IRB) approval, an electronic medical record (EMR) retrospective review was performed on patients who underwent pilon fracture ORIF at two American College of Surgeons-verified level 1 academic trauma centers between September 1, 2005, and September 30, 2016. The surgeons were all fellowship-trained orthopedic traumatologists.

Inclusion criteria included skeletally mature patients, AO/OTA 43B or C fractures[19] managed acutely or in a staged fashion with ≥6 months of clinical follow-up. Patients with missing/unidentifiable data, lack of measurable radiographs/computed tomography (CT) scan, or lack of follow up were excluded.

Clinical data points including patient demographics and comorbidities, AO/OTA fracture classification,[19] open fracture type,[20] intraoperative complications, type and number of additional procedures performed after index ORIF, time to fracture union and complications were recorded. Complications included superficial surgical infection (SSI, requiring antibiotics/wound care), deep infection (requiring return to operating room), nonunion, unplanned reoperation, and amputation.

Radiographic Measurements

Fractures were categorized as having anterior impaction or no anterior impaction through methodical, detailed review of pre-operative radiographic and CT imaging. Anterior impaction was defined as presence of cranial axial compression of the anterior one-third of distal tibia as assessed on pre-operative imaging (Figure 1). Quality of reduction was quantified, via the postoperative AP and lateral ankle radiographs, utilizing the following measures: anterior distal tibial angle (ADTA (degrees), lateral distal tibial angle (LDTA (degrees)), and lateral talar station (LTS (millimeters)). Postoperative CT scans were not part of the institutional protocols and therefore not routinely obtained. Although CT scans are more accurate for judging reduction, plain radiographs are the current gold standard for postoperative reduction evaluation to minimize patient radiation exposure and cost. However, on an individual basis, CT scans were obtained to further evaluate concerns for postoperative reduction or changes in the postoperative period.

Anterior Distal Tibial Angle (ADTA)

The ADTA was measured as described by Magerkurth and colleagues.[21] This angle was used to assess sagittal plane alignment. First, a line is drawn on the anterior and posterior tibial joint surface, with care taken to exclude osteophytes, on the lateral radiograph. A second line is then drawn within the anatomic, longitudinal axis of the tibia. The anterior angle between these lines defines the ADTA. (Figure 2) Normal angles range from 78° to 82°.[21] Other references support a much wider variation from 76°-92°.[16]

Lateral Distal Tibial Angle (LDTA)

The LDTA is measured by drawing a line across the weight bearing articular surface of the tibial plafond on the mortise radiograph. A second line is created along the anatomical, long axis of the tibia. The lateral angle is considered the LDTA (Figure 2). Normal angles vary widely and range from 86 to 92°.[16-18,21]

Lateral Talar Station (LTS)

The LTS is measured by creating a sector of a circle that is fitted to the talar joint surface to first define the talar joint radius.[20,22] The distance from the center of this

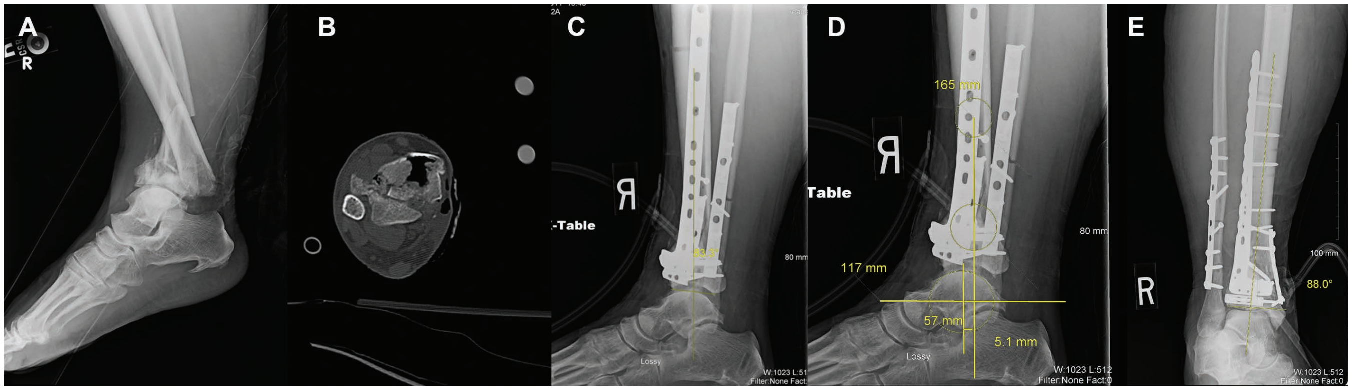

Figure 2. (A) An injured right ankle lateral radiograph showing a pilon fracture with anterior impaction and comminution; (B) an axial CT scan showing anterior pilon comminution; (C) an immediate postoperative lateral radiograph of the right ankle showing anterolateral primary plate and accessory anterior plate with ADTA of 83.3°; (D) an immediate postoperative lateral radiograph of the right ankle showing LTS of -5.1mm; (E) an immediate postoperative anteroposterior (AP) radiograph of the right ankle showing anterolateral primary plate with accessory anterior and medial plates, bone graft substitute, and an LDTA of 88°.

circle and the anatomic, longitudinal axis of the tibia is measured on the lateral radiograph (Figure 2). Normal ranges from –0.8076 mm to 3.1496 mm.[23]

Statistical Analysis

Statistical analysis included two-tailed t-test of unequal variance to compare fracture patterns, postoperative complications, and radiographic measurements of anterior impaction to patterns without anterior impaction, with a p-value of <0.05 determined as significant. A Chi-Square test was used to evaluate significant difference regarding OTA-AO classification between the groups.

RESULTS

A total of 208 pilon fractures met inclusion criteria. Of the total, 132 fractures (63.4%) were determined to involve anterior impaction and 76(36.6%) without anterior impaction prior to definitive fixation. The two cohorts were similar regarding age, BMI, tobacco use, and associated medical comorbidities (p<0.05; Table 1). The mean clinical and radiographic follow-up was 1.9 ± 1.7 years (min: 6 months, max: 8.4 years) for the anterior impaction cohort and 2.0± 1.7 years (min: 6 months, max: 8.3 years) for the no anterior impaction cohort.

Radiographic Results

The mean postoperative ADTA, LTDA, and LTS the anterior impaction cohort was 83.5° (69.7-99.6°), 89.7° (79-101.8°), and 2.4mm (-9.6–12.0mm), respectively. The mean postoperative ADTA, LTDA, and LTS for fractures without anterior impaction was 84.6° (75.3-99.8°), 88.9° (74.8-97.8°), and 2.0mm (-10.5–12.1mm), respectively. There was no significant difference in ADTA (p=0.06), LDTA (p=0.09) or LTS (p=0.22; Table 2).

Clinical Outcomes

Pilon fractures with anterior impaction did not demonstrate statistically significant differences for the rates of SSI (p=0.92), deep infection (p=0.81), nonunion (p=0.76), unplanned reoperation (p=0.98), or amputation (p=0.34) (Table 3).

DISCUSSION

Our data demonstrates that pilon fractures with anterior impaction do not have significant differences in postoperative ADTA, LDTA and LTS or clinical rates of complications including SSI, deep infection, non-union, unplanned reoperation, or amputation. While the radiographic measures are not significantly changed with the presence of anterior impaction in pilon fractures, the clinical significance is still unknown.

Anterior impaction is often recognized as comminution and cranial displacement of the anterior tibial articular surface that occurs in the event of significant dorsiflexion of the ankle during high-energy axial compression.[15] Frequently associated with OTA/AO type 43C fractures, anterior impaction can be difficult to re-

Table 1. Patient Cohort Characteristic Comparison Between Patients With and Without Anterior Impaction

	Anterior Impaction	No Anterior Impaction	P-value
Total Patients	192	130	
Age (SD)	43.3 (± 14.2)	46.9 (± 16.3)	0.06
Male	128	71	
Female	64	59	0.42
BMI (range)	31.3 (± 12.9)	32.6 (18.3-50.2)	0.18

SD = standard deviation; BMI = Body Mass Index

Table 2. Radiographic Alignment Measure Comparison Between Patients With and Without Anterior Impaction

Alignment Parameters			
Measure Alignment	Anterior Impaction	No Anterior Impaction	P-value
ADTA	83.44	84.88	0.01*
LDTA	89.70	89.36	0.12
LTS	2.41	1.75	0.44

* indicates significant; ADTA = Anterior Distal Tibia Angle (degrees); LDTA = Lateral Distal Tibia Angle (degrees); LTS = Lateral Talar Station (mm)

Table 3. Postoperative Complication Comparison Between Patients With and Without Anterior Impaction

Complications	Anterior Impaction (number of complications)	No Anterior Impaction (number of complications)	P-value
Superficial Infection	45	26	0.47*
Deep Infection	45	23	0.22*
Unplanned Reoperation	83	52	0.56
Nonunion	30	22	0.76
Amputation	12	5	0.34*

* indicates significance (p<0.5)

duce and, due to the associated comminution, difficult to maintain the reduction.[15] This often requires accessory plate fixation and graft or graft substitute augmentation (Figure 2). However, failure to achieve and maintain this reduction and anterior containment leads to persistent instability, anterior escape of the talus, and an increased risk of post-traumatic osteoarthritis due to asymmetric joint wear.[1-6,8-11,13,24]

The current literature fails to report the relationship of anterior impaction on both radiographic and clinical outcomes. Striving for anatomical reduction and maintaining it is the goal.[1-6,8-11,13-15,24-28] Anterior articular impaction increases the difficulty of correcting the sagittal plane and the articular surface due to comminution and the void left behind by reducing the impacted bone.[4] Even if the reduction is anatomic, the comminuted anterior fragments may resorb over time due to avascular necrosis and can create problems with anterior joint containment that increases the risk of postoperative tibiotalar arthritis.[38] Furthermore, limited ankle motion is common after complex pilon fractures and exacerbates the abnormal stress at the anterior tibiotalar joint surface (Figure 1). However, our average 2-year follow up study, although relatively short-term, suggests that presence of anterior impaction does not have a significant influence on postoperative clinical complications. Two years is enough time for avascular necrosis and collapse to happen.

The goals of surgical management of pilon fractures include reconstruction of the articular surface, restoration of the mechanical axes across the ankle joint, and stable fixation to allow early joint motion. Rüedi and Allgöwer[22] proposed these four classic technical principles that are still followed with the inclusion of advances in plating techniques, and updated imaging technology such as CT scans for preoperative planning. The majority of pilon fractures present a great risk of instability in the sagittal plane, whilst malleolar fractures often result in coronal plane instability.[29-31] Chronic sagittal malalignment with anterior subluxation of the talus causes progressive post-traumatic ankle arthritis due to abnormal contact stresses.[29-31] Post-traumatic ankle arthritis follows a consistent form and the tibiotalar joint compensates by forming anterior tibial rim osteophytes to contain the talus. This ultimately leads to anterior impingement, commonly associated with pain with ankle dorsiflexion and decreased ankle dorsiflexion which propagates the existing problem. Therefore, maintaining proper sagittal alignment has been considered an essential factor for favorable long-term outcomes.[29-31]

More recently, coronal plane alignment has been cited as an important factor during consideration of the arthritic ankle for long-term success of secondary procedures including tibiotalar arthrodesis or ankle arthroplasty.[29-32] In clinical practice, both sagittal and coronal planes should be carefully considered and maintained during definitive fixation. Our study results support that regardless of anterior impaction presence, objective radiographic outcomes are similar between the two groups at an average of 2-year follow-up.

Injury severity of the fracture pattern as well as the quality of reduction at time of definitive fixation have been known to correlate with function.[9,10,21,26] Multivariate analysis demonstrated lower physical component summary (PCS) scores in OTA/AO C-type fractures and patients with lower education level. Additionally, inadequate reduction (retained joint incongruity ≥ 2 mm), and asymmetric ankle range of motion were significant risk factors for decreased scores in PCS.[27] However, other studies argue that the most predictive factors for clinical outcome are patient demographic factors rather than radiographic injury or accuracy of reduction.[25] Despite variation in injury severity and patient-related factors, patient outcomes after pilon fractures have been reported to improve for up to five years after injury.[25] While our current data does not demonstrate difference in postoperative outcomes with the presence of anterior impaction, it is also difficult to control for presence of this fracture characteristic alone as high-energy pilon fractures are often unique in their presentation. Additional PROs in these patients would also be useful for determining effect on quality of life and functional status postoperatively.

Our study has inherent limitations including the retrospective nature and use of plain radiographs for postoperative alignment measurement. Over the last decade, postoperative imaging modalities have changed. Several studies have demonstrated the limitations in fluoroscopy and plain radiographs in the assessment of the articular surface and fracture reduction.[28,33-35] Further studies have demonstrated the improved accuracy of CT compared to conventional radiographs.[11,36-38] However, CT is not routinely obtained postoperatively due to cost, radiation exposure, as well as metal implant artifact obscuring accurate evaluation. Many of our cohorts did not have postoperative CTs, therefore these were not utilized. Additionally, our focus was to utilize radiographs to measure reduction alignment, as radiographs are the main imaging modality obtained during clinical follow-up. We, however, did not use comparison ankle radiographs to understand what measurements would be considered normal for each patient. Finally, patient reported outcomes (PROs) would help further clarify the relationship between anterior impaction and mid- to long-term functional outcomes.

CONCLUSION

The presence of anterior impaction did not demonstrate significantly different radiographic parameters post-operatively compared to pilon fractures without anterior impaction, which emphasizes that "normal" radiographic parameters can be achieved in these complex fractures. Further research is required to determine the most useful postoperative radiographic parameters and their correlation with clinical outcomes.

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DEFORMITY CORRECTION IN ANKLE OSTEOARTHRITIS USING A LATERAL TRANS-FIBULAR TOTAL ANKLE REPLACEMENT: A WEIGHT-BEARING CT ASSESSMENT

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ABSTRACT

Background: Ankle osteoarthritis (AO) is often secondary to prior trauma and frequently presents with joint deformity. Total ankle replacement (TAR) has been shown as a viable surgical option to reduce pain, improve function, and preserve ankle joint range of motion. The standard TAR uses an anterior approach, but recently a lateral trans-fibular approach has been developed. Our aim was to determine if the lateral TAR was able to correct alignment and improve patient reported outcomes (PROs) in patients with end-stage AO.

Methods: This IRB-approved, retrospective comparative study included 14 consecutive patients that underwent lateral trans-fibular approach TAR for end-stage AO. All patients had received pre- and post-operative WBCT imaging on the affected foot and ankle. Using multiplanar reconstruction of WBCT images, measures of coronal and sagittal plane ankle alignment: Foot and Ankle Offset (FAO), Talar Tilt Angle (TTA), Hindfoot Moment Arm (HMA), and Lateral Talar Station (LTS) were performed. PROs were collected pre- and postoperatively at the latest clinical follow-up.

Results: All patients demonstrated a significant deformity correction in all measurements performed: FAO (7.73%-3.63%, p=0.031), HMA (10.93mm – 5.10mm, p=0.037), TTA (7.9o-1.5o, p=0.003), and LTS (5.25mm-2.83mm, p=0.018). Four of the PROs measured exhibited significant improvement postoperatively, the Tampa Scale for Kinesiophobia (TSK) (42.7-34.5, p=0.012), PROMIS Global Physical Health (46.1-54.5, p=0.011), EFAS (5-10.3, p=0.004), and FAAM Daily Living (60.5-79.7, p=0.04). Multivariate analysis assessing the influence of deformity correction in the improvements of PROs found that PROMIS Global Physical Health was significantly associated with improvements in FAO and LTS, TSK associated with HMA, and FAAM Daily Living with FAO and TTA (p<0.05).

Conclusion: The results of this retrospective comparative cohort study suggest that the lateral trans-fibular TAR can correct different aspects of AO deformity. The method also impacted PROs, particularly TSK, PROMIS Global Physical Health, EFAS, and FAAM Daily Living. Direct correlation between some of the deformity correction measurements and the significantly improved PROs was found. The obtained data could help surgeons when making treatment decisions and be the base for comparative prospective studies.

Level of Evidence: III

Keywords: ankle osteoarthritis, arthritis, deformity, total ankle replacement, weigh-bearing computed tomography, foot and ankle offset, talar station

INTRODUCTION

Ankle osteoarthritis (OA) is a frequent, debilitating condition that can dramatically reduce patient's function and quality of life.[1] Different from other joints, ankle arthritis is usually posttraumatic, which often adds a deformity component to the condition. Rotational ankle fractures or sprains are known to cause secondary osteoarthritis in patients of all ages.[2] Surgical intervention

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Disclosures: Nacime Salomao Barbachan Mansur, MD, PhD - Brazilian Orthopedic Foot and Ankle Society: Board or committee member, American Orthopedic Foot and Ankle Society: Board or committee member. Cesar De Cesar Netto, MD, PhD - American Orthopaedic Foot and Ankle Society: Board or committee member, CurveBeam: Paid consultant; Stock or stock Options, Foot and Ankle International: Editorial or governing board, Nextremity: Paid consultant, Ossio: Paid consultant, Paragon 28: IP royalties; Paid consultant, Weightbearing CT International Study Group: Board or committee member, Zimmer: Paid consultant. The other authors have nothing to disclosure. The cited companies did not finance the study or participate in any phase of its conduction. Implants used at this study were from several companies as the surgeries were performed at a public hospital. All authors declare no support from any organization for the submitted work; Other authors have no financial relationships with any organizations that might have an interest in the submitted work in the previous ten years; no other relationships or activities that could appear to have influenced the submitted work.

Sources of Funding: The author Christian VandeLune received research funding from the Summer Research Fellowship, Carver College of Medicine. No other author(s) received financial support for the research, authorship, and/or publication of this article.

is often required for moderate to severe cases in attempt to reduce pain and improve mobility when non-operative treatment fails.[3]

Total ankle replacement (TAR) has been advocated with the idea of reducing pain and maintaining motion in patients with end-stage AO. Surgical techniques and implant evolutions during the last decades have significantly improved TAR short and long-term results.[4,5] Several authors have also described the capacity of TAR in correcting malalignment, a characteristic previously only associated with ankle arthrodesis.[6,7]

Standard TAR technique uses an anterior approach to access and prepare the joint, correct deformities, and insert the prosthesis. The anterior approach allows for adequate rebalancing of soft-tissue structures in the medial and lateral aspects of the ankle; however, correction of major coronal plane and sagittal plane deformities in particular can be challenging.[8,9] The alternative lateral trans-fibular approach TAR has the theorical advantages of allowing better correction of major coronal plane and sagittal plane deformities.[10] This is done by providing direct visualization of the center of rotation of the ankle joint, access to the frequently contracted posterior joint capsule, and most importantly by removing the rigid lateral strut by means of the needed fibular osteotomy.[11] This technique also has the added benefit of being able to lengthen and shorten the fibula to further correct the overall ankle deformity.[10] Still, this relatively new technique has not been fully tested in its ability to correct overall alignment and deformity aspects.[9]

Weight bearing computed tomography (WBCT), an imaging method that properly evaluates foot and ankle anatomical disposition under physiological standing load,[12-14] has been utilized previously to portray deformity correction and complications of residual deformity following TAR.[8,15] The foot and ankle offset (FAO) is an established WBCT three-dimensional, biometric measurement that gauges the overall balance and alignment between the ankle joint and the foot tripod.[16,17] FAO has been used in several previous studies to assess a multitude of different, complex foot and ankle deformities, demonstrating extremely high reliability when characterizing 3D alignment.[18-22]

The primary objective of this study was to use WBCT measurements to assess the lateral trans-fibular approach TAR's ability to correct coronal and sagittal plane ankle deformity. Secondly, our aim was to report the technique's ability to improve patient reported outcomes (PROs). Our main hypothesis was that lateral trans-fibular TAR would allow for significant correction of sagittal and coronal plane deformities, and that the corrections would be associated with improvement of PROs.

METHODS

Study Design and Subjects

This retrospective comparative study received institutional review board approval (IRB# 201912144) and complied with the Health Insurance Portability Accountability Act (HIPAA) and the Declaration of Helsinki. Inclusion criteria consisted of adult patients (more than 18 years of age) that underwent lateral trans-fibular approach TAR for end-stage ankle OA, with at least 5° of coronal and/or sagittal plane deformity, and that underwent preoperative and postoperative WBCT. Exclusion criteria included patients that underwent anterior ankle approach TAR, patients without ankle deformity in the coronal or sagittal planes, and patients with less than 9 months of clinical follow-up. PROs data was collected preoperatively and on the last post-operative visit. This study included a total of 14 ankles (5 right, 9 left) in 14 patients (7 male, 7 female). The average age and BMI were 63.9 years (range 43-83) and 32.7 kg/m^2 (standard deviation, 7.5), respectively. All included patients signed a written informed consent.

Conventional Surgical Procedure

All surgical procedures were performed by a single fellowship-trained foot and ankle orthopedic surgeon with more than 10 years of experience. All patients received the Zimmer-Biomet® (Warsaw, Indiana, US) Trabecular Metal™ TAR (Figure 1).

Patients were positioned supine on the operating table with a tourniquet on the ipsilateral upper thigh. A long approach was performed longitudinally in the lateral aspect of the ankle joint, immediately posterior to the distal fibula. The incision was curved and extended distally towards the sinus tarsi. A long oblique fibular osteotomy was then performed using an oscillating saw and constant saline irrigation, with the osteotomy line ending 1.5-2cm proximal to the ankle joint level. The fibular fragment was then provisionally fixed into the lateral aspect of the heel and into the calcaneal tuberosity with a 0.062 K-wire.

The pre-assembled correcting frame was brought into the field. A calcaneus pin was then inserted, transfixing the calcaneal tuberosity from medial to lateral. Once inserted, the calcaneal pin was grabbed by two pin hooks that were used to provide asymmetric traction, medially to correct varus deformity and laterally to correct valgus deformity. This was done until the talar dome was found to be parallel to the transverse horizontal bar/probe under fluoroscopic evaluation. With the coronal plane articular deformity corrected, a second pin was then inserted into the medial aspect of the talar neck under fluoroscopic guidance.

Anterior or posterior displacements of the tibia were

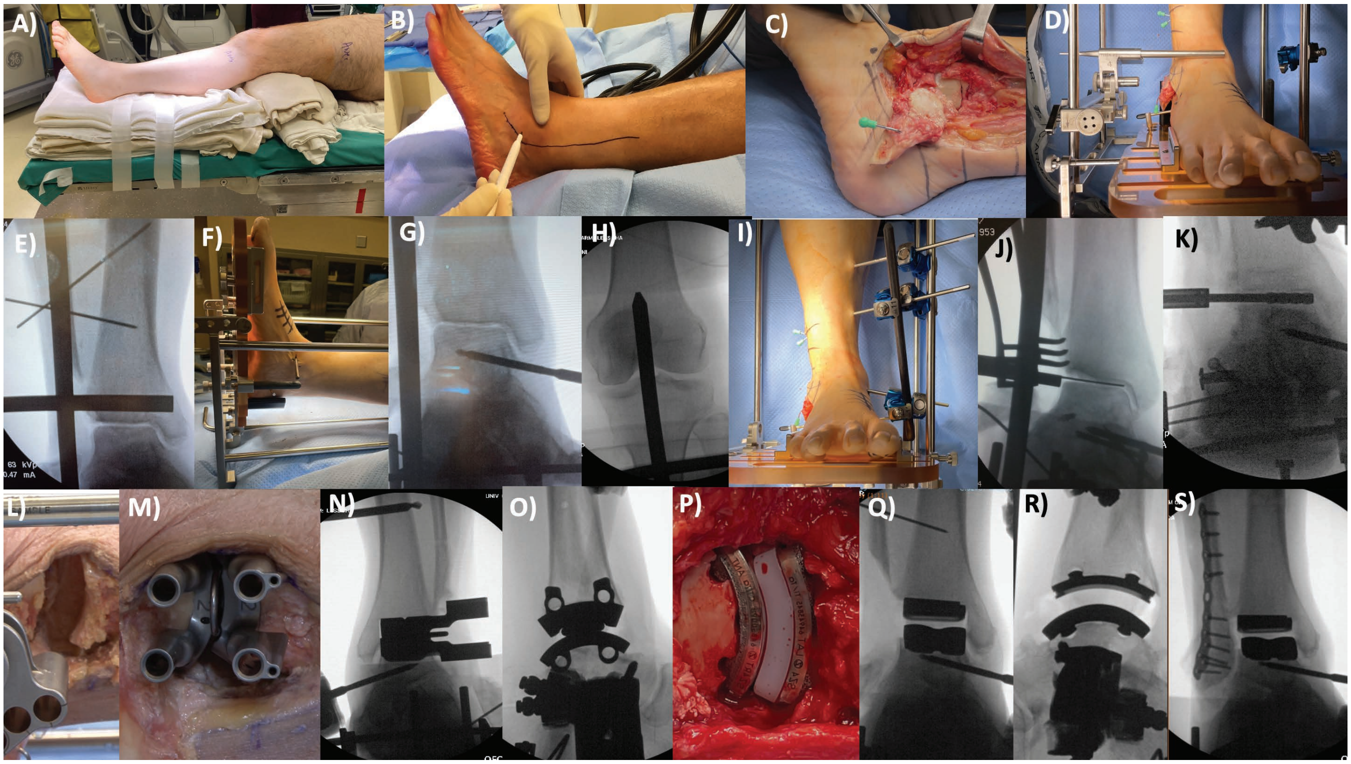

Figure 1. Summarized lateral trans-fibular Total Ankle Replacement technical sequence. After anesthesia, the patient is positioned supine with an ipsilateral bump to place the ankle in neutral rotation (A). The incision is marked at the fibular posterior edge aiming distally to the fourth ray (B). Fibular osteotomy is carried 1.5cm proximally to the ankle joint and its distal fragment rotated inferiorly and provisionally fixated to the calcaneus with a Kirschner wire (C). Posterior and anterior capsules are released. The frame is positioned in relation to the limb, placing the foot in 15 degrees of internal rotation (D). A Schanz pin is introduced on the calcaneal tuberosity and, by placing medial or lateral forces, the coronal position of the talus to the tibia is corrected (E). Talar rotation is adjusted using the same calcaneal pin, and another Schanz pin is placed on the talar body (F) from medial to lateral (G). Proximal alignment is secured by placing the outer stem centered on the lateral tibial spine (H). The hole alignment is again checked, and the tibia is fixed to the frame with two Schanz pins (I). Sizing is determined (J) and confirmed after first drilling the talus (K). Coupled arch drilling of the tibia and talus is performed (L), and the rails trials are positioned (M). After establishing proper rail and implant positioning on the anteroposterior (N) and lateral (O) views, rails are drilled. Final trials are placed, sagittal and coronal stability are checked clinically and radiographically, and the proper polyethylene size is determined. The final implant is introduced (P), and the final positioning is checked on the anteroposterior (Q) and lateral (R) views. The fibula is reduced, necessary lengthening or shortening is performed (when applied), and plate osteosynthesis is executed (S).

corrected by applying manual or pin traction to the distal tibia. Once adequate correction was achieved, the tibia was fixed into the frame by two additional pins. The probe was then utilized to check the position and curvature needed for an adequate cut. Once positioned, burring of the arthritic surfaces of the talus and the distal tibia was performed. Rail hole drill guides were then inserted and the position was checked under fluoroscopy to ensure appropriate alignment of the implants and adequate contact with the bone surfaces. Implant trials were inserted in the joint to assess for soft tissue tensioning, particularly deltoid ligament stability. Based on that, the thickness of the polyethylene was chosen. The definitive implants were then inserted, first the talar component followed by the tibial component, laterally to medially into the rail holes under press-fit. Range of motion was assessed again. Achilles' tendon lengthening was considered when less than 10 degrees of dorsiflexion was achieved with the knee in full extension. Lengthening or shortening of the fibula was performed based on fluoroscopic guidance and the amount of coronal plane deformity corrected. A lateral ligament reconstruction was performed with a soft-tissue anchor, reattaching the anterior talofibular ligament. Syndesmotic stability was checked and trans-syndesmotic fixation with suture buttons were performed when necessary. Postoperatively, patients were non-weightbearing in the splint for two weeks. Range of motion exercises and aggressive protocol of standing, deep knee bends were started at two weeks. Progressive weightbearing was initiated in a walking boot at 6-weeks. At 3-months, patients were transitioned out of the boot into protective sneakers and a hinged ankle brace. After 4-5 months, patients were weaned off the brace.

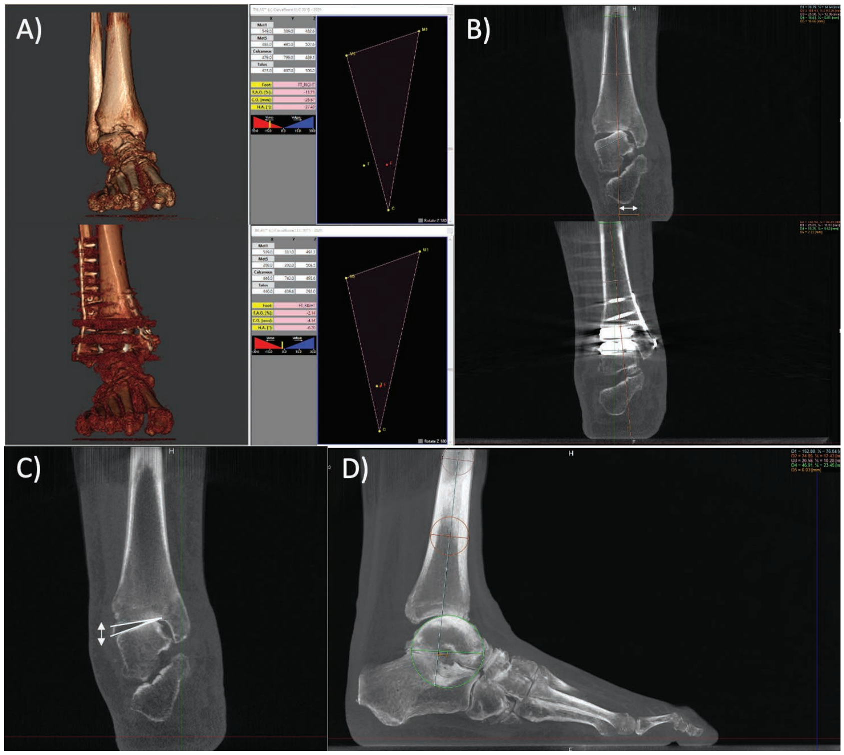

Figure 2. Section A shows an example of a FAO measurement pre/post-surgery. Section B shows an example of a HMA measurement pre/post-surgery. Sections C and D shows an example of a pre surgery measurement for TTA and LTS, respectively.

WBCT Measurements

WBCT scans were performed with a cone-beam CT low-extremity scanner (HiRise; CurveBeam, LLC, Warrington, PA, USA). Participants were instructed to bear weight normally and equally between the lower limbs, with feet shoulder width apart.[23] Raw, multiplanar, de-identified data was converted into sagittal, coronal, and axial plane images and evaluated using dedicated software (CubeVue™, CurveBeam®, LLC, Warrington, PA, USA). Measurements were performed by a single fellowship-trained foot and ankle orthopedic surgeon.

FAO was used to represent a measurement of three-dimensional deformity and was calculated using dedicated software (TALAS™, CubeVue™). Four points were manually marked, three on the weight bearing tripod of the foot and ankle (the first metatarsal head most plantar voxel, the fifth metatarsal head most plantar voxel, the calcaneal tuberosity most plantar voxel) and one at the center of the ankle joint (most proximal and central point of the talar dome).[18,23,24] FAO was then automatically calculated as a percentage by computing the amount of deviation from the center of the ankle joint to the bisecting line of the foot tripod. Physiological alignment (2 standard deviations) was determined to be from - 0.6% to 5.2%.[17,23]

For assessment of sagittal plane deformity, lateral talar station (LTS) was obtained using sagittal plane WBCT views. LTS was performed by drawing three circles, one on the tibia 10cm above the plafond, one on the tibia 5cm above the plafond, and the final circle fitting over talar dome configuration. A line connecting the center of the circles in the tibia is drawn and the distance from this sagittal line to the center of the talus circle is measured, portraying the LTS. The determined normal established range (2 standard deviations) was from −0.8076 mm to 3.1496 mm.[25]

To measure deformity in the coronal plane, Hindfoot Moment Arm (HMA) and Talar Tilt Angle (TTA) were calculated. HMA was calculated by first marking the axis of the distal tibia, which is found by measuring the midpoints of the tibial shaft at 5cm and 10cm proximal to the ankle joint line. The weight bearing point of the calcaneal tuberosity was then found and the distance between that point and the axis line of the distal tibia was measured in millimeters. Normal mean values were described as 6.1mm ± 13.6.[26,27] TTA was measured by tracing two lines, one tangent to the distal tibia articular surface and one tangent to the articular line of the talar dome. Normality was set as 0.0 ± 0.0.[28] Examples of the measurements performed are presented in Figure 2.

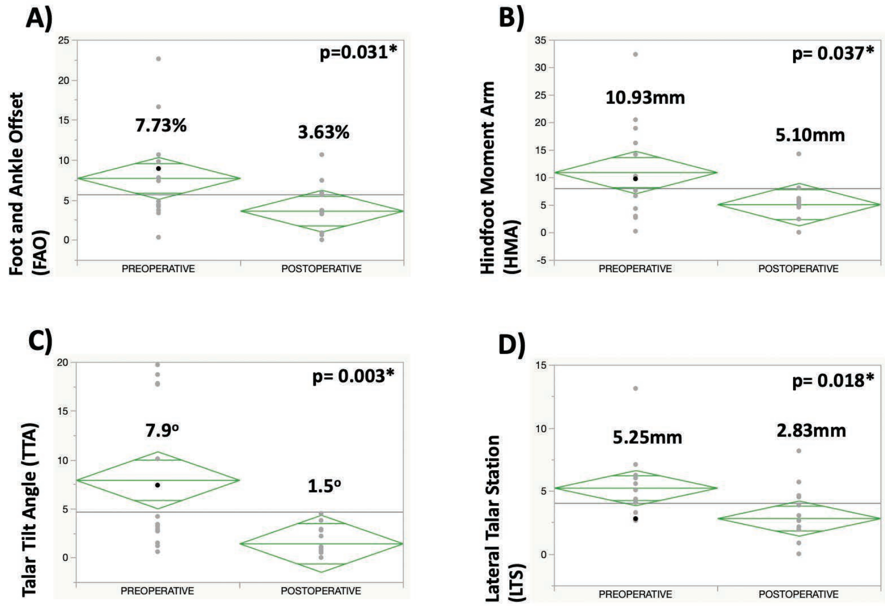

Figure 3. Average pre-operative vs. post-operative measurements with 95% confidence interval outlines and p-values for FAO (A), HMA (B), TTA (C), and LTS (D).

Patient Reported Outcomes (PROs)

Functional outcomes were prospectively gathered for patients preoperatively and at their latest follow-up. We assessed the PROMIS Global Physical Health score, the Tampa Scale of Kinesiophobia (TSK), the European Foot and Ankle Society (EFAS) score, the Pain Catastrophizing Scale (PCS), the Foot and Ankle Ability Measure (FAAM) Daily Living Score, and the FAAM Sports Score.[29-33]

Statistical Analysis

Measurements were assessed for normality by the Shapiro-Wilk test. One-way ANOVA and Wilcoxon tests were used for comparison among timeframes. A multivariate regression analysis was then performed to evaluate the influence of the improvements in deformity correction with the improvements of PROs. R^2 values were utilized as measures of association/correlation. Statistical significance was established for p values under 0.05. The JMP Pro 15 Software was used for statistical analysis.

RESULTS

The average follow-up time was 16.1 months (range, 11 to 24 months). A significant amount of deformity correction was observed in the coronal and sagittal planes, and three-dimensionally as well. Regarding 3D measurements, the mean FAO improved from 7.73% to 3.63%, with a mean improvement of 4.1% (95% CI, 0.41 to 7.8; p=0.031). In the coronal plane, the mean HMA decreased from 10.93mm to 5.10mm, with a mean difference of 5.8mm (95% CI, 0.4 to 11.3mm; p=0.037). The mean TTA decreased from 7.9 degrees to 1.5 degrees, with a mean difference of 6.5 degrees (95% CI, 2.4 to 10.6 degrees; p=0.003). Finally, in the sagittal plane the average LTS improved from 5.25mm to 2.83mm with a mean difference of 2.42mm (95% CI, 0.45 to 4.4mm; p=0.018). Graphical plots of the comparison between preoperative and postoperative alignment measurements are presented in Figure 3.

When considering improvement in PROs following surgery, at the latest follow-up, significant changes were seen on the following scores: PROMIS Global Physical Health improved from 46.1 to 54.5, with a mean improvement of 8.46 (95% CI, 2.2 to 14.7; p=0.011); TSK improved from 42.7 to 34.5, with a mean improvement of 8.2 (95% CI, 2.1 to 14.4; p=0.012); the mean EFAS score improved from 5 to 10.3, with a mean difference of 5.3 (95% CI, 1.9 to 8.6; p=0.004); lastly, the FAAM Daily Living Score improved from 60.5 to 79.7, with a mean difference of 19.2 (95% CI, 0.2 to 38.2; p=0.048). No significant changes were observed for the PCS (11.4 to 3.9, p=0.09) or FAAM Sports (36.15 to 52.9, p=0.23). Graphical plots of the comparison between preoperative and postoperative PROs are presented in Figure 4, along with 95% confidence intervals in Table 1.

In the multivariate analysis assessing the influence of deformity correction on the improvement of PROs, the PROMIS Global Physical Health was found to be significantly associated (p=0.0015) with improvements

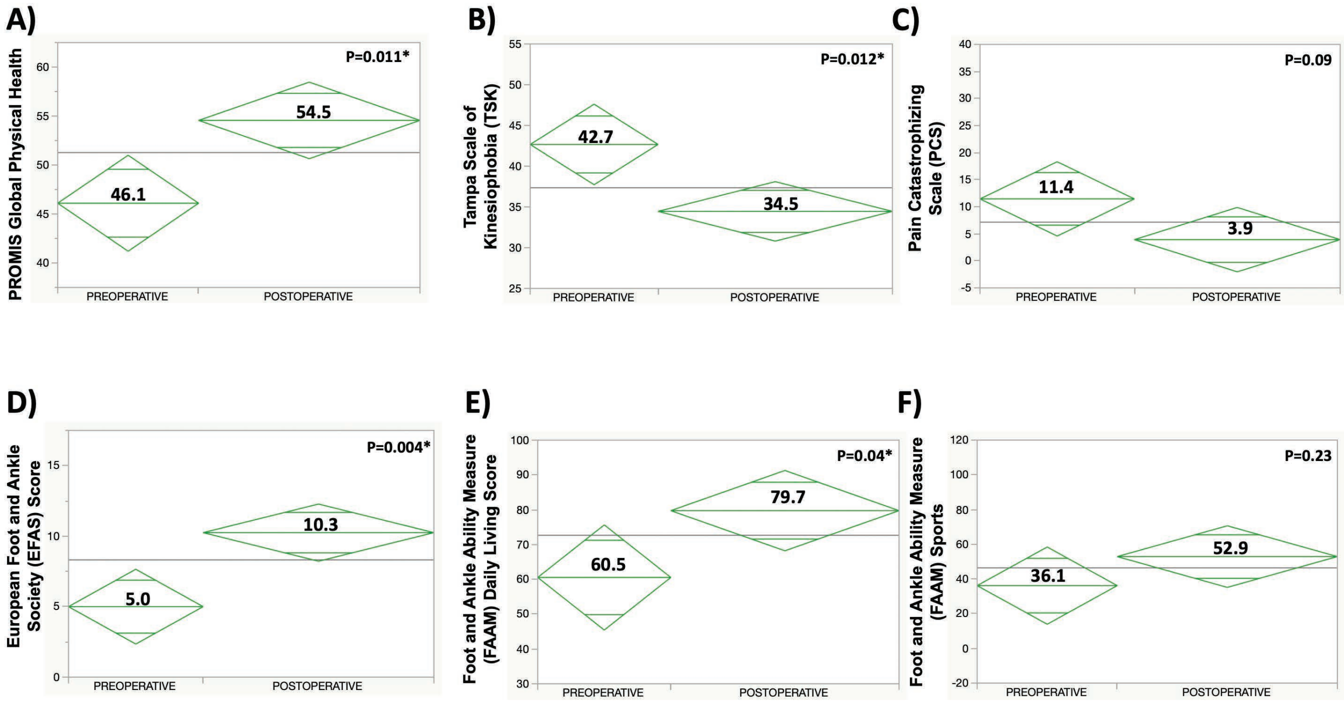

Figure 4. Graphical Plots of Patient Reported outcomes with 95% CI outlines. The averages of the specific measurements are included along with p-values.

Table 1. Patient Reported Outcome Measures Pre/post Operation

PRO Survey	PGPH	TSK	PCS	EFAS	FAAM Daily Living	FAAM Sports
Pre-Op Mean	46.1	42.7	11.4	5	60.5	36.1
Pre-Op 95% CI	41-51	37.72-47.61	4.58-18.31	2.35-7.65	45.43-75.65	13.91-58.41
Post-Op Mean	54.5	34.5	3.9	10.3	79.7	52.9
Post-Op 95% CI	50.65-58.46	30.80-38.105	(-)2.031-9.86	8.22-12.28	68.2-91.28	35.14-70.64

Mean Values and 95% CI are Included. PGPH: PROMIS Global Physical Health.

in FAO (p=0.00065) and LTS (p=0.00436), with a R^2 of 0.98. Improvements in TSK were significantly associated with changes exclusively in the HMA (p=0.0074), with a R^2 of 0.66. The improvements on FAAM Daily Living Score were significantly correlated (p=0.048) with improvements in the FAO (p=0.023) and TTA (p=0.029), with a R^2 of 0.78.

Eight out of the 14 patients received a concurrent associated bone alignment surgical procedure on their foot and ankle. The procedures performed with the TAR included first tarsometatarsal joint fusion, cotton osteotomy, medial malleolus prophylactic fixation, peroneal tendon synovectomy, and Achilles' tendon lengthening. A summary of all associated procedures performed is presented in Table 2.

DISCUSSION

In this retrospective comparative study, we evaluated deformity in pre- and post- operative WBCT imaging of patients who underwent lateral approach trans-fibular TAR for end stage OA. Patient reported outcomes were assessed and correlated with the deformity correction. All measurements of deformity were found to be significantly improved and some of the PROs were significantly improved. An association was found between these improved PROs and our deformity correction measurements. These findings confirm our hypothesis.

Early studies of the lateral approach TAR have reported safe and effective surgical technique, reliable implant, and positive initial outcomes.[10,11,34-36] Usuelli et al. investigated alignment of the lateral approach TAR by measuring the tibial slope (beta angle) on weight bearing radiographs. They compared the slope of anterior approach and lateral approach TARs to a control group. They found that the tibial slopes of the lateral approach TAR, on average, were more similar to the anatomic tibial slope measured in normal ankles.[37] The authors also found a mean alpha angle (medial distal tibial angle) of 89.3 degrees. Usuelli et al., in a large series, reported a sagittal alignment on the lateral group

Table 2. Associated Procedures to Total Ankle Replacements (TAR)

Patient	Associated Procedures to TAR	Implant Size	Polyethilene Size
1	Bröstrom	3	0
2	Bröstrom. Syndesmosis Fixation. LapiCotton. MDCO.	4	0
3	Bröstrom	2	2
4	Bröstrom. Syndesmosis Fixation.	6	2
5	Bröstrom. Syndesmosis Fixation. PB lenghtening. Cotton. MDCO. LCL.	4	4
6	Bröstrom	3	0
7	Bröstrom	4	2
8	Bröstrom. Syndesmosis Fixation.	4	2
9	Bröstrom. Protective medial malleolus screw	4	2
10	Bröstrom. Medial malleolar fixation with anti-gliding plate	2	0
11	Bröstrom. Protective medial malleolus screw.	5	2
12	Bröstrom. LapiCotton.	4	2
13	Bröstrom. Achilles lengthening.	3	2
14	Bröstrom. Achilles lengthening. Fibular lenghtening.	4	2

MDCO: medial displacement.

of 35.1%, an alpha angle of 2.7 degrees, and a HMA of 4.8mm on the 24th week follow-up.[38] They also noticed an increase in valgus position of the hindfoot over the temporal course.[38] DeVries et al. used the lateral distal tibial angle (LDTA) and anterior distal tibial angle (ADTA) to measure changes in deformity and alignment when using the lateral approach. They had 11 patients for a 12 month follow up with weight bearing radiograph imaging, and found significant improvement in both LDTA (91.8 to 90.5) and ADTA (84.6 to 85.7) measures. Using Magnetic Resonance Imaging (MRI) with a metal artifact reduction software, de Cesar Netto et al. showed a mean TLS of 0.22mm in lateral approached TAR.[39] We did not measure the lateral slope (beta angle) or the MDTA/ADTA in our study, but our mean TTA, a coronal plane alignment representation, was 1.5 degrees (complementary: 88.5), our mean HMA was 5.10mm, and mean TTS was 2.83mm. These results were consistent with the balance the other authors exhibited. These findings may support evidence that the lateral approach trans-fibular TAR can significantly correct coronal and sagittal alignment.[40]

Mosca et al. compared PROs from patients undergoing lateral total ankle replacement and found significant improvement in American Orthopaedic Foot and Ankle Society score (AOFAS) (45 to 91.8), the 36-Item Short-Form survey (SF36) (62.5 to 88.9), and the Visual Analogue Scale (VAS) (8.2 to 1.2).[41] Usuelli et al., in a minimal 2 years follow-up, demonstrated a mean VAS of 1.43, a mean 86.82 for the AOFAS, a 12-Item Short-Form survey (SF12) with a mean Physical Component Summary (PCS) of 46.25, and a mean Mental Component Summary (MCS) of 53.12.[42] In a 12-month period, Bianchi et al. showed improvement in the FFI-pain (53.67 to 16.95), in the FFI-disability (64.19 to 20.76), in the VAS (7.81 to 2.29), and in the AOFAS (40.95 to 86.38).[43] Barg et al., in a series of 55 patients undergoing lateral TAR with a high number of concomitant procedures and a 24-month minimal clinical follow-up, also demonstrated good functional results.[44] Improvement on VAS (7.9 to 0.8), PROMIS physical (37.0 to 48.1), and PROMIS pain (65.4 to 54.9) were reported.[44] Our functional results were in line with what was previously published, although it is difficult to compare different outcome measures. We were able to show significant ($ps<0.048$) changes in PROMIS Global Physical Health (46.1 to 54.5), TSK (42.7 to 34.5), EFAS (5 to 10.3), and FAAM Daily Living (60.5 to 79.7), but not for the PCS (11.4 to 3.9, $p=0.09$) or FAAM Sports (36.15 to 52.9, $p=0.23$).

Our study adds to this body of evidence by providing measures of FAO improvement, a three-dimensional assessment of foot and ankle alignment. The only study that made this assessment was performed by Lintz et al., who performed a comparison between this three-dimensional tool and cystic formation after anterior TAR.[8] Values in FAO below -2.75% and above 4.5% were associated with a higher cyst volume. The mean FAO presented by our study, 3.63%, remained on the safe range proposed by Lintz et al., which could explain the improvement and correlation of this measurement with the PROs we demonstrated. Many studies found relations between preoperative malignment and postsurgical results, but few made associations among postoperative alignment and postoperative outcomes.[45,46] When analyzing anterior TARs, Nielson et al. did not find associations between postoperative sagittal balance and short-term functional outcomes.[47] Johnson-Lynn et al. were able to find association among a coronal plane alignment value, the MDTA, Foot and Ankle Outcome Score, and AOFAS scale.[48] Our study was the first to describe positive relations between improvement in three-dimensional measurements and PROs, supporting the idea that these two entities are related. We could also demonstrate that 98% of changes in PROMIS Global Physical Health were explained by improvements in FAO and LTS. TSK rises were 66% explained by HMA. 78% of the enhancements in FAAM Daily Living Score were attributed to FAO and TTA improving. This could be a brief representation of the lateral total ankle replacement's capacity in correcting deformities that might be translated into clinical results.

It is important to recognize the weaknesses of this study. First, it was a retrospective study that used clinical and radiographical collected data. The lateral approach TAR was also not compared to other treatments or techniques. We only included certain PROs, which in total could not represent the multitude of patients' idiosyncrasies. This study did not access complications or the need for follow up surgeries in the long term. Only one reader and one surgeon were responsible for the observations and interventions. We did not present a large sample, which could have contributed to the absence of some correlations between alignment and reported outcomes. Finally, a significant percentage of patients in the study received concurring associated procedures that can confound the correction assessment. On the other hand, adjuvant procedures are performed on most of the performed TAR worldwide and we found statically significant differences in our small sample.

CONCLUSION

In conclusion, this study showed that the lateral approach trans-fibular TAR can significantly correct ankle deformity in the coronal and sagittal planes in patients presenting with end-stage AO. Clinical benefit was also demonstrated with improvement in multiple PROs during follow up. Additionally, association was found between alignment improvement and functional results. Further prospective and comparative studies are needed to support these results.

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PATIENT REPORTED OUTCOMES AFTER CONVERSION VS. PRIMARY TOTAL HIP ARTHROPLASTY: A PROPENSITY MATCHED ANALYSIS

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ABSTRACT

Background: Conversion total hip arthroplasty (cTHA) is increasingly utilized as a salvage procedure for complications associated with fracture fixation around the hip and acetabulum and for failed hip preservation surgery. While primary THA (pTHA) has a high success rate, little is known about outcomes following conversion THA. The purpose of this study is to evaluate patient reported outcomes (PROs) and complication rates following conversion THA compared to primary THA.

Methods: Patients that underwent cTHA or pTHA from 2015-2020 at a large tertiary referral academic center were retrospectively identified. THA patients were propensity matched in a 1:1 fashion by age, body mass index (BMI), and sex. Pain scores and PROMIS physical function (PF), pain interference (PI), and depression (DA) scores were compared at preoperative and final postoperative follow up timepoints using independent t-tests. Differences in complication and reoperation rates between cohorts were assessed using chi square analysis.

Results: A total of 118 THAs (59 cTHA, 59 pTHA) were included in this analysis with an average follow up of 21.3 months. cTHAs were most commonly performed following hip fracture fixation (50.8%). The conversion cohort had significantly longer lengths of stay (3.6 days vs 1.9 days, p<0.01) and greater use of revision-type implants (39.0% vs 0.0%, p<0.01) compared to pTHA. There was no significant difference in complication rates (cTHA = 15.3%, pTHA = 8.5%; p=0.26), with intraoperative fracture being the most common for both. Primary and conversion THA groups also experienced similar reoperation rates (cTHA = 5.1%, pTHA = 6.8%; p=0.70). No significant differences in PROs at final follow up were identified between groups.

Conclusion: Patients undergoing cTHA required increased utilization of revision hip implants and had longer lengths of stay, but had comparable complication and reoperation rates, and ultimately demonstrated similar improvements in PROMIS scores compared to a matched cohort of pTHA patients.

Level of Evidence: III

Keywords: promis, conversion total hip, patient reported outcomes, arthroplasty, hip replacement

INTRODUCTION

Conversion total hip arthroplasty (cTHA) is increasingly utilized as a salvage procedure after failed hip preservation surgery or for complications associated with fracture fixation around the hip and acetabulum. Most commonly, cTHA addresses failures that occur after prior treatment of fractures around the hip including those treated with open reduction and internal fixation, cephalomedullary fixation, and hemiarthroplasty. Despite best efforts, complications such as post-traumatic arthritis, femoral head osteonecrosis, nonunion, infection, implant failure and loss of fixation do occur.[1-3] In the setting of prior surgery with progressive disabling post-traumatic arthritis, loss of fixation, implant cutout, or pain, cTHA can be a good option for pain relief and improved function. As the incidence of hip fractures increases, a greater number of patients are likely to undergo treatment for surgically related complications, leading to an increased utilization of cTHA as a salvage option.[4,5]

Despite being part of the same diagnosis related group (DRG), multiple studies have demonstrated that cTHA is more complicated than primary THA (pTHA) in many ways. Altered anatomy and previously placed implants add to the complexity of the procedure. Studies that have evaluated cTHA have found the procedure to be associated with increased resource utilization, cost, and perioperative complications.[6-14] Unfortunately, few studies have assessed improvement in patient reported outcomes (PROs) after cTHA.[15-17]

As healthcare delivery in the United States shifts towards alternative payment models and focuses more on value-based, outcomes-driven care, PROs will become in-

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

Sources of Funding: No sources of funding declared.

creasingly important in measuring and maximizing value in healthcare.[18] The National Institutes of Health (NIH) Patient-Reported Outcomes Measurement Information System (PROMIS) is one such PRO which has been utilized in arthroplasty to evaluate pTHA.[19,20] The PROMIS Computer Adaptive Test (CAT) is capable of increasing the efficiency and accuracy of short-form versions of the questionnaire utilizing Item Response Theory to ask a more appropriate subsequent set of questions. While multiple domains of questions exist, Physical Function (PF), Pain Interference (PI) and Depression Assessment (DA) are commonly utilized. The purpose of this study is to compare the 1) procedure characteristics, 2) complication rates, and 3) pre-operative and post-operative PROMIS CAT PF, PI, and DA scores of patients undergoing cTHA compared to pTHA. Our hypothesis is that patients undergoing cTHA will have similar PROMIS scores as compared to the pTHA cohort but will have increased perioperative complications, length of stay and discharge to skilled nursing facilities (SNF).

METHODS

Patient Population

Following institutional review board approval, patients that underwent a primary or conversion THA at a large tertiary referral academic center from 2015 to 2020 were retrospectively identified through billing records using current procedure terminology (CPT) codes 27130 and 27132. Arthroplasty performed for primary treatment of fracture, tumor, revision of prior arthroplasty, or in the setting of active infection were excluded. Patients were excluded if they had underlying dementia and/or were unable to appropriately complete the questionnaires. Patients were also excluded if they had incomplete preoperative PRO survey data, or if they did not have a minimum of 6 months of postoperative follow up.

Data Collection

Demographic and baseline characteristics of the patient population were recorded including age, sex, body mass index (BMI), smoking status, Charlson Comorbidity Index (CCI), and specific comorbidities such as hypertension and diabetes mellitus. Details related to cTHA were also collected including time to conversion, indication for conversion, and need for revision-type or specialty implants. Perioperative information was recorded including surgeon type (arthroplasty or trauma fellowship-trained), approach utilized, cemented or non-cemented implants, length of hospital stay (LOS), and discharge destination.

PRO questionnaire data was collected from preoperative and all postoperative follow up visits including PROMIS PF, PI, and DA domains as well as visual analog scale (VAS) pain scores. Any complications or reoperations during the perioperative or postoperative period were recorded (up to one year). Complications included intraoperative fracture, periprosthetic fracture, surgical site infection, dislocation, symptomatic heterotopic ossification (HO) requiring surgical excision, surgical site hematoma requiring surgical evacuation, and trochanteric nonunion. Surgical site infections were considered superficial if treated with antibiotics alone, while deep infections referred to those requiring surgical intervention. Reoperations included component revision and/or open reduction and internal fixation for periprosthetic fracture, irrigation and debridement and component exchange, hematoma evacuation, and HO excision.

Table 1. Baseline Characteristics

	Primary (N=59)	Conversion (N=59)	†p-value
Age (Mean ± SD, years)	61.4 ± 13.5	60.9 ± 15.5	0.875
Sex (n)			0.257
Female	66.1% (39)	55.9% (33)	
Male	33.9% (20)	44.1% (26)	
Body Mass Index (n)			1.000
Non-obese (< 30 kg/m²)	62.7% (37)	62.7% (37)	
Obese (≥ 30 kg/m²)	37.3% (22)	37.3% (22)	
Smoking Status (n)			0.068
Non-smoker	94.9% (56)	84.8% (50)	
Smoker	5.1% (3)	15.2% (9)	
CCI (Mean ± SD)	2.3 ± 1.7	2.4 ± 1.9	0.724
Hypertension (n)			0.460
No	49.2% (29)	42.4% (25)	
Yes	50.8% (30)	57.6% (34)	
Diabetes Mellitus (n)			0.729
No	93.2% (55)	91.5% (54)	
Yes	6.8% (4)	8.5% (5)	

SD = Standard deviation; CCI = Charlson Comorbidity Index
†p-values calculated using independent t-tests and chi square analysis for continuous and categorical variables, respectively

Statistical Analysis

Statistical analysis was performed using Stata/SE® (StataCorp LP, College Station, TX). Conversion and primary THA patients were matched using one-to-one propensity score matching based upon age, sex, and BMI.[21] These parameters were chosen as they are similar to previous investigations in arthroplasty literature.[11,14,22,23] Patient baseline and perioperative characteristics were compared between conversion and primary cohorts using chi square analysis and independent t-tests for categorical and continuous variables, respectively. Com-

Table 2. Conversion Details

	Conversion (N=59)
Time to Conversion (Mean ± SD, years)	7.9 ± 11.4
Reason for Conversion (n)	
Femoral neck fracture fixation	20.3% (12)
IT/ST fracture fixation	30.5% (18)
Acetabular fracture fixation	18.6% (11)
Hip resurfacing/hemiarthroplasty	13.6% (8)
Other (SCFE, DDH, PAO)	17.0% (10)
Revision Implants (n)	39.0% (23)
Revision femoral component	28.8% (17)
Revision femoral component + dual mobility	5.1% (3)
Revision acetabular component + dual mobility	1.7% (1)
Revision femoral + acetabular components	1.7% (1)
Dual mobility	1.7% (1)

SD = Standard deviation; SCFE = Slipped capital femoral epiphysis; DDH = Developmental dysplasia of the hip; PAO = Periacetabular osteotomy

Table 3. Perioperative Characteristics*

	Primary (N=59)	Conversion (N=59)	†p-value
Surgeon (n)			**<0.001**
Arthroplasty fellowship-trained	74.6% (44)	39.0% (23)	
Trauma fellowship-trained	23.7% (14)	47.5% (28)	
Other	1.7% (1)	13.6% (8)	
Approach (n)			**0.017**
Anterior/Lateral	61.0% (36)	39.0% (23)	
Posterior	39.0% (23)	61.0% (36)	
Cemented (n)			0.242
No	96.6% (57)	91.5% (54)	
Yes	3.4% (2)	8.5% (5)	
Length of Hospital Stay (Mean ± SD, days) ǂ	**1.9 ± 1.2**	**3.6 ± 3.0**	**<0.001**
Discharge Destination (n)			0.066
Home	91.4% (53)	79.3% (46)	
Skilled Nursing Facility	8.6% (5)	20.7% (12)	

SD = Standard deviation
*Boldface indicates statistical significance
†p-values calculated using independent t-tests and chi square analysis for continuous and categorical variables, respectively
ǂ One outlier with 70-day hospital stay in Conversion group excluded from this analysis

plication and reoperation rates were assessed between groups using chi square analysis. PROs at final follow up and improvement in PROs from baseline were compared between conversion and primary cohorts using independent t-tests. Statistical significance was set at $p<0.05$.

RESULTS

A total of 151 cTHA were identified. Patients were excluded if they did not have pre-op PROMIS scores (29 patients), if they had incomplete PROMIS data, could not complete PROMIS questionnaires, or had <6 months follow-up (58 patients), or underwent staged procedures for infection or revision arthroplasty (5 patients), leaving 59 cTHAs that met inclusion criteria. A total of 118 THAs (59 conversions, 59 primaries) in 115 patients were included in this analysis after successful 1:1 propensity-score matching. The average length of postoperative follow up was 21.3 ± 14.2 months. Table 1 details the characteristics of this patient population. There were no differences identified between primary and conversion cohorts with regard to age, sex, BMI, smoking status, or comorbidity burden ($p>0.05$ for all).

Details regarding the cTHAs are reported in Table 2. On average, cTHA were performed 7.9 ± 11.4 years after the index procedure. Conversion THAs were most commonly performed following hip fracture fixation (50.8%). Revision-type implants were utilized in 39.0% of the cTHAs, most common being a revision-type (diaphyseal engaging) femoral component (28.8%), while no pTHAs utilized revision-type implants ($p<0.01$).

Table 3 details the operative characteristics for the conversion and primary cohorts. Primary THAs were most likely to be performed by an arthroplasty fellowship-trained surgeon (74.6%). Conversion THAs were most often performed by trauma fellowship-trained surgeons (47.5%), followed closely by arthroplasty fellowship-trained surgeons (39.0%). The approach utilized was significantly different between groups, with conversions more frequently performed through a posterior approach compared to primaries (61.0% vs 39.0%, $p=0.02$). Cement fixation was infrequently utilized in both cohorts (pTHA = 3.4%, cTHA = 8.5%; $p=0.24$). More cTHA patients were discharged to a skilled nursing facility compared to pTHA patients (20.7% vs 8.6%, $p=0.07$), however, this did not reach statistical significance. Patients undergoing cTHA had significantly longer postoperative lengths of stay (3.6 days vs 1.9 days, $p<0.01$) compared to pTHA. Of note, one patient in the conversion cohort had a 70-day hospitalization due to the development of acute respiratory failure during the postoperative period requiring a prolonged stay in the intensive care unit. This outlier was excluded from the length of stay analysis to avoid skewing the data.

Table 4. Patient Outcomes

	Primary (N=59)	Conversion (N=59)	†p-value
Final Follow Up (Mean ± SD, months)	22.3 ± 14.4	20.1 ± 14.0	0.397
Surgical Complications (n)	8.5% (5)	15.3% (9)	0.255
Reoperations (n)	6.8% (4)	5.1% (3)	0.697
PROMIS Physical Function (Mean ± SD)			
Preoperative	36.5 ± 5.5	34.6 ± 6.3	0.087
Final Δ	6.2 ± 9.0	6.6 ± 8.6	0.788
Final follow up	42.7 ± 9.3	41.3 ± 9.8	0.417
PROMIS Pain Interference (Mean ± SD)			
Preoperative	64.0 ± 6.0	64.6 ± 6.5	0.590
Final Δ	-8.2 ± 10.8	-7.6 ± 10.4	0.784
Final follow up	55.7 ± 9.6	57.3 ± 10.6	0.388
PROMIS Depression (Mean ± SD)			
Preoperative	51.3 ± 10.8	53.8 ± 10.0	0.194
Final Δ	-4.3 ± 9.0	-3.2 ± 8.4	0.505
Final follow up	46.9 ± 9.0	50.7 ± 11.4	0.052
VAS Pain Score (Mean ± SD)			
Preoperative	5.8 ± 3.1	5.6 ± 3.0	0.756
Final Δ	-3.0 ± 3.7	-3.0 ± 3.6	1.000
Final follow up	2.8 ± 3.1	2.6 ± 3.1	0.760

SD = Standard deviation; PROMIS = Patient reported outcomes measurement information system; VAS = Visual analog scale
†p-values calculated using independent t-tests (continuous variables) and chi square analysis (categorical variables)
Δ = Final follow up score - Preoperative score

Complication rates and patient reported outcomes are described in Table 4. There was no significant difference in complication rates between groups (cTHA = 15.3%, pTHA = 8.5%, p=0.26). The most common complications among both groups were intraoperative fracture (cTHA = 4, pTHA = 2) and periprosthetic fracture (cTHA = 2, pTHA = 2). Additional complications observed in the conversion group included surgical site infection (n=1), dislocation (n=1) and trochanteric nonunion (n=1). Additional complications in the primary group included symptomatic HO (n=1) and hematoma requiring surgical evacuation with subsequent superficial surgical site infection (n=1). Primary and conversion THA groups also experienced similar reoperation rates (cTHA = 5.1%, pTHA = 6.8%; p=0.70), with the most common being component revision/fixation for periprosthetic fracture (cTHA = 2, pTHA = 2). Other reasons for reoperation included irrigation and debridement of a surgical site hematoma (n=1) and HO excision (n=1) in the primary group, and irrigation and debridement with component exchange for infection (n=1) in the conversion group. PROMIS physical function, PROMIS pain interference, and VAS pain scores were similar between conversion and primary cohorts at final follow up (p>0.05 for all). Conversion THA trended toward higher PROMIS depression scores (50.7 vs 46.9, p=0.052) compared to pTHA at final follow up, though this did not reach statistical significance. However, improvement in PROMIS depression from preoperative values was similar between groups (cTHA Δ = -3.2, pTHA Δ = -4.3; p=0.51).

DISCUSSION

Conversion THA is being increasingly utilized as a salvage surgery after failed fracture fixation, progressive arthritis after previous hip surgery, or prior hip salvage procedures. Patient reported outcomes after pTHA have been extensively evaluated and the success of THA at relieving pain and improving quality of life is evident.[19,24-26] Despite being part of the same diagnosis related group, cTHA is a much more complex procedure due to multiple factors including altered anatomy and pre-existing implants requiring larger and more extensive exposures. Studies have demonstrated increased resource utilization for patients undergoing cTHA secondary to increased length of stay and readmission rates, need for blood transfusions, disposition to subsequent inpatient care, length of surgical procedure and increased cost of implants. Perioperative complications including prosthetic joint infection, hip dislocation, and need for revision surgery have also been found to be higher in this population.[6-14]

In a large propensity matched database study evaluating National Surgical Quality Improvement Project (NSQIP) data files, cTHA patients demonstrated greater rates of complications (7.5% vs. 4.5%, odds ratio 1.68, CI 1.39-2.02), longer LOS, and statistically significant differences in non-home bound discharge.[13] A subsequent review of the American College of Surgeons NSQIP database found that patients undergoing cTHA are more similar to patients undergoing revision arthroplasty (rTHA) with similar demographic, clinical, and perioperative characteristics, underscoring the complex nature of the patient population.[12] Ryan et al. reviewed 163 cTHA performed at a tertiary medical center. As compared to pTHA, cTHA was associated with about 19% greater cost, increased operative times, LOS, blood loss, and perioperative complications.[7] Similarly, Schwarzkopf et al. compared 119 cTHA to 251 pTHA and found that patients undergoing cTHA had increased LOS (3.8 days vs 2.8 days), longer surgical time, and greater likelihood of utilizing revision-type implants.[6] This is in line with the current study, as our cTHA cohort similarly demonstrated increased LOS and higher likelihood of utilizing revision-type implants. Although patients undergoing cTHA trended toward a higher rate of discharge to a skilled nursing facility, statistical significance was not reached. In spite of the increased risks, patients continue to elect to undergo cTHA to ease their pain and improve their function. However, little is known about patient reported outcomes after cTHA.

To our knowledge, this is the first study evaluating PROMIS scores in a propensity matched cohort comparing cTHA to pTHA. Our results demonstrate that in a one-to-one, propensity matched study of patients undergoing pTHA versus cTHA, there are no significant differences in PROs, including VAS, PROMIS CAT PF, PI, and DA, at preoperative and final postoperative timepoints. At final follow-up, cTHA patients were functioning as well as pTHA patients and exhibiting similar improvements in PROs. Previous studies have demonstrated improved WOMAC and Harris Hip Scores after cTHA from failed bipolar hemiarthroplasty as well as conversion from failed CMN, despite relatively high short-term complication rates.[9,17,27] Additionally, Tadevich et al. evaluated a matched cohort of cTHA and pTHA patients and found that UCLA activity level scores between the two groups were similar at one year follow-up.[15] These reports support the findings of the present study, suggesting that cTHA leads to acceptable patient outcomes.

Increased scrutiny is being placed on patient outcomes, complications, and cost of episode of care.[7] In an effort to elucidate the perceived value in conversion arthroplasty, this study demonstrates that despite the increased short-term risk profile and increased resource utilization associated with this procedure, patient outcomes may ultimately be similar to that of primary arthroplasty, which has a previously established record of high success. In the present study, cTHA patients did demonstrate increased resource utilization, with increased length of stay and greater use of revision-type implants. This is also in-line with previous studies. This may be useful for pre-operative patient counseling and provides justification for the increased resource utilization, risk profile, and appropriate reimbursement.

Limitations of this study include the retrospective nature of chart review as well as exclusion of patients who may have been lost to follow up or were without sufficient PRO data. Selection bias may exist against those who did not complete PROMIS questionnaires either due to disinterest, time constraints, or due to tablet availability in the setting of COVID-19. In addition, this study is somewhat limited by a small sample size. However, this procedure is relatively uncommon and there is very limited information on the subject in current literature. This study was also performed at a large, tertiary-care academic medical center in New York, so these results may not be generalizable across all patient populations. Despite these shortcomings, the current study was able to evaluate long term PROs for a large group of patients undergoing a relatively rare procedure in a 1:1 propensity matched fashion.

CONCLUSION

Patients undergoing cTHA required increased utilization of revision hip implants, had longer lengths of stay and comparable complication rates, but ultimately demonstrated similar improvements in PROMIS scores compared to a matched cohort of pTHA. Further research should focus on multicenter studies examining this relatively rare but quickly growing complex patient population.

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LONGER LENGTH OF STAY IS ASSOCIATED WITH MORE EARLY COMPLICATIONS AFTER TOTAL KNEE ARTHROPLASTY

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ABSTRACT

Background: Length of stay (LOS) following total knee arthroplasty (TKA) has decreased over recently years. In 2018, the Centers for Medicare and Medicaid Services removed TKA from Inpatient-Only List (IPO), incentivizing further expansion of outpatient TKA. However, many patients may still require postsurgical hospitalization. The purpose of this study was to assess early outcomes for TKA based on length of stay (LOS).

Methods: We identified patients undergoing elective, primary TKA in the National Surgical Quality Improvement Program database using CPT code 27447 between 2015 and 2018. Patients were stratified by length of stay (LOS) 0 days, 1-2 days, and ≥3 days. Thirty-day rates of any complication, wound complications, readmission, and reoperation were assessed. Multivariate analysis was performed to adjust for confounding variables.

Results: 5,655 (3%) patients underwent outpatient TKA, 130,543 (59%) had LOS 1-2 days, and 84,986 (38%) had LOS ≥3 days. Any complication was experienced in 4.1% of those with LOS 0 days, 4.3% for those with LOS of 1-2 days, and 10.5% for patients with LOS ≥3 days ($p<0.0001$). Readmission occurred in 2.2%, 2.6%, and 4.0% for the 3 groups, respectively ($p<0.0001$). After multivariate analysis, there was no significant difference in any outcome measure between patients with LOS 0 and 1-2 days, however those with LOS ≥3 days had higher odds of complications, reoperation, and readmission.

Conclusion: A significant number of patients had LOS ≥3 days following TKA and had more comorbidities and complications. Outpatient TKA was not associated with increased early complication compared to those with LOS of 1-2 days. Despite expansion of outpatient surgery, postsurgical hospitalization remains an integral part of care following TKA.

Level of Evidence: III

Keywords: total knee arthroplasty, complications, length of stay, outpatient surgery

INTRODUCTION

There has been an increasing amount of total knee arthroplasty (TKA) procedures performed in the United States and further growth is anticipated, with some projections estimating 1.26 million TKAs occurring annually by 2030.[1] Procedural growth has been paralleled by a transformation of the perioperative course from a prolonged hospitalization to shorter length of stay (LOS), with an increasing number of patients undergoing TKA as an outpatient procedure.[2-4] Many factors, such as improvements in surgical technique, preoperative optimization of chronic medical conditions, patient education initiatives, increased adoption of multimodal analgesia, and hospital administrative pressures have contributed to this transition.[5-9] Development of novel models of reimbursement and bundle payment, such as the Bundled Payments for Care Improvement initiative and Comprehensive Care for Joint Replacement model may have also contributed.[10,11] Effective January 1st, 2018, the Centers for Medicare and Medicaid Services (CMS) removed TKA from the Inpatient-Only List (IPO), incentivizing further expansion of outpatient TKA.

Shorter hospitalizations and shifting more care to the home setting after TKA provide clear benefits, including reduction of costs associated with immediate post-surgical hospitalization.[12] However, there is concern that shorter hospitalizations and associated reductions in monitoring during the early postoperative period may result in increased complications or readmissions, particularly in those patients at highest risk for postoperative complications.[13,14] Additionally, reduction in post-surgical hospitalization may result in increased burden placed upon the patient, their caregivers, and also the surgeon.[15,16] Studies assessing the impact of shorter LOS have reported mixed results on complications and, despite movement towards same-day discharge, outpatient TKA may not be feasible or appropriate for all patients with end-stage arthritis.[13,17,18] Therefore, the purpose of

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

Sources of Funding: No sources of funding declared.

this study was to assess differences in 30-day complication rates related to LOS following TKA. Additionally, we sought to compare the demographics and comorbidity profiles of those able to discharge on the same-day as TKA with those requiring longer LOS.

METHODS

The American College of Surgeons National Quality Improvement Program (ACS NSQIP) database was queried to identify patients who underwent primary TKA between years 2015 and 2018 using Common Procedural Terminology (CPT) code 27447. The ACS NSQIP database includes data from over 600 voluntarily participating hospitals, the majority of which are located within the United States. Hospitals are both academic and private institutions and patients with public and private insurance are included. Data collection is performed by trained nurse abstractors, who document patient demographic information, medical comorbidities, perioperative data, and 30-day complication data. An internal auditing mechanism is in place and a cumulative disagreement rate of <2% has previously been reported.[19] All data collected and maintained in the ACS NSQIP database are de-identified and compliant with the Health Insurance Portability and Accountability Act. The ACS NSQIP user guide contains complete details regarding data collection.[20] This study was reviewed by our institutional review board and granted a human subjects research exemption.

Eligible patients underwent primary TKA as determined by CPT code. Patients undergoing emergent or non-elective surgery, bilateral TKA, revision TKA, recent chemoradiation treatment, or with active disseminated cancer were excluded. In order to establish a cohort most representative of elective, primary TKA, patients with the following characteristics were also excluded: patients residing in non-home locations prior to surgery, those with a non-clean wound class, and patients with documented preoperative sepsis. All CPT codes billed at time of primary TKA were individually reviewed and patients were excluded if unrelated procedures or those for non-primary indications, such as revision arthroplasty, tumor excision, or arthroscopy of other joints, were performed at time of index primary TKA. A list of concurrent included CPT codes is provided in Appendix 1.

Age, body mass index (BMI), race, sex, and other patient demographic data were collected. Medical comorbidities were also collected, and included diabetes, chronic obstructive pulmonary disease (COPD), dialysis, ascites, congestive heart failure (CHF), preoperative steroid use, and bleeding disorders. Patients were subsequently stratified based on documented length of stay (LOS) into three groups: LOS 0 days, LOS 1-2 days, and LOS ≥3 days. 30-day incidence of wound complications, deep infection, readmission, reoperation, and any complication were assessed. Wound complication was a composite variable, comprised of superficial incisional surgical site infection (SSI), deep incisional SSI, organ space SSI, and wound disruption/dehiscence. Deep infection was also a composite variable, including both deep incisional SSI and organ space SSI. Any complication was defined as the occurrence of any of the following complications: readmission, reoperation, pneumonia, unplanned reintubation, deep vein thrombosis, pulmonary embolism, renal insufficiency, acute renal failure, urinary tract infection, stroke, cardiac arrest, myocardial infarction, allogenic blood transfusion, sepsis, septic shock, clostridium difficile infection, superficial incisional SSI, deep incisional SSI, organ space SSI, and wound disruption/dehiscence. Mean LOS in days and operative time in minutes were also determined for each of the three groups.

Univariate statistical analysis was performed using chi-squared test for categorical variables and Kruskal-Wallis Test for continuous variables. Multivariate logistic regression was then performed to assess for differences in occurrence of complication outcome measures between the three groups adjusting for age, race, sex, BMI, functional status, ASA classification, smoking status, recent weight loss, recent steroid use, diabetes, COPD, CHF, ascites, dialysis, and bleeding disorders. Criteria for inclusion in the multivariate analysis was p<0.1, additionally recent weight loss and ascites were included as potential variables of interest. All statistical analyses were performed with use of SAS 9.4 (SAS Institute, Cary, NC), and the statistically significant level was set at p<0.05.

RESULTS

In total, 221,184 eligible patients undergoing elective, primary TKA between 2015-2018 were identified in the ACS NSQIP database. Of these, 5,655 (2.6%) had LOS 0 days, 130,543 (59.0%) had LOS 1-2 days, and 84,986 (38.4%) had LOS ≥3 days. The mean age was 65.7 (±9.1) years for patients with LOS 0 days, 66.0 (±9.7) years for those with LOS 1-2 days, and 68.4 (±9.1) years for patients with LOS ≥3 days (p<0.0001). Higher mean BMI was associated with increased length of hospitalization. Mean BMI was 31.6 (±6.0) kg/m2 for LOS 0 days, 32.8 (±6.5) kg/m2 for LOS 1-2 days, and 33.5 (±7.2) kg/m2 for LOS ≥3 days (p<0.0001). Incidence of diabetes was higher with greater LOS, increasing from 14.4% in patients with LOS of 0 days, 16.5% in those with LOS 1-2 days, and 21.2% in patients hospitalized for ≥3 days (p<0.0001). Mean operative time was 82.8 (±28.6) minutes with LOS of 0 days, 87.7 (±31.8) minutes with LOS of 1-2 days, and 91.9 (±37.5) minutes for LOS ≥3 days

Table 1. Patient Demographics and Comorbidities

	LOS 0 days (n=5,655)	LOS 1-2 days (n=130,543)	LOS ≥3 days (n=84,986)	p-value
Age - years (SD)	65.7 (9.1)	66.0 (9.0)	68.4 (9.7)	<0.0001
<55	10.3%	10.3%	8.1%	
55-65	33.5%	32.1%	25.5%	
65-75	40.1%	40.1%	38.6%	
>75	16.2%	17.5%	27.8%	
Female (%)	53.4%	58.1%	67.2%	<0.0001
BMI – kg/m2 (SD)	31.6 (6.0)	32.8 (6.5)	33.5 (7.2)	<0.0001
Race				<0.0001
Asian	4.2%	2.0%	2.0%	
Black	6.3%	7.3%	8.7%	
Other	7.8%	12.5%	24.3%	
White	81.7%	78.2%	65.0%	
Diabetes (%)	14.4%	16.5%	21.2%	<0.0001
COPD (%)	2.1%	2.7%	4.6%	<0.0001
Smoking	6.8%	8.1%	8.3%	0.04
Congestive Heart Failure	0.1%	0.2%	0.5%	<0.0001
Weight Loss	0.2%	0.1%	0.1%	0.009
Dialysis	0.1%	0.1%	0.2%	<0.0001
Ascites	0.0%	0.0%	0.0%	0.14
Steroid Use	2.4%	3.2%	4.0%	<0.0001
Bleeding Disorder	1.4%	1.5%	2.5%	<0.0001
ASA				<0.0001
1	2.0%	1.9%	1.6%	
2	60.1%	51.5%	41.9%	
3	37.3%	45.4%	54.1%	
≥4	0.6%	1.2%	2.4%	
Functional Status				<0.0001
Totally Independent	99.7%	99.3%	98.5%	
Partially Dependent	0.3%	0.6%	1.4%	
Totally Dependent	0.0%	0.1%	0.1%	
Mean LOS – days (SD)	0 (0)	1.6 (0.5)	3.8 (3.1)	<0.0001
Operative Time – minutes (SD)	82.8 (28.6)	87.7 (31.8)	91.9 (37.5)	<0.0001

(p<0.0001). Complete demographic and comorbidity data are provided in Table 1.

Complete data regarding incidence of complications is provided in Table 2. Wound complications occurred in 0.8% of patients with both LOS of 0 and 1-2 days and 1.3% in patients with LOS ≥3 days (p<0.0001). The rate of deep infection was 0.3% in patients with both 0- and 1-2-day LOS and 0.4% when LOS was ≥3 days (p<0.0001). Readmission occurred for 2.2% of patients with LOS of 0 days, 2.6% of patients with LOS of 1-2 days, and 4.0% of patients whose LOS was ≥3 days (p<0.0001). Any complication was observed in 4.1% of patients with LOS of 0 days, 4.3% in those with LOS of 1-2 days, and 10.5% of those with LOS ≥3 days (p<0.0001).

Odds for complications based on LOS are presented in Table 3. There was no difference in odds of wound complications, deep infection, readmission, reoperation, or any complication between patients with LOS of 0 days and 1-2 days, before or after adjustment for

Table 2. Incidence of 30-day Postoperative Complications

	LOS 0 days	LOS 1-2 days	LOS ≥3 days	p-value
Wound Complications	0.8%	0.8%	1.3%	<0.0001
Superficial Infection	0.4%	0.4%	0.7%	<0.0001
Wound Infection	0.1%	0.1%	0.2%	<0.0001
Organ Space Infection	0.2%	0.2%	0.2%	0.13
Wound Dehiscence	0.2%	0.2%	0.3%	<0.0001
Deep Infection	0.3%	0.3%	0.4%	<0.0001
Readmission	2.2%	2.6%	4.0%	<0.0001
Reoperation	0.9%	0.8%	1.5%	<0.0001
Any Complication	4.1%	4.3%	10.5%	<0.0001
Pneumonia	0.3%	0.3%	0.4%	<0.0001
Reintubation	0.1%	0.1%	0.2%	<0.0001
Pulmonary Embolism	0.4%	0.2%	0.9%	<0.0001
Renal Insufficiency	0.1%	0.1%	0.2%	<0.0001
Urinary Tract Infection	0.7%	0.5%	1.0%	<0.0001
Stroke	0.1%	0.0%	0.1%	<0.0001
Cardiac Arrest	0.0%	0.1%	0.1%	<0.0001
Myocardial Infarction	0.1%	10.0%	0.3%	<0.0001
Transfusion	0.3%	0.4%	3.0%	<0.0001
Deep Vein Thrombosis	0.5%	0.5%	1.1%	<0.0001
Sepsis	0.2%	0.1%	0.2%	<0.0001
Septic Shock	0.0%	0.0%	0.1%	<0.0001
Clostridium difficile infection	0.0%	0.0%	0.0%	<0.0001
Failure to wean vent	0.0%	0.0%	0.1%	<0.0001

Table 3. Odds for Complications Based on Length of Stay

	LOS 1-2 vs LOS 0 (ref)	LOS ≥3 vs LOS 0 (ref)	LOS ≥3 vs LOS 1-2(ref)
Unadjusted			
Any Complication (OR)	1.03 [0.90-1.18]	2.73 [2.39-3.12]	2.65 [2.56-2.74]
Wound Complications (OR)	0.99 [0.73-1.33]	1.62 [1.21-2.21]	1.65 [1.52-1.80]
Deep Infection (OR)	0.91 [0.55-1.50]	1.32 [0.80-2.19]	1.46 [1.25-1.70]
Reoperation (OR)	0.96 [0.72-1.28]	1.78 [1.33-2.36]	1.85 [1.71-2.01]
Readmission (OR)	1.16 [0.96-1.38]	1.84 [1.54-2.21]	1.59 [1.52-1.67]
Adjusted*			
Any Complication (OR)	0.99 [0.86-1.13]	2.37 [2.08-2.71]	2.41 [2.32-2.49]
Wound Complications (OR)	0.88 [0.65-1.19]	1.29 [0.95-1.75]	1.46 [1.34-1.60]
Deep Infection (OR)	0.83 [0.50-1.37]	1.14 [0.69-1.89]	1.37 [1.17-1.61]
Reoperation (OR)	0.91 [0.69-1.22]	1.65 [1.24-2.21]	1.81 [1.66-1.97]
Readmission (OR)	1.09 [0.91-1.31]	1.56 [1.30-1.87]	1.43 [1.4-1.50]

Ref = reference. Values presented as OR [95% Confidence interval]
* Adjusting for age, race, sex, BMI, functional status, ASA classification, smoking status, recent weight loss, recent steroid use, diabetes, COPD, CHF, ascites, dialysis, and bleeding disorders.

potential confounders. Patients with LOS of ≥3 days had significantly higher odds for reoperation (OR: 1.78 [95% Confidence Interval (CI): 2.39-3.12]), readmission (OR: 1.84 [95% CI: 1.54-2.21]), wound complications (OR: 1.62 [95% CI: 1.21-2.21]), and any complication (OR: 2.73 [95% CI: 2.39-3.12]). After multivariate analysis, significant differences remained for reoperation (OR: 1.68 [1.26-2.24]), readmission (OR: 1.56 [1.30-1.87]), and any complication (OR: 2.37 [2.08-2.71]). When compared to patients with LOS of 1-2 days, patients with LOS of ≥3 days had significantly higher odds for wound complications, deep infection, reoperation, readmission, and any complication in both the univariate and multivariate analyses (Table 3).

DISCUSSION

In this study, the majority of patients required some postsurgical hospitalization following TKA< with 59.0% having LOS of 1-2 days and 38.4% requiring LOS of 3 or more days. There were greater odds for reoperation, readmission, and any complication for patients hospitalized for ≥3 days, when compared to patients with LOS 0. Similarly, patients with LOS of ≥3 days were found to have greater odds for complications compared to those with LOS of 1-2 days. Conversely, patients undergoing primary, elective TKA with LOS of 0 days did not have increased odds for wound complications, deep infection, reoperation, readmission, or any complication when compared to patients with LOS of 1-2 days. Increased incidence of complications observed with longer LOS is likely related to significantly higher overall medical comorbidity in these patients, such as greater age, have higher BMI, more diabetes, and higher ASA scores. Despite extensive efforts of modern presurgical optimization, many of these risk factors may be non-modifiable and postsurgical hospitalization may be a part of their postsurgical care.

Similar to the current study, Otero et al. found LOS exceeding 3 days to be independently associated with increased risks for 30-day complications after TKA.[18] Conversely, Lovecchio et al. found greater rates of 30-day complications when comparing patients with LOS of 1-2 days compared to those undergoing outpatient surgery.[12] As duration of hospitalization increased, the mean BMI, mean age, proportion of patients with higher ASA classification, and prevalence of medical comorbidities, such as CHF, diabetes, COPD, and end-stage renal disease requiring dialysis, also increased. Greater levels of medical comorbidities result in certain patients requiring longer duration of hospitalization following TKA and have a resulting increased risk for early complications. COPD, CHF, coronary artery disease, and cirrhosis have been associated with occurrence of complications at greater than 24 hours following primary TJA.[13]

Courtney et al. reported no increased risk for readmission, reoperation, and any complication for patients able to undergo outpatient TKA or total hip arthroplasty.[13] In a separate study, Courtney et al. found appropriately selected Medicare-aged TKA patients, defined in the study as age greater than or equal to 65 years, may undergo outpatient TKA, however those with a LOS of 1 day had fewer complications than patients undergoing outpatient surgery.[17] The lack of difference in odds for complications, reoperation, or readmission observed in the present study may be related to the inclusion of more current data, a larger cohort of patients, and focus on solely TKA patients for analysis. The present study includes data from 2015-2018, which was the most current data available at the time, while prior studies include data from 2015 and earlier. As a result of more current data and recent expansion of outpatient TKA, the current study includes more than 5,500 patients, whereas other recent studies are limited to fewer than 1,300.[13,14,17,18]

Patients not discharged on postoperative day 0 and requiring longer hospitalization were older and were more often female. Female sex has previously been identified as an independent risk factor for requiring an inpatient stay after TKA.[17] Weiner et al. also identified age greater than 75 years, female sex, and non-Hispanic black patients having increased risk for hospitalization greater than 2 days after total hip arthroplasty.[21] Further investigation into the impact of sex on duration of hospitalization is needed. It is possible older females are more frail overall and have more difficulty safely mobilizing following TKA. We also found operative time to significantly increase with increasing hospital LOS, which may relate to patient factors or overall surgical complexity. Bradley et al. found each point increase in BMI to be associated with 2.9% longer LOS and 1.46 minutes greater operative time.[22] While surgical factors and precise reasons for duration of hospitalization are not captured as part of the ACS NSQIP database, it is possible greater operative time reflects greater surgical complexity and resulting difficulties with mobilization or pain control.

Successful and safe outpatient TKA is dependent on preoperative medical optimization, careful patient selection, and appropriate aligned practice infrastructure.[14,17] While formal scoring systems to guide selection of patients for outpatient TKA exist, such as the Outpatient Arthroplasty Risk Assessment, there is not a widely accepted standard for determining what patients may undergo outpatient TKA and surgeons may utilize clinical experience in combination with patient preference to determine appropriateness of same-day discharge.[23] While differences in demographics and comorbidities did exist when comparing the three groups in this study, overall size of these differences between patients with LOS 0 and LOS 1-2 was small. It is possible some of the patients with short hospitalization following TKA could undergo outpatient TKA if procedures were in place to facilitate this or their postsurgical hospitalization was related to non-medical factors, such availability of transportation or caregivers. An important aspect of outpatient TKA is ensuring patients have access to adequate support at home, which is not quantified in the ACS NSQIP database.[16] Traditional postsurgical care has been provided in the hospital setting. Outpatient surgery requires redeployment of resources to provide these services using a different method and may shift responsibility or burden for providing these to the surgeon.[15] Procedures in-place to care for patients unable to discharge on postoperative day 0 are essential. Despite careful patient selection and established protocols, outpatient TJA may remain difficult to successfully execute, as a randomized study found 24% of patients unable to discharge same day as planned.[24] Despite pressures from payers and governmental regulations, there remains a portion of patients who are not candidates for same-day discharge following TKA and further study is needed to develop criteria to guide decisions for hospitalization after TKA.

Further study is needed to develop standardized guidelines to determine

This study is not without limitations. This study was retrospective in nature and performed using prospectively collected data in the ACS NSQIP database. While this database does have quality control protocols in-place, the findings of this paper remain dependent on accurate coding and data collection. The ACS NSQIP database reports on 30-day complications and events outside of this window are not reported in this study, although adverse effects from reduced duration of hospitalization seem likely to occur during this early perioperative period. While the ACS NSQIP database does include participating hospitals across the United States, this is a small portion of patients undergoing TKA nationally and this subset may not be representative of all patients. Data available for analysis is limited to variables reported in the ACS NSQIP database, therefore not all patient or socioeconomic factors that may contribute to LOS or complications were considered. Additionally, specific reasons for the occurrence of complications and reasons for readmission or reoperation were not considered as part of this study.

When assessing surgeries occurring between 2015 and 2018, nearly 40% of patients undergoing primary, elective TKA required postsurgical hospitalizations of 3 or more days. These patients were older, had more medical comorbidities, and experienced more complications than patients with LOS of 0 or 1-2 days. Despite regulatory changes and pressures to expand outpatient TKA, successfully performing these procedures with same-day discharge requires careful patient selection, presurgical medical optimization, and care coordination. Despite these advances, a significant number of patients remain at higher risk for perioperative complications and postsurgical inpatient care may continue to be an integral part of their care following TKA.

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DIFFERENCES IN INFECTION RATES BY SURGICAL APPROACH IN TOTAL HIP ARTHROPLASTY AND PATIENT SEX: A SYSTEMATIC REVIEW

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ABSTRACT

Background: There exists conflicting data that patient sex may influence complication and revision rates when undergoing total hip arthroplasty (THA), specifically when comparing different surgical approaches. Differences in body fat or muscular distribution are proposed mechanisms, but these are poorly understood and not well described in current literature.

Methods: A systematic review of the literature was conducted from PubMed, Embase, and Web of Science from inception of the database through September 15, 2020. Studies were included if they included patients undergoing primary elective unilateral THA, delineated infections by surgical approach, and delineated infections by patient sex. Basic science, cadaveric, and animal studies were excluded as were case reports. Two authors screened abstracts and then extracted data from the full text article.

Results: Three studies, including 1,694 patients undergoing 1,811 THA were included. 80 infections were included. No study reported a statistically significant difference in infection risk by patient sex or surgical approach, though there was substantial heterogeneity in study design, approach, and analysis.

Conclusion: Limited data suggests no relationship between sexes across surgical approaches for infection rates. However, poor reporting and small sample sizes preclude definitive conclusions from being drawn. Future studies should emphasize reporting differences in outcomes by patient sex to better elucidate differences, if any, in adverse outcomes between sexes following THA across surgical approaches.

Level of Evidence: IV

Keywords: total hip arthroplasty, direct anterior approach, posterior approach, anterolateral approach, infection, revision

INTRODUCTION

The total hip arthroplasty (THA) is one of the most commonly performed orthopaedic surgeries in the United States, with over 400,000 individuals undergoing the procedure every year.[1] In 2010, it was estimated that a total of 2.5 million adults are living with a prosthetic hip.[2] The surgery is deemed highly successful, with a low risk of revision, a reduction in chronic pain, and improvement in quality of life markers.[3–5] The surgical infection rate is low with a surgical site infection (SSI) rate of 2.5% and a peri-prosthetic joint infection (PJI) rate of 0.9%, however infectious complications are devastating in their economic impact.[6] The additional cost of a PJI after a THA costs an average of $30,000 per patient, and the total cost of PJI's after both hip and knee replacements is projected to be $753.4 million in the United States by 2030, with the increase mainly driven by increasing volume.[6] In addition to the monetary costs, the morbidity and mortality of these infections is devastating with reduced functional hip scores, increased risk of further complications, and extended hospital stays.[7–10]

Given the success of the procedure and the staggering number of patients who will undergo THA in the future, it is necessary to understand the risks of infectious complications. In the attempt to find the most successful operation, numerous surgical approaches have been designed to minimize complications and optimize functional outcomes. These include the direct anterior, anterolateral, direct lateral, posterolateral, and direct posterior approaches, each with their own specific risks and benefits. Specifically, the direct anterior approach (DAA) has gained popularity among orthopaedic surgeons due to the minimization of muscular damage as well as the easily hidden post-surgical scar.[11] However,

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Disclosures: DTW, NVS, AME, ATS, AJP, BK, VS, and QN declare they have no conflicts of interest. Author AS has received research support from Stryker and is consultant to Stryker.

Sources of Funding: No sources of funding declared.

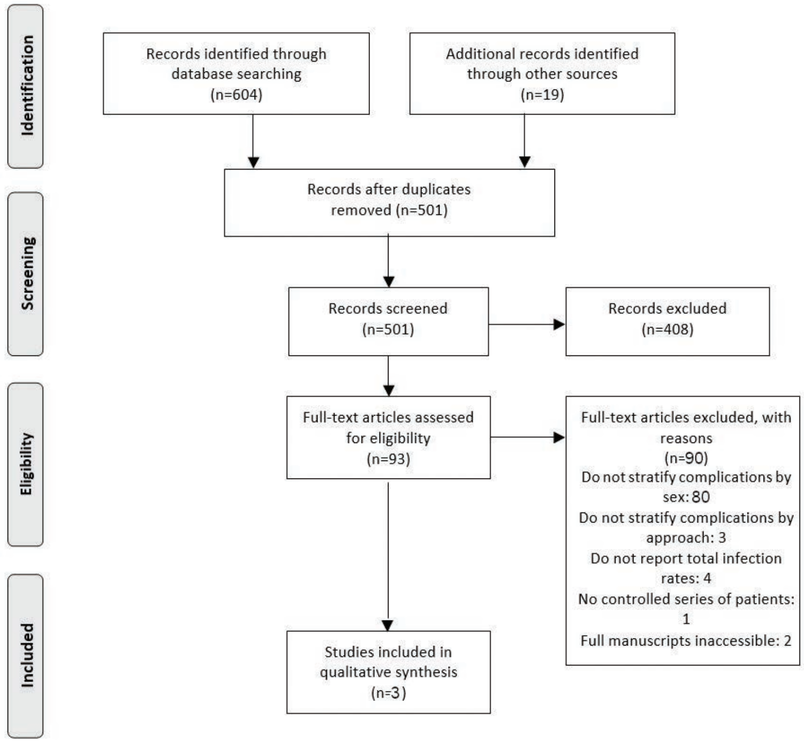

Figure 1. A PRISMA diagram outlining the studies eligible for and included in the present review.

concerns have been raised due to the proximity of the incision to the inguinal region and genitals, and some studies suggest an increased risk of complications with this approach.[12]

There is conflicting evidence on the risk of post-operation infectious complications based on sex, with some evidence supporting an increased risk in women, with an increasing risk in obese women without corresponding increase in obese men.[13–15] However, there are several large studies which suggest an increased risk of revision due to infection in men as opposed to women.[16,17] Some of these discrepancies have been attributed to geographic or regional perioperative differences, with European men at a higher risk of revision, and American men at a lower risk.[18] Despite these incongruencies, there is a lack of research into further specific risk factors between men and women. Moreover, there have been no systematic attempts to evaluate the available research on sex specific infection rates based on THA surgical approach. This study therefore seeks to evaluate the available evidence regarding the risk of infection by the various THA approaches and further sub-stratifying by patient sex.

METHODS

In order to perform an objective and thorough examination of the available data, this study was performed under the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines (Figure 1).[19]

Literature Search

A systematic review was conducted using PubMed, Embase, and Web of Science databases in order to identify studies that reported on infection rates stratified by sex and surgical approach following a primary elective THA. The databases were searched from their inception through September 15, 2020. Using Boolean operators AND and OR, the following terms were searched: “Infection”, “surgical site infection” “superficial infection”, “deep infection”, “postoperative complication”, “postoperative infection”, “surgical approach”, “anterior approach”, “lateral approach”, “posterior approach”, “anterolateral approach”, “posterolateral approach”, “comparison of approach”, “arthroplasty, replacement, hip”, “hip prosthesis”, “THA”, ”total hip”, “total hip replacement”, and “hip” with associated wildcards and MeSH terms.

Abstracts were selected if they were primary observational studies or randomized controlled trials (RCTs) written in the English language that also met the following criteria: 1) Patients underwent a primary elective unilateral THA procedure; 2) The study reported on infections by surgical approach; and 3) The study reported on infections by patient sex. Complications included diagnosis of superficial wound infection, wound dehiscence, deep wound infection, periprosthetic joint infection (PJI), or total infection rates. To avoid bias from non-standard approaches or, non-total hip arthroplasty, studies evaluating experimental minimal incision variants, bilateral THA's, hemiarthroplasties, or robot-assisted surgeries were excluded. In addition, publications were excluded if they were basic science studies, cadaveric studies, animal studies, case reports, letters to the editor, editorials, personal correspondences, or review articles.

Two of the investigators (DTW and NVS) reviewed all titles and abstracts from the identified articles. Following review of selected abstracts, the full articles were obtained for all but two studies. Despite best efforts, the full text of two studies were unavailable for access. The references contained in all of the articles were used to further identify studies that were not captured in the initial database search. The authors then reviewed the full- text articles for inclusion/exclusion criteria. If a disagreement or uncertainty arose among the articles included, another author aided in resolution. The final inclusion or exclusion was unanimously decided.

RESULTS

Following review of the available full-texts, two studies met inclusion criteria. Five additional studies that would be eligible for inclusion if sex related infection data was reported were identified. The corresponding authors of these papers were contacted to request infection data stratified by patient sex. The specific data was obtained for one of the five additionally identified studies. Therefore, that resulted in a total of three publications from which data was gathered. Cumulatively this data included 1,694 patients, who underwent 1,811 THA operations (several studies evaluated consecutive THA operations on the same patient). In total 80 infective wound complications were reported.

Jahng et al.[20] performed a retrospective study evaluating risk factors for post-operative complications in patients undergoing THA via the DAA. They included a consecutive 651 DAA THA operations in 611 patients performed by two surgeons over the course of three years. Forty patients underwent consecutive THAs on the contralateral hip, none were performed simultaneously. The author's primary outcome measure was wound complications, which include wound dehiscence and superficial infection among others, requiring additional treatment in the first 90 days post- operatively. A total of 364 females and 287 males were included. Of the 364 females that underwent surgery, 37 (10.1%) sustained complications of which five (1.3%) required reoperation. Of the 287 males undergoing THA, there were 38 (13.2%) wound complications of which eight (2.7%) required reoperation, the difference between groups was non-significant (p=0.217). Univariate risk factors identified included diabetes mellitus (OR 4.1; 95% confidence interval [CI] 2.1-8.0), smoking (OR 2.9; 95% CI 1.2-7.0), and obesity. Obesity severity increased risk with class I (OR 2.1; 95% CI 1.2-3.9), obesity class II (OR 2.8, 95% CI 1.2-6.4), and morbid obesity (OR 9.7; 95% CI 3.8-24.8). Multivariate analysis also identified obesity and diabetes mellitus as risk factors.

Tsai et al.[21] performed a prospective analysis on 1,003 patients undergoing a consecutive 1,077 anterolateral THAs. They had a mean follow-up period of 59 months. They did not specify primary outcome measures, but recorded perioperative factors such as incision length, blood loss, type of implant etc, as well as postoperative complications, which included infections. Of these 1,003 patients, 560 were male and 443 were female. Four infectious complications occurred, three males (0.5%) and one female (0.2%) experienced surgical site infections. They did not report whether these differences between the two sexes was significant. No risk factors for infectious or noninfectious complications were identified in this study.

Fransen et al.[22] performed a retrospective cohort study evaluating all patients who underwent DAA THA without a fluoroscopy table, or posterolateral approach (PLA) THA by a single surgeon within one year. This was performed in a large volume hospital in the attempt to find differences in outcomes between the two approaches while accounting for the possible bias of a fluoroscopic table used in DAA that was reported in prior studies. The primary outcome was Harris Hip Score results (HHS), with secondary outcomes including infections and other complications. A total of 80 patients undergoing 83 operations were identified. Forty-five patients underwent the DAA approach, of which 15 were males and 30 were females. Whereas 35 patients underwent the PLA, of which 13 were male and 22 were female. Three of the patients undergoing PLA underwent consecutive contralateral surgeries totaling 38 hips undergoing a THA using the PLA approach. The authors identified only a single patient who experienced a superficial wound infection, a female in the PLA group (0.4%) and statistical significance was not reported. No infections in the DAA group were reported. No infectious risk factors including sex were reported.

In summary, this study identified four studies which reported on infection rates specific to both patient sex and surgical approach. None of the identified studies attempted to find a statistical difference in outcomes by sex; and the groups were too varied for group analysis and the studies were widely ranging in their surgical approaches, reported outcomes, and number of patients.

DISCUSSION

Total hip arthroplasties are an effective operation with a favorable safety profile and low perioperative infection rate.[3–6] However, when infections arise, they can significantly impact quality of life, and drastically increase healthcare system costs.[23–25] It is crucial to identify risk factors for these adverse outcomes to reduce the morbidity and mortality inherent to these complications. Furthermore, multiple surgical approaches for performing THAs exist, all with their own risks and benefits. Stratification of risk factors for each approach allows for improved clinical decision making and perioperative planning.

Obesity is another known risk factor with conflicting results. Obesity may increase risk on women but not men.[15] Other studies have found obesity to be a risk factor, without a difference between men and women.[26] Concerns have been raised that the proximity to the groin would increase infection risk in DAA operations, as would an overhanging pannus in obese patients, it is unknown if the differing fat distribution among men and women would influence this.[27] However, it has been reported that DAA approach may be associated with increased infection risk when compared to other approaches.[12,27,28] Further prospective research is warranted to determine the effect of obesity on THA outcomes and the impact that patient sex has on this relationship.

This systematic review sought to answer whether sex and surgical approach were important variables for postoperative infection risk. The study identified a total of 1,833 unilateral THA operations performed on a total of 1,694 patients; these included 1077 hips undergoing the anterolateral approach, 696 hips undergoing the DAA approach, and 38 undergoing the posterolateral approach.[20–22] Only the DAA and PL were directly compared within the included studies.[22] Eighty infective wound complications were reported, of which 39 occurred in females versus 41 in males. Thirty-seven of the complications that occurred in females were from those undergoing the DAA approach compared to 38 of the infections in males. None of the studies reported a statistical difference between these rates or identified sex as a risk factor for postoperative complications.

Statz et al.[29] reported on a series of 1573 DAA THA performed at a single institution and found that 18 patients subsequently required an irrigation and debridement (I&D) for superficial wound dehiscence. The authors identified body mass index (BMI) greater than 30, 35, and 40 to all be independent predictors for the need for a superficial I&D. They further reported that female sex was independently associated with the need for I&D (HR: 5.5). Recently, Bendich et al.[30] compared the DAA and posterior approach for multiple adverse postoperative events including infection. They reported no difference in risk of infection (OR: 1.5, 95% CI: 0.5-5.2) between surgical approaches. While the authors did not explicitly compare infection risk by sex, they reported 6/1498 female patients and 3/850 male patients undergoing a DAA THA and 3/1498 female patients and 3/850 male patients undergoing THA by posterior approach developed an infection. This data further underscores the need for more prospective research that delineates postoperative infection by sex and surgical approach.

There are several limitations to this systematic review that should be considered. The primary limitation is the paucity of data on the outcomes of interest. The total sample size of this review was 1,716 patients, with the majority of this from just two studies, Jahng et al.[20] and Tsai et al.[21] The other study included the final 80 patients.[22] Within this the majority of the data was comprised of just two approaches, and these studies did not compare surgical approaches. The small sample size reduces the power of this study and ability to find statistical differences that may be present.

Additionally, one of the studies by Tsai et al.[21] was prospective in nature, whereas the other three studies were retrospective, which reduces the generalizability of their findings. The disparate methods of the present studies, outcomes of interest, and surgical approaches used do not allow for the combination of the present data to increase sample size and generalizability of their findings. For example, there is no standardization between what is defined as a severe compared to a mild infectious complication. These limitations reduce the ability to draw meaningful conclusions with respect to the study outcomes of interest. What this review highlights is a lack of data concerning an important clinical question. This study identified 79 studies that did not report on infection rates by patient sex, and five studies that directly related to the question of interest but lack outcome reporting by sex. This emphasizes a need for a shift in the norms of what data is reported in studies that examine THA outcomes.

The lack of data, combined with the aforementioned conflicting data concerning the differences in outcomes between THA and patient sex points to the necessity for further research. The collection of patient sex is a standard aspect of study design, and it is an easy step for all authors to include complication rates by patient sex in all future studies. This will allow future meta- analyses to take place, which can effectively answer the question of whether surgical approach and postoperative infections vary between male and female patients, allowing potential factors driving these differences to be identified. Additionally, large scale database studies and prospective trials should examine these differences directly. The results of these will allow for a better personalization of care for patients, and a reduction in postoperative complications.

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MEDICAID PAYER STATUS IS ASSOCIATED WITH INCREASED 90-DAY RESOURCE UTILIZATION, REOPERATION, AND INFECTION FOLLOWING ASEPTIC REVISION TOTAL HIP ARTHROPLASTY

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ABSTRACT

Background: Prior literature has demonstrated increased resource utilization and perioperative complications in patients with a Medicaid payor status undergoing primary total hip and knee arthroplasty. This relationship has yet to be explored in patients undergoing revision total hip arthroplasty (rTHA).

Methods: The National Readmissions Database was queried from 2010 to 2015 for all patients undergoing aseptic rTHA. 90-day complication data were collected, and patients were separated into two cohorts based on insurance payor type: Medicaid and non-Medicaid. Patients were propensity score matched 2:1 on a number of comorbid and operative characteristics. The relationship between Medicaid payor status and postoperative outcomes was then assessed using binomial logistic regression analysis.

Results: 3,110 Medicaid patients were identified and matched to 6,175 non-Medicaid patients. Medicaid patients had increased odds of an early prosthetic joint infection (Odds Ratio [OR] 1.29, p=0.019), superficial surgical site infection (OR: 1.48, p=0.003), and early reoperation (OR: 1.18, p=0.045). Medicaid patients also experienced higher odds of readmissions, extended length of stay, non-home discharge status, and medical complications. Finally, the Medicaid cohort had a $3,332 (95% CI: 2,412-4,253, p<0.001) increased adjusted total cost of care when compared to the non-Medicaid cohort.

Conclusion: This study identifies the Medicaid payor status as an independent risk factor for increased resource utilization, reoperation, and infection in the early postoperative period for patients undergoing rTHA. This relationship is likely due to an interplay of multiple variables, including socioeconomic status and access to care.

Level of Evidence: IV

Keywords: total hip arthroplasty, revision total hip arthroplasty, medicaid, revision total knee arthroplasty, insurance

INTRODUCTION

Total hip arthroplasty (THA) remains one of the most common and successful surgeries performed in the United States (U.S.).[1] Nearly $15 billion in annual healthcare expenditures are allocated to patients undergoing primary THA, with projected growth continuing through 2030.[2-4] The expansion of primary THA has driven a concomitant increase in revision THA (rTHA) volume.[5,6] The economic impact of rTHA is substantial[5,7-10] and rTHA disproportionately consumes nearly 20% of the total Medicare expenditures dedicated to hip arthroplasty.8 With the emergence of value-based payment models aimed at curtailing these costs, preoperative identification of patients at risk of above-expected resource utilization has become increasingly important.[11-15]

Following primary total joint arthroplasty, Medicaid payor status has been found to be independently associated with increased morbidity, mortality, postoperative resource utilization, and costs when compared to privately insured patients.[4,16-22] However, it is not known whether the same relationship exists in the rTHA cohort. With the growing emphasis on value, this relationship is important to define. Understanding the relationship between Medicaid payor status and resource utilization following rTHA could aid in the refinement of risk-adjustment of reimbursement models.

Risk adjustment is central to the sustainability of bundled care models to avoid unintentionally disincentivizing providers from caring for high risk patients. Clearly, this also risks exacerbating health disparities. Therefore, the purpose of this study is to compare resource utilization, complications, and readmissions between patients with and without Medicaid payor status following rTHA.

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Disclosures: Dr. Thomas Bradbury - IP Royalties from TJO, Inc and Zimmer; Paid Consultant TJO, Inc., Paid consultant for Zimmer-Biomet. Dr. George Guild - Omega grant, Smith & Nephew Fellow Grant, Institutional Research support (Stryker, Smith & Nephew). Paid consultant for TJO, Inc.; Paid consultant for Smith & Nephew. Stock options in TJO. Member of AAHKS education committee. Applied for dual modular femur patent.

Sources of Funding: No sources of funding declared.

We hypothesized that Medicaid payor status would be associated with increased readmission, complications, resource utilization and total cost of care when compared to matched controls.

METHODS

Patient Selection

Population-level data was acquired from the Nationwide Readmission Database (NRD). The NRD is a publicly available all-payor database maintained by the Agency for Healthcare Research and Quality (AHRQ), as part of the Healthcare Cost and Utilization Project (HCUP). The database contains information on all inpatient stays occurring within a calendar year in 27 states. The database is coded such that same-state readmissions occurring within the same calendar year can be captured, even if the readmission occurred at a different hospital than the initial inpatient stay. Thus, the database allows for the capture of inpatient complications and those occurring during or causing a subsequent readmission – allowing researchers to capture major complications occurring in the 90-day postoperative period. The NRD has been used previously to study the association of Medicaid status on postoperative outcomes in a primary hip and knee arthroplasty setting.[4]

For the purposes of this study, the NRD was queried from 2010-2015 for patients undergoing rTHA using International Classification of Disease Ninth Revision-Clinical Modification (ICD-9) procedural codes 00.70 (revision of hip replacement, both acetabular and femoral components), 00.71 (revision of hip replacement, acetabular component), 00.72 (revision of hip replacement, femoral component), 00.73 (revision of hip replacement, acetabular liner and/or femoral head only), and 81.53 (revision of hip replacement, not otherwise specified). As the database does not allow for patient follow-up between calendar years, quarter 4 of each year was excluded as 90-day follow-up for these patients could not be ensured. Additionally, the study period was stopped in the 3rd quarter of 2015 to prevent cross over with ICD-10 coding which could compromise cohort homogeneity. Furthermore, we excluded those undergoing revision for a prosthetic joint infection (ICD-9 code 996.66) as these patients are known to have different risk profiles and postoperative course then those undergoing revision for aseptic indications. Furthermore, those under 18 years old and those with missing baseline information or payor status (described below) were also excluded.

The primary payor for the index operation was identified. The national readmission database categorizes the payor as either Medicare, Medicaid, private insurance, self-pay, no charge, or other (includes Worker's Compensation, the Civilian Health and Medical Program of the Uniformed Services, and the Civilian Health and Medical Program of the Department of Veterans Affairs). Two cohorts of patients were then created, those with a Medicaid payor and those with other payor types (those with any of the other categories above, per precedence).[4]

Baseline demographic and operative characteristics were also identified. This included age, sex, surgery type (both components, acetabulum only, femur only, or isolated modular component exchange), zip-code income quartile (i.e. local prosperity as a composite estimate of socioeconomic status), hospital funding (private or public), and patient smoking status. Additionally, comorbid information was collected using the Elixhauser comorbidity index as done in a previous study.[23] The number of comorbidities were tallied and quantified as the total number of comorbidities present. These were grouped as follows: 0, 1, 2, 3+. Each comorbidity was weighted equally.

Outcomes of Interest

Postoperative complications were identified using ICD-9 diagnosis and procedure codes, as well as variables unique to the NRD (which included discharge status, length of stay (LOS), and hospital charges). Medical complications were included if they occurred during the initial inpatient stay or if they prompted readmission. Readmission for prosthetic joint infection or repeat revision surgery were counted separately. Extended LOS was defined as those patients staying in the hospital for greater than 4 days. Hospital charges were converted to cost with the use of cost-to-charge ratios provided by the NRD. Additionally, cost was adjusted for inflation to 2015 dollars using the US Consumer Price Index.[24]

Statistical Analysis

This investigation utilized chi-square or independent sample T-tests to perform univariate analysis. Our raw data demonstrated inherent differences in baseline variables between Medicaid and non-Medicaid patients (Table 1). To adequately control for these baseline characteristics, 2-to-1 propensity score matching was subsequently utilized to match two non-Medicaid controls to one Medicaid patient.

In order to calculate propensity scores, binary logistic regression was utilized, and the payor status (Medicaid) served as the outcome variable. Our study identified several confounding variables (Table 1), which were included in the propensity score model. Non-Medicaid patients were then matched 2-to-1 to Medicaid patients using a greedy matching algorithm based on propensity score. This study utilized caliper matching, in which non-Medicaid patients within a certain caliper width of the propensity score of a Medicaid patient had potential to be matched. Our caliper width was set at 0.20 standard

Table 1. Medicaid Payor Status in Revision THA by Patient Demogrpahics and Comorbidities, Unmatched and Matched Cohorts

	Unmtached				Matched			
Characteristic	Non-Medicaid	Medicaid	P-Value	Stand. Diff.	Non-Medicaid	Medicaid	P-Value	Stand. Diff.
Total	71,783 (95.85)	3,111 (4.15)	<0.001	1.316	6,175 (66.51)	3,110 (33.49)		0.005
Age, yrs (mean ± SD)	67.81 ± 12.68	52.27 ± 10.83			52.22 ± 11.17	52.28 ± 10.82	0.812	
Sex			0.093	0.031				0.014
Male	29,692 (41.36)	1,334 (42.88)			2,691 (43.58)	1,334 (42.89)	0.530	
Female	42,091 (58.64)	1,777 (57.12)			3,484 (56.42)	1,776 (57.11)		
Elixhauser			0.130	0.028				0.025
0	10,446 (14.55)	484 (15.56)		0.006	904 (14.64)	483 (15.53)	0.717	0.003
1	10,446 (14.55)	734 (23.59)		0.037	1,465 (23.72)	734 (23.60)		0.003
2	10,446 (14.55)	692 (22.28)		0.016	1,383 (22.40)	693 (22.28)		0.013
3+	10,446 (14.55)	1,200 (38.57)			2,423 (39.24)	1,200 (38.59)		
Component Replaced			<0.001	0.028				0.040
Both Components	36,983 (51.62)	1,774 (57.02)		0.006	3,641 (58.96)	1,773 (57.01)	0.141	0.003
Acetabulum	11,335 (15.79)	468 (15.04)		0.051	923 (14.95)	468 (15.05)		0.011
Femoral	12,532 (17.46)	484 (15.56)		0.083	937 (15.17)	484 (15.56)		0.046
Liner or Head-Ball Exchange	10,933 (15.23)	385 (12.38)			674 (10.91)	385 (12.38)		
Private Hospital			<0.001	0.202				0.052
No	7,716 (10.75)	553 (17.78)			975 (15.79)	552 (17.75)	0.016	
Yes	64,067 (89.25)	2,558 (82.22)			5,200 (84.21)	2,558 (82.25)		
Income Quartile of Patient Zipcode			<0.001	0.395				0.010
1	14,576 (20.31)	1,179 (37.90)		0.051	2,308 (37.38)	1,178 (37.88)	0.761	0.003
2	17,149 (23.89)	812 (26.10)		0.124	1,620 (26.23)	812 (26.11)		0.010
3	19,277 (26.85)	670 (21.54)		0.357	1,305 (21.13)	670 (21.54)		0.022
4	20,781 (28.95)	450 (14.46)			942 (15.26)	450 (14.47)		
Smoking Status			<0.001	0.582				0.049
No	65,100 (90.69)	2,118 (68.08)			4,345 (70.36)	2,118 (68.10)	0.025	
Yes	6,683 (9.31)	993 (31.92)			1,830 (29.64)	992 (31.90)		

SD: Standard Deviation, Stand. Diff.: Standardized Difference, DM: Diabetes Mellitus; *Lower standardized difference suggests a smaller difference between cohorts, value <0.10 indicates a negligable difference

deviations of the logit of the propensity score. Patients were matched at random when multiple control subjects had propensity scores that were equally close to an exposed subject.

The propensity score distribution between matched (Figure 1B) and unmatched (Figure 1A) data sets were compared to assess covariate balance. The propensity score distributions of Medicaid patients and non-Medicaid patients in the matched data set most closely resembled one another. Standardized differences between covariates before and after matching were then analyzed, with a standardized difference of <0.10 suggesting negligible difference between control and exposure groups.

Finally, to isolate the effect of Medicaid payor status within the parameters of this study, binomial logistic regression was then utilized to control for any remaining cohort differences. Total healthcare costs between Medicaid and non-Medicaid patients were compared using a generalized linear model with gamma distribution and a logarithmic link function. Table 1 demonstrates the covariates in these models. This study utilized SAS (version 9.4, Cary, NC) for all statistical analysis, and generated Figure 1 with R (version 4.0.2).

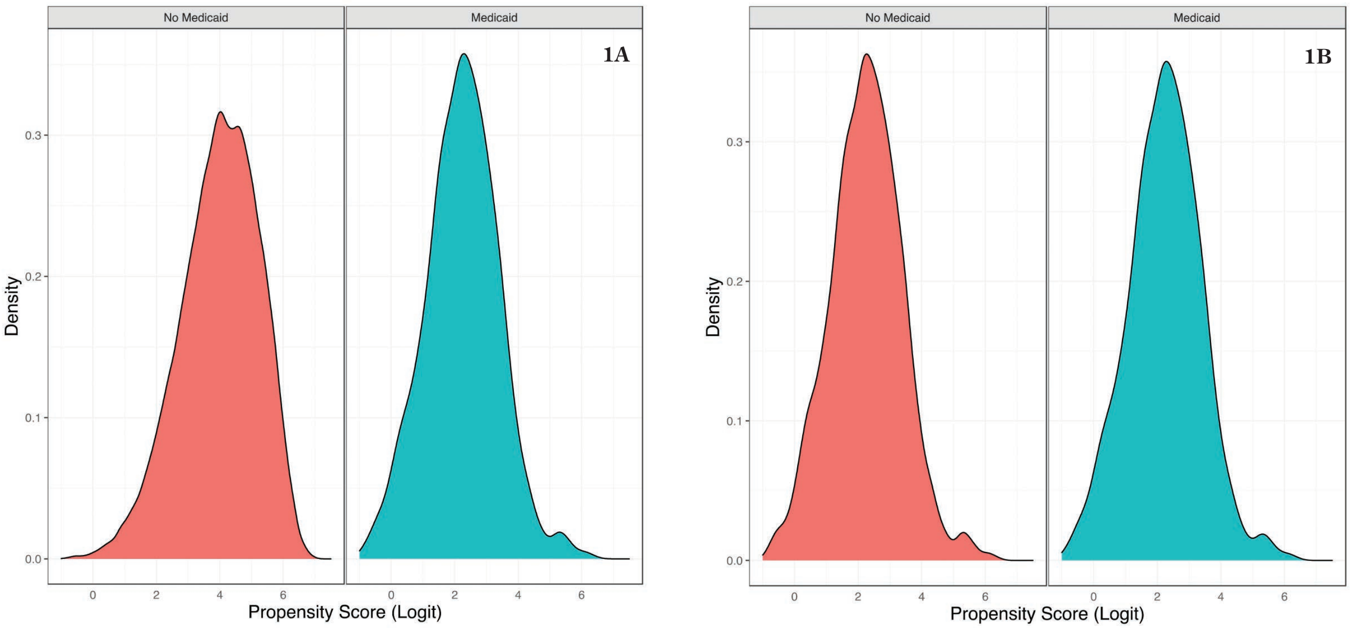

Figure 1. Propensity-score Distribution in Unmatched and Matched Revision THA Data Sets: Non-Medicaid and Medicaid Patients. (A) Propensity Score Distribution (Density) of Unmatched Datase. (B) Propensity Score Distribution (Density) of Matched Dataset.

RESULTS

Baseline Demographics and Matching

A total of 74,894 patients in the NRD were identified as undergoing aseptic rTHA between 2010-2015 (Table 1). This included 71,783 (95.9%) non-Medicaid patients and 3,111 (4.2%) Medicaid patients. At baseline, there were multiple differences between payor cohorts in the unmatched dataset. Non-Medicaid patients were on average 15 years older than the Medicaid patients (67.81 vs. 52.27, p<0.001). Likewise, Medicaid patients were more likely to be smokers (31.9% vs. 9.31%, p<0.001), be of the lowest zip-code income quartile (37.90% vs. 20.31%), undergo both component revision (57.02% vs. 51.62%, p<0.001), and undergo revision at a publicly funded hospital (17.78% vs. 10.75%, p<0.001). Many of these variables had large standardized differences, indicating cohort heterogeneity.

2-to-1 propensity score matching produced cohorts of 6,175 (66.5%) non-Medicaid patients and 3,110 (33.5%) Medicaid patients. All standardized differences in the matched dataset met a criterion of <0.10 (all standardized differences <0.052, Table 1) indicating a successful match.

Payor Status and Resource Utilization

Resource utilization metrics were compared between Medicaid and non-Medicaid patients, including readmission, discharge status, extended LOS, and hospital costs during index admission (Table 2). 30-day and 90-day readmission rates were 9.9% and 17.5% for non-Medicaid patients and 12.5% and 21.4% for Medicaid patients, respectively (p-value <0.001 and < 0.001). Likewise, rates of an extended length of stay (LOS) for non-Medicaid and Medicaid patients were 39.8% and 52.8%, respectively. Similarly, rates of non-home discharge were 21.2% and 26.5%, respectively (p-value <0.01). Cost of the initial inpatient stay was $18,506 for non-Medicaid patients and $20,674 for Medicaid patients (p-value < 0.001). Using multivariate analysis that controlled for demographic and comorbid data, Medicaid patients demonstrated a 1.30 times increased odds of 30-day readmission (95% confidence interval [95% CI]: 1.14-1.49, p-value <0.001) when compared to non-Medicaid patients. Similarly, Medicaid patients had a 1.29 times increased odds of 90-day readmission (95% CI 1.14-1.44, p-value <0.001), a 1.78 times increased odds of an extended LOS (95% CI 1.62-1.95, p-value < 0.001), and a 1.42 times increased odds of a non-home discharge destination (95% CI 1.27-1.58, p-value < 0.001) when compared to non-Medicaid patients (Table 3). Additionally, there was a $3,332 (CI:2,412-4,253; p-value <0.01) adjusted cost increase when comparing Medicaid patients to non-Medicaid patients.

Payor Status and Surgical Complications

Surgical complications, including wound infection, prosthetic joint infection, and early reoperation, were also higher in Medicaid patients compared to non-Medicaid patients (Table 2). For instance, Medicaid patients had higher incidence of PJI (3.6% v.4.67%, p=0.016; non-Medicaid v. Medicaid), superficial surgical site infection (2.2% v. 3.2%, p=0.004), and early reoperation (6.75% v. 7.97%, p=0.031). This relationship was conserved on multivariate analysis, where Medicaid patients had increased odds of an early prosthetic joint infection (Odds Ratio [OR] 1.29, CI:1.04-1.60, p=0.019), superficial SSI (OR: 1.48, CI:1.14-1.92, p=0.003), and early reoperation (OR: 1.18, CI:1.01-1.39, p=0.045) (Table 3). However, Medicaid payor status did not impact the odds of developing wound dehiscence (OR: 1.10, CI:0.84-1.45, p=0.474).

Payor Status and Medical Complications

On univariate analysis, Medicaid payor status was also associated with most medical complications queried, including pneumonia, deep vein thrombosis (DVT), or acute kidney injury (Table 2). On multivariate analysis this equated to a 1.32 (CI:1.07-1.63,p=0.008) times increased odds of pneumonia, a 1.57 (CI:1.15-2.15, p=0.004) times increased odds of deep vein thrombosis, a 1.37 (CI:1.18-1.69, p=0.003) times increased odds of acute kidney injury, and a 1.45 (CI:1.21-1.75, p<0.001) times odds of developing a urinary tract infection (Table 3). No difference in rates of myocardial infarction were seen (OR:1.10, CI:0.52-2.32, p=0.789).

DISCUSSION

As a result of the Affordable Care Act (ACA) Medicaid has undergone a substantial expansion. Additionally, the incidence of rTHA continues to rise.[2,3] The relationship between Medicaid payor status and outcomes following rTHA was previously unknown. However, the results of this investigation indicated that Medicaid payor status is associated with increased odds of PJI, revision surgery, medical complications, and DVT after rTHA. To our knowledge, this is the first study that performs a population-level analysis to examine the association of payor status with postoperative complications and resource utilization metrics following rTHA. Prior literature investigating similar parameters has been limited by less representative populations, combining hip and knee arthroplasty data, and/or does not focus on revision arthroplasty despite its unique risk and cost profile from primary reconstruction.[4,15,18,19,25,26]

In our study, both univariate and multivariate analysis demonstrated significant differences in 90-day outcomes between matched Medicaid and non-Medicaid cohorts. Prior studies have demonstrated that while Medicaid patients are younger in age, they often have higher prevalence of medical comorbidities.[18,21] Our study design addressed these known differences (i.e., smoking history and medical comorbidities) through propensity score matching. However, given the granularity of our population-level data, we are unable to assess the disease

Table 2. Univariate Analysis of 90-Day Complications in Matched Cohorts, rTHA

Characteristic	Non-Medicaid	Medicaid	P-Value
30-Day Readmission	614 (9.94)	390 (12.54)	<0.001
90-Day Readmission	1,080 (17.49)	665 (21.38)	<0.001
Extended LOS (>4 Days)	2,455 (39.76)	1,642 (52.80)	<0.001
Non-Home Discharge	1,306 (21.16)	825 (26.54)	<0.001
Any Wound Infection	319 (5.17)	211 (6.78)	0.002
Early Prosthetic Joint Infection	224 (3.63)	145 (4.66)	0.016
Superficial SSI	137 (2.22)	100 (3.22)	0.004
Wound Dehisence	149 (2.41)	83 (2.67)	0.456
Early Reoperation	417 (6.75)	248 (7.97)	0.031
Myocardial Infarction	20 (0.32)	11 (0.35)	0.814
Pneumonia	242 (3.92)	157 (5.05)	0.013
Deep Vein Thrombosis	93 (1.51)	72 (2.32)	0.005
Acute Kidney Injury	248 (4.02)	164 (5.27)	0.006
Urinary Tract Infection	312 (5.05)	218 (7.01)	<0.001
C. difficile Infection	32 (0.52)	27 (0.87)	0.045
Cost [USD, IQR]	18,506 [12,927]	20,674 [15,389]	<0.001

LOS: Length of Stay, SSI; Surgical Site Infection

Table 3. Multivariate Analysis of 90-Day Complications in Matched Cohorts, rTHA

Characteristic	Odds Ratio (95% CI)	P-Value
30-Day Readmission	1.30 (1.14-1.49)	<0.001
90-Day Readmission	1.29 (1.15-1.44)	<0.001
Extended LOS (>4 Days)	1.78 (1.62-1.95)	<0.001
Non-Home Discharge	1.42 (1.27-1.58)	<0.001
Any Wound Infection	1.34 (1.11-1.60)	0.002
Early Prosthetic Joint Infection	1.29 (1.04-1.60)	0.019
Superficial SSI	1.48 (1.14-1.92)	0.003
Wound Dehisence	1.10 (0.84-1.45)	0.474
Early Reoperation	1.18 (1.01-1.39)	0.045
Myocardial Infarction	1.10 (0.52-2.32)	0.789
Pneumonia	1.32 (1.07-1.63)	0.008
Deep Vein Thrombosis	1.577 (1.15-2.15)	0.004
Acute Kidney Injury	1.37 (1.18-1.69)	0.003
Urinary Tract Infection	1.45 (1.21-1.75)	<0.001
C. difficile Infection	1.74 (1.04-2.91)	0.036
Adjusted Cost Difference [USD]	+$3,332 (2,412-4,253)	<0.001

LOS: Length of Stay, SSI; Surgical Site Infection; CI: confidence interval severity of these matched factors. While this represents an obvious limitation in our work, it is also highlighting a relationship which may be driving a component of the risk observed in patients with Medicaid payor status. Transcending the boundaries of specialty and disease metrics, Medicaid patients often have more severe disease and more disease sequelae across many phases of medical care.[27-36] This has routinely been attributed to a lack of access to quality care, a disparity that is well documented for patients on need-based federally-funded health insurance.[37,38] This represents a complex issue, as it is clear that payor status is not a direct harbinger of an unsatisfactory outcome, but rather represents a meaningful composite marker of a constellation of risk factors that sum to drive our findings. However, when combined with the advanced cost associated with the perioperative care of rTHA patients, this threatens to disrupt the goals of systematic changes.[7-10]

There are many socioeconomic factors which may further elucidate the discrepant outcomes observed between the Medicaid and privately insured patient. The Medicaid population is known to more frequently have limited access to care, lack of home support for perioperative rehabilitation, lower income status and lower levels of health literacy.[37,38] While we have identified Medicaid payor status as a risk factor for increased 90-day complications, resource utilization and readmission rates, this association needs to be further explored. The Medicaid population often has inferior social and fiscal determinants of health, which may increase their predisposition for postoperative complications and readmissions. For instance, this population has previously been shown to have a limited ability to obtain appropriate transportation to their clinical visits.[37,38] Therefore, patients undergoing rTHA may be physically unable to attend their postoperative visits and physical therapy appointments due to transportation constraints. Furthermore, the vast majority of surgical candidates in an orthopaedic preoperative clinic consists of referrals from a primary care provider. Due to the limited number of primary care providers, long wait times for appointments and reduced willingness of physicians to care for the Medicaid patient population,[37] Medicaid patients may often present with advanced or neglected hip pathologies. Further, unlike its Medicare counterpart, the Medicaid program currently offers minimal funding for inpatient rehabilitation programs which may lower the recovery ceiling in these patients.

While the ACA enables previously uninsured patients to gain insured access to elective and semi-elective adult reconstructive procedures, the increased resource utilization and 90-day complications associated with Medicaid payor status demonstrated in this study have significant implications on access to care. As alternate payment models (APMs), such as bundled payment models, become more prevalent, hospitals and providers inherently benefit by reducing costs without compromising quality of care.[11,12] These findings are concerning as current payment models have failed to adjust reimbursements despite previous evidence demonstrating increased rates of inpatient mortality as well as inferior peri- and post-operative outcomes associated with Medicaid payor status.[16-20]

In this study, Medicaid patients demonstrated significantly higher 30- and 90-day readmission rates, extended LOS, non-home discharge and as a result, increased adjusted cost differences ($+3,332) when compared to non-Medicaid patients undergoing rTHA. In bundled payment models, readmission and discharge to a rehabilitation facility consume a substantial portion of the allocated episode of care resources.[39,40] Furthermore, our study identified higher rates of wound infection, superficial SSI, early reoperation rates and medical complications among Medicaid patients. These complications, in combination or alone, dramatically increase both the surgical morbidity and costs per episode of care, for patients with Medicaid payor status. As has been demonstrated in the primary arthroplasty setting,[4] this has the undesired potential to disincentivize surgeons and institutions to assume care for a costlier cohort with inferior outcomes. Unfortunately, this is not theoretical, as it is known that patients with commercial insurance have a higher likelihood of having their insurance accepted by orthopaedic surgeons than those with Medicaid.[41] This is compounded by the fact that Medicaid reimburses less than private insures.[42] Given this, it is our hope hope that this data is used to drive policy that will appropriately risk adjust reimbursement models. Ultimately, this approach will have an intended long-term goal of diminishing the clear distinction between the Medicaid and non-Medicaid patient that currently exists and allow for more equitable access to care.

This study has several strengths and limitations. A key strength of this study lies in the large, nationally representative sample derived from a nationwide database. Furthermore, the statistical methodology used in this study is robust, controlling for cohort heterogeneity to the greatest extent possible. Still, there are limitations which must be addressed. First, as with any analysis of a large database, we are reliant on complete and accurate coding of procedures and complications. Second, while our statistical methodology is robust and controls for cohort heterogeneity to the greatest extent possible, the potential for unmeasured confounding persists. For instance, as mentioned previously, we are unable to control for some components of socioeconomic status as well as comorbid disease severity. These include factors such as education level, employment status, personal income level, among others. Other factors such as surgical technique, surgeon experience and case complexity of a heterogeneous procedure were not incorporated in our analysis. Still, we used zip code income quartile as a surrogate for socioeconomic status and controlled for the presence of many comorbidities, therefore isolating payor status to the greatest extent possible.

CONCLUSION

In this study, Medicaid patients undergoing rTHA demonstrated increased 90-day readmission rates, all-cause 90-day morbidity, hospital length of stay, resource utilization and total cost of care when compared to matched non-Medicaid patients. As such, Medicaid likely represents a reliable index of these patients' constellations of social determinants of health. As APMs, such as bundled payment models, continue to increase in prevalence, concerns over disparate access to care for this population may be perpetuated and exacerbated. In order to provide equitable care for this vulnerable patient population and avoid financial penalties for surgeons and hospitals, risk adjustment models should account for Medicaid payor status. Unlike primary THA, much of rTHA is typically, at best, semi-elective, and may be obligate to restoring a functional hip. While it is clear the Medicaid population needs high quality, comprehensive care, this must not come at a penalty to surgeons and hospitals.

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RESIDENT PARTICIPATION DURING REVISION TOTAL KNEE ARTHROPLASTY IS NOT ASSOCIATED WITH INCREASED RISK OF 30-DAY POSTOPERATIVE COMPLICATION

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ABSTRACT

Background: Academic teaching institutions perform approximately one third of all orthopedic procedures in the United States. Revision total knee arthroplasty (rTKA) is a complex and challenging procedure that requires expertise and extensive planning, however the impact of resident involvement on outcomes is poorly understood. The aim of the study was to investigate whether resident involvement in rTKA impacts postoperative complication rates, operative time, and length of hospital stay (LOS).

Methods: The American College of Surgeons National Surgical Quality Improvement Program registry was queried to identify patients who underwent rTKA procedures from 2006-2012 using CPT codes 27486 and 27487. Cases were classified as resident involved or attending only. Demographics, comorbidities, and 30-day postoperative complications were analyzed. Multiple logistic regression analysis was performed to identify independent risk factors for increased 30-day postoperative complications. Wilcoxon rank sum tests were performed to determine the impact of resident involvement on operative time and LOS with significance defined as p<0.05.

Results: In total, 2,396 cases of rTKA were identified, of which 972 (40.6%) involved residents. The two study groups were similar, however the resident involved cohort had more patients with hypertension and ASA class 3 (p=0.02, p=0.04). There was no difference in complications between the cohorts (No Resident vs Resident-involved: 7.0% vs 6.7%, p=0.80). Multivariate analysis identified obesity (OR: 1.81, 95% CI: 1.18-2.79, p=0.01), morbid obesity (OR: 1.66, 95% CI: 1.09-2.57, p=0.02), congestive heart failure (OR: 5.97, 95% CI: 1.19-24.7, p=0.02), and chronic prosthetic joint infection (OR: 3.16, 95% CI: 2.18-4.56, p<0.01), as independent risk factors for 30-day complications after rTKA. However, resident involvement was not associated with complications within 30-days following rTKA (OR: 0.91, 95% CI: 0.65-1.26, p=0.57). Resident involvement was associated with increased operative time (p<0.001) and LOS (P<0.001).

Conclusion: Resident involvement in rTKA cases is not associated with an increased risk of 30-day postoperative complications. However, resident operative involvement was associated with longer operative time and length of hospital stay.

Level of Evidence: III

Keywords: resident education, revision total knee arthroplasty, TKA

INTRODUCTION

Total knee arthroplasty (TKA) is an effective procedure that provides pain relief and improvement of function. Amid the increase in volume of primary TKA and continued expansion of indication criteria and patient selection, the volume of revision TKA (rTKA) has increased. With increasing incidence of rTKA, it is imperative that future surgeons develop an appropriate framework for preoperative planning, postoperative management, and necessary technical skills to successfully care for patients that require rTKA.[1]

Academic teaching institutions perform approximately one third of all orthopedic procedures in the United States. Therefore, operative participation of residents in various settings including rTKA are a fundamental aspect of resident education. However, resident participation in surgical specialties, like orthopedic surgery, is a potential source of patient apprehension.[2] In addition to patient concern, training residents can significantly increase operative time especially while training junior ortho-

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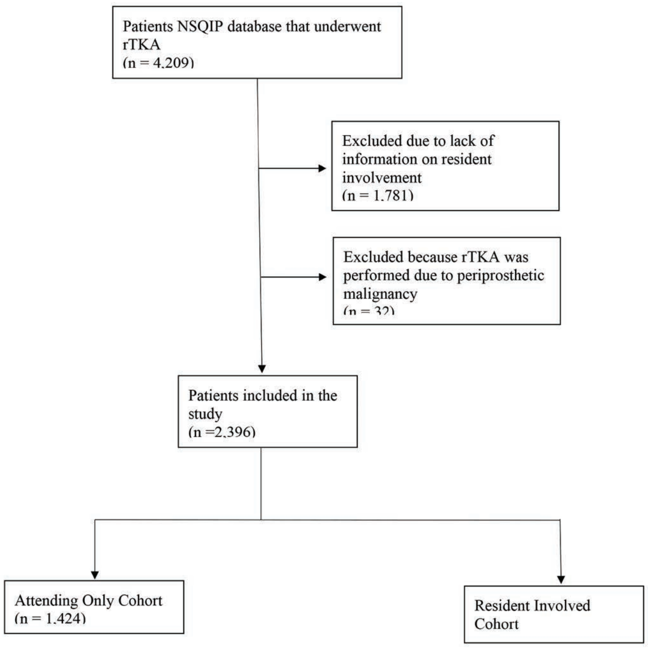
Disclosures: The authors report no potential conflicts of interest related to this study.

Sources of Funding: No sources of funding declared.



NSQIP: American College of Surgeons National Surgical Quality Improvement Program; rTKA: Revision total knee arthroplasty

Figure 1. Flowchart of Inclusion and Exclusion Criteria.

pedic residents.[3] While in some procedures, operative time may have minimal impacts, multiple studies have demonstrated that increased operative time increases the risk of postoperative complications in the setting of total joint arthroplasty procedures.[4-7] As a result, academic surgeons have to balance training residents while minimizing adverse events and providing efficient care, especially while performing challenging procedures that require extensive planning and skill.

Prior studies have demonstrated that resident participation does not have a significant impact on postoperative complications after various primary orthopedic procedures including primary TKA.[8-16] However, the impact of resident involvement in complex revision cases on intraoperative and postoperative outcomes is poorly understood. The aim of the study was to investigate whether resident involvement in rTKA impacts postoperative complication rates, operative time, and length of hospital stay (LOS). We hypothesize that resident participation during rTKA would not have a significant impact on postoperative complications, LOS, or operative time.

Table 1. Comparison of Comorbidities Between Resident Involved and Attending Only Cohorts Undergoing Revision Total Knee Arthroplasty

Comorbidities	Attending Only (n= 1,424)	Resident Involved (n= 972)	P-Value
Age, years			
< 50 years	123 (8.6)	90 (9.3)	0.60
50 - 59.9 years	308 (21.6)	238 (24.5)	0.10
60 – 69.9 years	451 (31.7)	312 (32.1)	0.83
70 – 79.9 years	386 (27.1)	243 (25)	0.25
>80 years	156 (11)	89 (9.2)	0.15
Male Sex	568 (39.9)	419 943.1)	0.16
Body Mass Index, m/kg^2			
Normal	536 (37.6)	383 (39.4)	0.38
Obese	408 (28.7)	278 (28.6)	0.98
Morbid Obesity	480 (33.7)	311 (32.0)	0.38
Diabetes Mellitus	324 (22.8)	191 (19.7)	0.07
Smoke	168 (11.8)	113 (11.6)	0.90
Chronic Obstructive Pulmonary Disease	63 (4.4)	38 (3.9)	0.54
Congestive Heart Failure	5 (0.4)	4 (0.41)	0.81
Hypertension	991 (69.6)	633 (65.1)	**0.02***
ASA Classification			
1-No Disturb	18 (1.3)	14 (1.4)	0.71
2- Mild Disturb	589 (41.4)	427 (43.9)	0.21
3- Severe Disturb	784 (55.1)	493 (50.7)	**0.04***
4- Life Threat	42 (2.9)	37 (3.8)	0.25
5- Moribund	0 (0)	1 (0.1)	0.23
Reason for Revision TKA			
Component Failure	1087 (76.3)	725 (74.6)	0.33
Prosthetic Joint Infection	197 (13.8)	163 (16.8)	**0.04***
Aseptic Necrosis/ Osteolysis	27 (1.9)	12 (1.2)	0.21
Peri-prosthetic Fracture	110 (7.7)	67 (6.9)	0.44
Stiffness	3 (0.2)	5 (0.51)	0.21

Bold*: significant finding (P<0.05); '-': not calculable

METHODS

Data Source

Patients undergoing rTKA were identified utilizing the American College of Surgeons National Surgical Quality Improvement Program database (ACS-NSQIP). The NSQIP database prospectively collects perioperative patient variables from private and academic hospitals across the United States.[16] The data is collected by expert clinical reviewers and includes information up to 30 days following the procedure. Information collected includes patient demographics, medical comorbidities, preoperative laboratory values, operative time, length of hospital stay (LOS), and postoperative complications within 30 days of surgery. The last year that NSQIP database collected resident involvement information was 2012; therefore, data of patients who underwent rTKA from 2006 to 2012 was obtained and analyzed for this study.

Table 2. Comparison of Complication Rates Between Resident Involved and Attending Only Cohorts following Revision Total Knee Arthroplasty

Adverse Events	Attending Only	Resident Involved	Unadjusted
	(n= 1,424)	(n= 972)	P-Value
Overall Complication Rate	99 (7.0)	65 (6.7)	0.80
Medical Complication Rate	64 (4.5)	47 (4.8)	0.70
Pulmonary Embolism	8 (0.56)	1 (0.1)	0.07
Deep Vein Thrombosis	9 (0.63)	11 (1.1)	0.19
Urinary Infection	23 (1.6)	15 (1.5)	0.89
Renal Insufficiency	4 (0.28)	1 (0.1)	0.65
Pneumonia	9 (0.63)	5 (0.51)	0.71
Systemic Infection (Sepsis, Septic Shock)	11 (0.77)	14 (1.4)	0.11
Surgical Complication Rate	56 (3.9)	30 (3.1)	0.27
Wound Infection	15 (1.1)	4 (0.4)	0.08
Wound Dehiscence	9 (0.63)	7 (0.72)	0.79
Superficial SSI	10 (0.7)	8 (0.82)	0.74
Deep SSI	18 (1.3)	11 (1.1)	0.77
Neurologic Injury	4 (0.28)	0 (0)	0.15

Bold*: significant finding (P<0.05); '-': not calculable

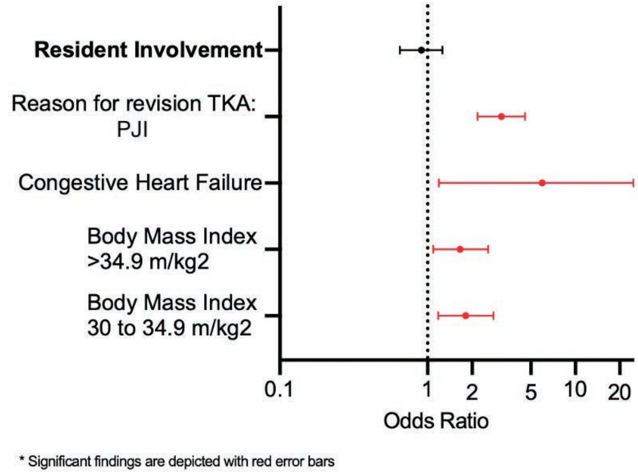


Figure 2. Risk Factors for 30-Day Complications After Revision Total Knee Arthroplasty.

Patient records were retrieved and analyzed using Current Procedural Terminology (CPT) and International Classification of Diseases Ninth Revision (ICD 9) codes. Cases are de-identified and selected based on a systematic sampling process with a reported inter-observer disagreement rate of 2%.[16,17] Due to the de-identified nature of the data, this study was granted exemption from the local institutional review board (IRB).

Patient Selection, Demographics, and Comorbidities

A total of 4,309 rTKA cases were identified during the study period using CPT codes 27486 and 27487. Patients with incomplete/incongruent information regarding resident participation (n=1,781) and those with revision due to periprosthetic malignancy (n=32) were excluded from the study. After exclusion, 2,396 cases were included, of which 972 (40.6%) consisted of at least one resident involved. (Figure 1)

Basic patient demographics including age and sex are recorded in the database and were compared between resident involved and non-resident procedures. Age was stratified by 10-year increments with patients identified as <50 years, 50-59.9years, 60-69.9 years, 70-79.9 years, and >80 years. Body mass index (BMI) was calculated from each patients' height and weight and was defined as normal for BMI 18 to 29.9 kg/m^2, obese for BMI 30 to 39.9 kg/m^2, and morbidly obese as BMI > 40 kg/m^2. Other preoperative conditions including diabetes mellitus, smoking history, chronic obstructive pulmonary disease, congestive heart failure, hypertension, and American Society of Anesthesiologist class (ASA) were compared between the two cohorts. Diabetes mellitus is categorized as insulin-dependent, non-insulin dependent, or no diabetes in the database; however, for the purposes of this study patients were categorized as having diabetes mellitus (insulin-dependent or non-insulin dependent) or not. The indication for rTKA was determined using ICD 9 codes and were categorized as component failure, prosthetic joint infection (PJI), aseptic necrosis, periprosthetic fracture, or dislocation. (Table 1).

Outcomes

The NSQIP database tracks patients for any occurrence of various adverse events for 30 days postoperatively. Therefore, only 30-day postoperative complications were compared between the cohorts. The primary outcomes evaluated were overall complications, surgical complications, medical complications, operative time, and LOS. Overall complications were defined as any occurrence of medical or surgical complications. In this study, surgical complications were defined as any occurrence of superficial surgical site infection (SSI), deep SSI, wound dehiscence, wound infections, and neurologic deficits. Medical complications were defined as any occurrence of pulmonary embolism (PE), deep vein thrombosis (DVT), urinary tract infection (UTI), renal insufficiency, pneumonia, or sepsis.

Statistical Analysis

Pearson Chi-square tests and Fischer exact tests were performed for univariate analysis to compare patient demographics, preoperative comorbidities, indication for rTKA, and postoperative complications after rTKA between the resident involved and non-resident cohorts. A multiple binomial regression analysis was performed to control for potential confounding variables and identify independent risk factors for increased complication rates within 30-days following rTKA. Additionally, Wilcoxon rank sum test was performed to compare operative time and LOS between the cohorts. All statistical analyses were performed using R version 4.0, with statistical significance defined as p<0.05.

RESULTS

Patient Characteristics

Overall, 2,396 cases of rTKA were included in the study, with 40.6% of the revision cases involving a resident. Patients in the resident involved cohort had a significantly higher incidence of patients with ASA class 3 and hypertension (p=0.04; p=0.02; Table 1). In regard to the indication for rTKA, the resident involved cohort had a higher incidence of PJI (16.8% vs 13.8%, p=0.04; Table 1).

Postoperative Complications

On univariate analysis, there was no significant difference in overall complication rate (6.7% vs 7.0%, p=0.80), surgical complication rate (3.1% vs 3.9%, p=0.27), or medical complication rate (4.8 vs 4.5%, p=0.70) between the resident involved and non-resident cohorts (Table 2).

Multivariate analysis identified obesity (OR: 1.81, 95% CI: 1.18-2.79, p=0.01), morbid obesity (OR: 1.66, 95% CI: 1.09-2.57, p=0.02), congestive heart failure (OR: 5.97, 95% CI: 1.19-24.7, p=0.02), and chronic prosthetic joint infection (OR: 3.16, 95% CI: 2.18-4.56, p<0.01), as independent risk factors for 30-day complications after rTKA (Table 3). However, resident involvement was not associated with complications within 30-days following rTKA (OR: 0.91, 95% CI: 0.65-1.26, p=0.57). (Figure 2)

Operative Time and LOS

Resident participation in rTKA cases significantly prolonged operative times (146 vs 125 minutes, p<0.001) and increased LOS duration (resident involved vs non-resident: 4.6 vs 3.9 days, p<0.001). (Table 4)

DISCUSSION

Resident training, inside and outside of the operating room, is a fundamental pillar of academic orthopedic institutions. While maturation of the next generation of orthopedic surgeons is critical, there is concern re-

Table 3. Independent Risk Factors for Complications Within 30-days After Revision Total Knee Arthroplasty

Age, (Reference: <50 years)		
50 - 59.9 years	1.36 [0.67-2.99]	0.42
60 – 69.9 years	1.56 [0.79-3.39]	0.23
70 – 79.9 years	1.40 [0.68-3.13]	0.38
> 80 years	2.10 [0.94-4.99]	0.08
Male Sex	1.19 [0.85-1.66]	0.32
Body Mass Index (Reference: 18.5 to 30 m/kg^2)		
Obese (30 to 34.9 m/kg2)	1.81 [1.18-2.79]	**0.01***
Morbid Obesity (>34.9 m/kg2)	1.66 [1.09-2.57]	**0.02***
Diabetes Mellitus	1.10 [0.73-1.66]	0.64
Smoking History	1.44 [0.86-2.34]	0.15
Chronic Obstructive Pulmonary Disease	1.37 [0.67-2.61]	0.36
Congestive Heart Failure	5.97 [1.19-24.7]	**0.02***
Hypertension	0.80 [0.55-1.17]	0.24
ASA (reference: 1- No Disturb)		
2- Mild Disturb	5.58 [0.45-23.5]	0.97
3- Severe Disturb	7.28 [0.19-94.1]	0.97
4- Life Threat	12.3 [0.22-31.2]	0.97
Reason for Revision TKA (reference: Component failure)		
Infected Implant	3.16 [2.18-4.56]	**<0.001***
Aseptic Necrosis/ osteolysis	0.42 [0.02-2.11]	0.41
Peri-prosthetic Fracture	1.14 [0.56-2.10]	0.69
Stiffness	-	0.99
Resident Involvement	0.91 [0.65-1.26]	0.57

Bold*: significant finding (P<0.05); '-': not calculable

Table 4. Comparison of Operative Time and Length of Hospital Stay

Variable	Attending Only	Resident Involved	P-Value
	n=1,424	n= 972	
Operative time, min (SD)	125.0 (60.1)	145.8 (67.1)	**<0.001***
Length of hospital stay, days (SD)	3.9 (3.2)	4.6 (5.3)	**<0.001***

Bold*: significant finding (P<0.05); '-': not calculable garding patient safety with resident participation during operative cases.[2] The findings of this study are valuable in informing orthopedic residents as well as resident educators. This study determined that resident participation during rTKA was not associated with increased risk of 30-day postoperative complications. However, resident participation during rTKA was associated with significantly longer operative time as well as increased length of hospital stay.

Prior studies have assessed the impact of resident participation on postoperative complications after various orthopedic,[8,10-12,15,18-21] and non-orthopedic procedures[22-25] with conflicting findings. Haughom et al. assessed the impact of resident participation during primary TKA and concluded that resident participation in primary TKA does not increase risk for short-term morbidity or mortality.[15] Similarly, resident participation was not associated with increased risk of short-term morbidity or mortality after primary total hip arthroplasty (THA).[8] These findings have also been demonstrated for patients undergoing total shoulder arthroplasty,[10,11] knee arthroscopy,[18] anterior cruciate ligament reconstruction,[19] and other orthopedic procedures. The findings of the present study are consistent with prior studies and demonstrates that resident participation during rTKA was not significantly associated with 30-day medical, surgical or overall complications. However, unlike prior studies, this is the first study to assess the impact of resident participation on revision cases, which involves additional skill and challenging factors.

In the current climate of cost-effective, value-based outcomes, length of procedure and postoperative hospital stay have become important parameters that have been assessed.[26] This has been emphasized to the degree that there is now a growing trend to perform common inpatient procedures on an outpatient or short-stay basis. In fact, in January 2018, the Center for Medicare and Medicaid Services (CMS) removed primary TKA as an inpatient only procedure in order to facilitate cost-effective care for Medicare and Medicaid patients.[27,28]

The present study determined that resident participation was associated with longer operative time for rTKA when compared to non-resident cases. The fact that resident involvement in surgical procedures increases operative time is known. In 2016, Allen and colleagues evaluated 29,134 cases covering 246 procedures (including various surgical specialties) and found that overall involving, cases involving a resident consisted of significantly longer operative times.[29] Orthopedic specific studies agree with these findings.[8,15,20,30] Beletsky et al. retrospectively assessed the impact of resident participation during common sports medicine procedures. This study reported that resident participation was on average 15 minutes longer compared to the attending only cases ($p<0.01$).[13] Haughom et al. determined that in primary THA, resident involvement significantly increased operative time.[15] Similarly, resident participation was associated with increased operative time during primary TKA.[15] However, even after multivariate regression analysis, these studies reported no difference in risk of complications associated with resident involvement.

Multiple studies have demonstrated the impact of operative length and postoperative complications. Duchman et al. recently investigated how the length operative time impacts postoperative complications. By utilizing the NSQIP database, they reported that an operative time consisting more than 120 minutes was an independent predictor of any complication, including wound complications. Additionally, multi-variate analysis showed that a subsequent increase of operative time by 30-minutes, beyond 120 minutes, significantly added additional risk of complications.[4] The previously mentioned studies investigating resident involvement in primary TKA and THA procedures demonstrated with sub-analysis, that increased operative time increased the risk for postoperative complications.

Prior studies have conflicting information regarding the impact of resident participation in LOS. Recently, Perfetti et al. determined that academic teaching departments had 10% shorter LOS ($p<0.001$) compared to non-academy centers for elective lumbar laminectomy and discectomy for degenerative lumbar conditions.[31] However, Nandyala et al. noted a significantly longer LOS for elective lumbar spine surgery at academic teaching institutions.[32] However, the previously mentioned studies have established that resident participation during primary THA or TKA do not have a significant impact on LOS.[8,15] Contrary to these previous studies findings, the current study demonstrated that rTKA cases involving a resident consisted of longer LOS. However, this was by only ~17 hours, limiting the significance of these findings. Additionally, our increased LOS might be due to additional factors, including increased operative time, which has been previously correlated with increased LOS.[33]

There are limitations that must be considered when interpreting the findings of the study. First, the retrospective nature of the study limits causal conclusions and only associations can be ascertained. Second, the NSQIP database is limited to 30-day postoperative complications; therefore, we were unable to assess complications that occur past this time point. Third, NSQIP does not collect relevant orthopedic information such as radiographic findings, type of implants used in primary TKA, type of implants used for rTKA, chronicity of symptoms, or patient reported outcome measures that may play an important role for postoperative complications. Fourth, NSQIP does not detail the extent of resident participation during the surgery and only reports whether a resident was listed during the case. Additionally, stratification of resident by year in residency was not available for all years. Therefore, associations between year of residency and 30-day complications was not studied. Lastly, NSQIP is the largest available database with information regarding resident participation during operative procedures. Therefore, the lack of short-term complications for the resident involved cohort may be secondary to a type II error.

CONCLUSION

Resident involvement in rTKA cases is not associated with an increased risk of 30-day postoperative complications. However, resident operative involvement was associated with longer operative time and length of hospital stay.

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CLEAN OR DIRTY? A SYSTEMATIC REVIEW OF SPLASH BASIN USE AND ITS INFECTIOUS POTENTIAL IN ORTHOPAEDIC SURGERY

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ABSTRACT

Background: Splash basins are used in orthopaedic surgery cases to wash and hold instruments intraoperatively. This systematic review aims to summarize information on contamination of splash basins intraoperatively.

Methods: A systematic review was conducted using the following search terms: "splash basin" or "splash bucket." Two authors independently reviewed the literature. Studies were included if they reported on intraoperative splash basin contamination rates. Studies were excluded if they were not relevant to orthopaedic surgery, non-English articles, or repeat studies yielded by different online databases.

Results: There were seven studies included in this review. The median contamination rate of sterile water or physiologic saline splash basins was 23.9% [range: 2%-74%]. The addition of surgical antiseptics to sterile water splash basins was associated with 0% contamination rates in two studies. The most frequent splash basin contaminants identified in bacterial culture were coagulase negative staphylococcus (50%) and staphylococcus aureus (10%).

Conclusion: The splash basin appears to be a frequent source of contamination in the operating room. Many studies suggest abandoning splash basin use altogether, although the efficacy of alternative methods such as cleaning instruments with lap pads in avoiding contamination of the sterile field has not been studied. Further investigation into surgical teams' use of the splash basin and the contents of the splash basin as they relate to contamination rates may help advance our understanding of optimal use of this surgical tool. Shorter case durations and dilute surgical antiseptics in splash basins appear associated with lower splash basin contamination risk.

Level of Evidence: V

Keywords: splash basin, contamination, splash bucket, infection, orthopaedic surgery, total joint arthroplasty, periprosthetic joint infection, operating room sterility

INTRODUCTION

Splash basins are used in orthopaedic surgery to clean and hold instruments intraoperatively.[1-7] Splash basin use is still encouraged by nursing and surgical technologist associations to maintain sterility.[8,9] These splash basins are recommended to be filled with sterile water given the potential for instrument corrosion with normal saline.[10]

In 2013, an international committee of orthopaedic surgeons recommended against splash basin utilization because of unacceptably high contamination risk.[11] More recently, two study groups added dilute surgical antiseptics to splash basins, and subsequently found a significant decrease in basin fluid contamination rates.[6,7] Despite these developments, the overall use of splash basin use remains largely unchanged over the years.[10] Although they reside on the sterile field, splash basins have large surface areas that could allow for airborne microbes to settle and house many instruments soiled with bioburden. Anto et al. reported that on average, 46 instruments were placed in the splash basin during orthopaedic surgery cases.[3] The potential for splash basin contamination is particularly worrisome given instruments are taken from it and reintroduced into the operative site.

Prevention of intraoperative contamination is important given the persistent one to two percent periprosthetic joint infection (PJI) rate in joint arthroplasty cases.[12] PJI requires long courses of antibiotics and subsequent operative interventions to definitively treat.[13] There have been important strides made in reducing PJI rates such as the use of prophylactic antibiotics.[14] However, efforts targeted towards reducing contaminants in the operating room and reservoirs for their introduction into the surgical wound are important in continuing to improve infectious outcomes after orthopaedic surgery.

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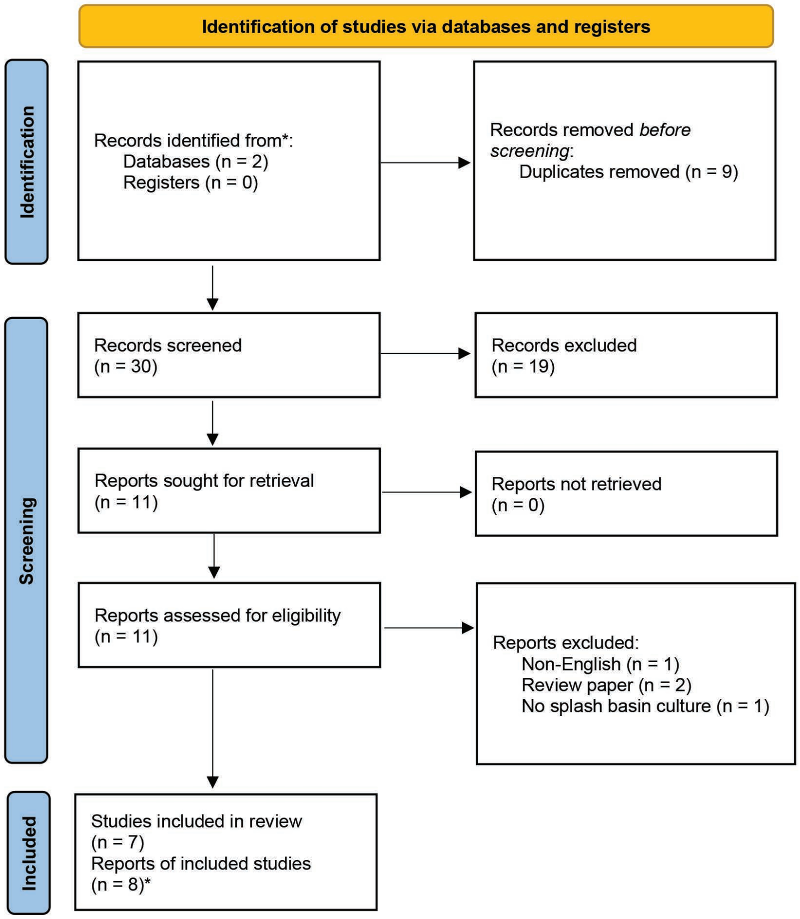
Disclosures: The authors report no potential conflicts of interest related to this study.

Sources of Funding: This study was supported by an unrestricted grant from the Doren Family Foundation.



* A correction to one study's methods was also published and accounted for in our results.

Figure 1. Displays a summary of our systematic review methodology.

The maintenance of splash basin sterility appears vital in mitigating infection risk. An overview of splash basin contamination rates and common microorganisms has not been well-described. In this systematic review, we explore the notion that perhaps splash basins are not as sterile as previously thought and give recommendations for best practices with this surgical tool.

METHODS

Review methodology

A systematic review was conducted using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines of publications from 1970 to 2021. Pubmed and Ovid databases were searched using the following search terms: "splash basin" or "splash bucket." Two authors independently reviewed the literature. Studies were included if they reported on intraoperative splash basin contamination rates. Studies were excluded if they were not relevant to orthopaedic surgery, non-English articles, or repeat studies yielded by different online databases. Citations of relevant studies were also reviewed. Our PRISMA methodology is summarized in Figure 1. An example of a splash basin after a routine clean primary elective hip arthroplasty at our institution can be found in Figure 2.

Data Aggregation and Reporting

Each study's first author, journal published, year published, country of investigation, study design, and number of cases was collected. Patient and operation information reported by studies including patient age and sex, operations completed, case type (clean, contamination/dirty), urgency (elective vs. emergent/urgent) were also included. Perioperative statistics including operative time, use of prophylactic antibiotics, and operating room airflow (laminar airflow, rate of air exchange) were noted. Culturing technique, contamination rates, and bacterial species yielded from culture were listed. Clinical outcomes relevant to infection and follow-up times were also recorded when available.

Figure 2. A used splash basin after a primary total hip arthroplasty.

Additional Analysis

The rate of bacterial species contaminating the splash basin was calculated by dividing the number of reported cases for a given bacterial species or group in all studies by the total number of organisms reported.

RESULTS

Systematic Review Synthesis

There were 39 studies yielded from our initial search. After title and abstract review, there were 9 duplicates removed and 19 studies that did not report on splash basin contamination rates. The following reasons were used to exclude studies after manuscript review: non-English article (n=1), review paper (n=2), and no splash basin contamination rate reported (n=1). There were 7 studies included in our study after exclusion.[1-7] Relevant information about study design and publication can be found in table 1.

Case Selection

Five of seven studies cultured joint arthroplasty cases,[3-7] four of which were specified as being elective.[3-6] Of the remaining two, one investigated splash basin samples of hand, joint, and trauma orthopaedic cases, including open injuries.[1] The other cultured splash basins from elective orthopaedic cases.[2]

Splash Basin Fluid

There were six studies that used sterile water in splash basins (range 2%-74%)[1,3-7] and one by Anderson et al. that used physiologic saline (62%).[2] Two studies used surgical antiseptics diluted in sterile water. There were 53 splash basins with 0.05% chlorhexidine solution cultured in the Lindgren study[6] and 52 splash basins with 0.02% povidone-iodine in the Nazal study.[7]

Contamination Rates and Culturing Technique

The median contamination rate of sterile water or physiologic saline splash basins was 23.9% [range: 2%-74%]. In the 1980s, the first two studies on splash basin contamination reported the highest rates of contamina-

Table 1. Study Designs of Included Splash Basin Contamination Studies

#	Author	Year	Location	Cases	Design	Inclusion	Exclusion
1	Baird	1984	USA	78	CS	Randomly selected orthopaedic cases	
2	Andersson	1984	Sweden	21	CS	Consecutive, elective orthopaedic procedures, longer than 1 hour	
3	Anto	2006	Ireland	21	CS	All patients undergoing primary THA or TKA	
4	Glait	2011	USA	46	CS	Randomly selected clean primary joint arthroplasty cases	Positive culture on preop control swab
5	Jonsson	2014*	Iceland	90	CS	92 consecutive primary total hip and knee replacements for osteoarthritis	
6	Lindgren	2018	USA	100**	RCT	Primary TKA/THA cases	Revision hx of PJI, CHG allergy, declined participation, basin discarded, poor sterile technique in collecting sample, excess coagulation incorrect randomization, splash basin unused
7	Nazal	2020	USA	100***	RCT	Age >=18, undergoing total joint arthroplasty	Revision, hx of PJI, shellfish allergy, splash basin unused

*Study occurred from 1991-1992, published in 2014 with 20 year follow-up.
**Sterile water group (n=47), chlorhexidine group (n=53)
***Sterile water group (n=48), chlorhexidine group (n=52)
Index: #= number. Pub Year= year of publication. USA= United States of America. CS= Case series. RCT= Randomized Controlled Trial.

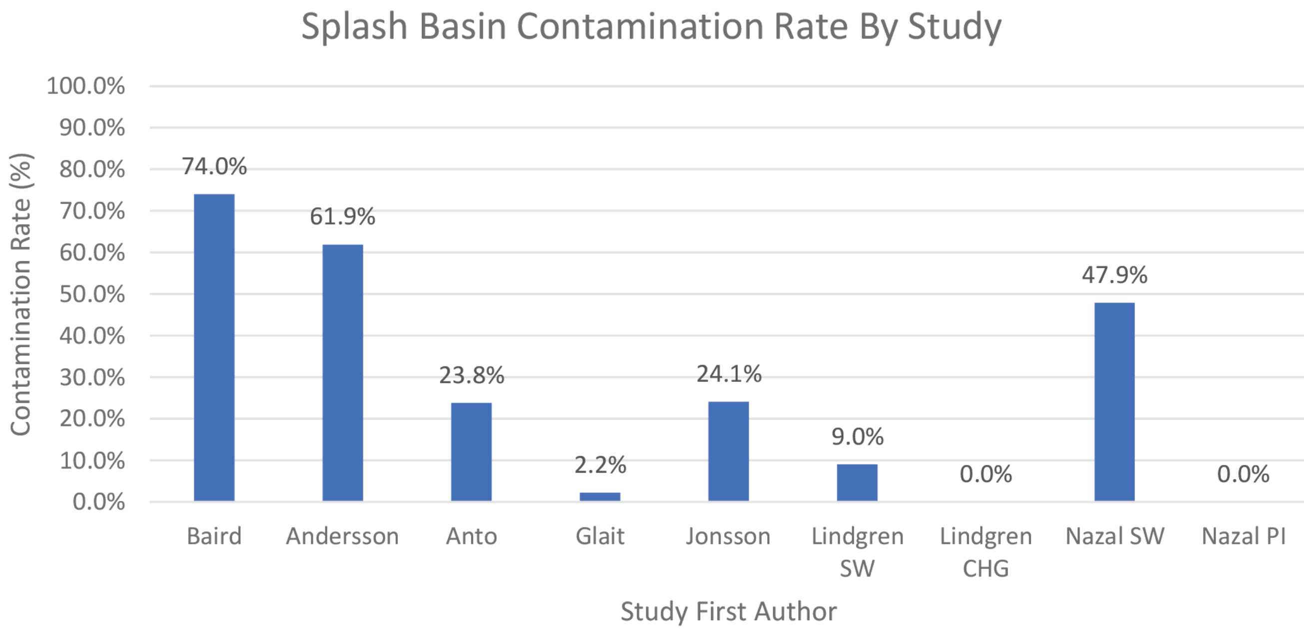


Figure 3. Demonstrates splash basin contamination rates reported in literature. All studies used sterile water or physiologic saline unless otherwise specified (sterile water [SW], chlorhexidine gluconate [CHG], povidone-iodine [PI]).

tion found in this review. Baird et al. found a 74% contamination rate in randomly selected clean or contaminated orthopaedic cases, while Andersson et al. found a 61.9% contamination rate in consecutive elective orthopaedic cases. Both studies did not limit their patient population to arthroplasty patients,[1-2] did not utilize laminar airflow, and poured splash basin fluid through a grid membrane for culture. Anto et al. found a 23.8% contamination rate in 21 splash basins used in primary elective total joint arthroplasties, in operating rooms with laminar airflow, and used the grid membrane culturing technique.[3] The study with the lowest contamination rate (2.2%) by Glait et al. was completed in randomly selected elective joint arthroplasty cases, in operating rooms with laminar airflow, and used a culture swab technique along the bottom of the splash basins.[4] Although it was published in 2014 with 20-year follow-up, the Jonsson et al. study was completed from 1991 to 1992, found a 24.1% contamination rate in 92 consecutive primary total joint arthroplasties, in operating rooms without laminar airflow, and used a culture swab technique to yield organisms for culture.[5]

Prior to 2018, every study utilized sterile water other than Andersson et al. They used physiologic saline in their retrospective case series. Two studies, published in 2018[6] and 2020[7], were both randomized controlled trials, with sterile water control groups and dilute surgical antiseptic experimental groups. Lindgren et al. found an 8.5% contamination rate and Nazal et al. found a 47.9% contamination rate in sterile water splash basins of primary elective total joint arthroplasties using grid membrane culturing techniques. Splash basins with surgical antiseptic diluted in sterile water had no contamination detected after grid membrane culture.[6,7] Contamination rates by study can be found in Figure 3.

Microbial Culture Findings

There was a total of 203 contaminants identified amongst all studies. Amongst them, the most frequent bacterial species found in culture were coagulase negative Staphylococci including Staphylococcus epidermidis (49.8%), Staphylococcus aureus (9.9%), unspecified gram-negative rods (7.9%), Diptheroids (7.4%), Bacillus species (3.9%), Pseudomonas species (3.4%), other gram-positive cocci (3.4%), Corynebacterium species (3.0%). Other organisms (12%) were as follows: unspecified other (2.5%), Micrococcus species (2.5%), Lactobacillus species (1.0%), actinobacter (0.5%), Streptococcus viridans (0.5%), Cupriavidus paucaulus (0.5%), Moraxella (0.5%), Kocuria species (0.5%), Clavicbacter michiganensis (0.5%), and Sphingobacterium multivorum (0.5%) [Figure 4].

Only one study commented on non-microbial contents of the splash basin. Lindgren et al. found soft tissue or fat, which they referred to as debris, in 54% of fluid samples.

Surgical Staff

The number of surgical staff in the operating averaged 7 in one study [range: 4-10][2], and 9 in two other studies (SD: 1.8 people[3]; 95% CI: 8-9[6]). The number of gowned personnel was specified only by one study, which found an average of 3 scrubbed in people per surgery.[3] There

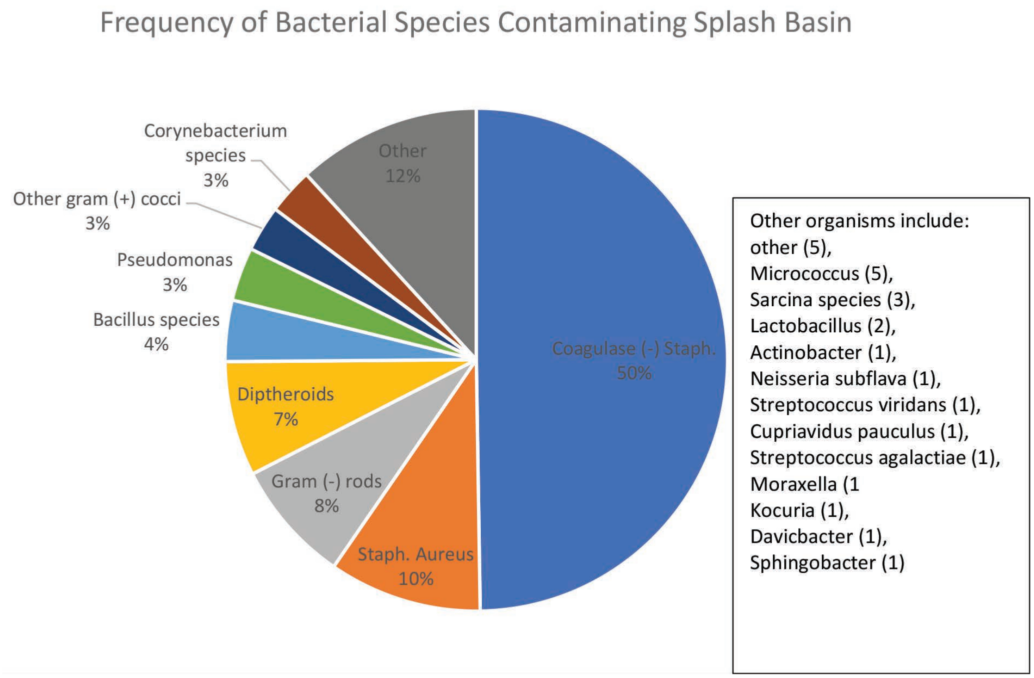


Figure 4. Shows the frequency of organisms contaminating splash basins.

was no association found in the only study that analyzed a relationship between number of OR personnel and splash basin contamination.[2]

Splash Basin Location

Andersson et al. studied splash basin contamination as it relates to placement in the operative field.[2] They found the following contamination rates based on splash basin placement: on the assisting table (8/12 samples), under the assisting table (2/3 samples), or on a table two to three meters from the assisting table (3/6 samples); the authors determined there was no significant difference between splash basin contamination based on placement in the OR. Another study specified splash basin placement on the back table but did not attempt to study the association between splash basin location and contamination rates.[6]

Splash Basin Handling/Operative Time

Andersson et al. limited splash basin samples to cases that lasted at least one hour[2] but did not report any analysis between splash basin contamination and operative time. No other studies excluded splash basins from cases with relatively short operative times.

All but two studies referred to splash basin opening time and incision time interchangeably. Lindgren et al. found an average time from splash basin procurement to fluid sample collection of approximately 90 minutes, which they acknowledge was less than other studies.[6] There was no time from splash basin opening to incision reported, or analysis on the association of operative time and contamination in their study.

Glait et al. determined an average of 75 minutes (SD: 30 minutes) between splash basin opening and initial incision.[4] The only case of contamination was recorded in the study was from a unicompartmental knee arthroplasty case with a time from basin opening to wound closure of 240 minutes, relative to the mean of 180 minutes (SD: 45 minutes) in uncontaminated cases.

This trend between longer operative times and greater risk of contamination was shared by other studies included in this review. One found that 35% of splash basin samples collected from cases lasting 130 minutes or longer were contaminated relative to 13% of samples collected before that timepoint.[5] Nazal et al. also found that mean operative time was significantly higher in cases with contaminated splash basins (70 minutes [SD: 33 minutes]) relative to negative samples (59 minutes [SD: 16 minutes]).[7]

Laminar Airflow

Laminar airflow was used by two studies,[3,4] not used by two studies,[2,5] and not reported on by the remaining three.[1,6,7] Amongst studies using laminar airflow, there were 300 air changes a minute and contamination rates of 23.8%[3] and 2.2%.[4] Studies not using laminar airflow reported 12 and 17 air changes a minute, and contamination rates of 61.9% and 24.1%, respectively.[5,2]

Postoperative Infection

Postoperative infection rates ranged from 0-2.4% in studies.[1,3,5] There was no association between splash basin contamination and infection.[6] One study found a 2.4% infection rate (1/41 cases) in contaminated splash basins relative to 2.0% infection rate in uncontaminated controls (1/49 cases), with no significant difference between groups.[3]

DISCUSSION

Splash basin contamination appears to be a significant problem in orthopaedic surgery. A wide range of contamination rates is reported in the literature likely due to differences in culturing techniques, case selection, and operating room sterility practices between study groups.[15-21] This variability does not discount the splash basin as a potential source of infection, particularly in longer orthopaedic cases.

The most frequent contaminants, coagulase negative Staphylococci and Staphylococcus aureus, are also the most frequent causes of periprosthetic joint infection in total joint arthroplasty cases.[12] Many contaminants appear to be human skin flora.[22] These bacteria also may be more likely to come from the operating room environment than the patient's own skin or surgical wound.[23] They are most likely spread to the splash basin in a similar way they are spread to the operative site, through direct contact with the surgical team's gloves or instruments.[24,25]

The use of surgical antiseptics appears highly effective in reducing the frequency of splash basin contamination, perhaps because of their efficacy against staphylococci species.[26] With no contamination being found in splash basins using surgical antiseptics (0.05% CHG solution,[6] 0.02% PI solution),[7] and no reported side effects or significant additional costs amongst studies using them,[27] this intervention deserve further investigation for incorporation into clinical practice.

There are no studies directly comparing contamination rates between different surgical antiseptic solutions or differing concentrations of antiseptic. More study on protocols for patients with known allergies to surgical antiseptics or changes in wear properties of instruments after the addition of surgical antiseptics is also needed.[28,29]

Knobben et al. described the potential for intraoperative sterilization using chlorhexidine gluconate, comparing colony forming units after inoculation of gloves with Staphylococcus species.[24] They showed that immersion in 0.04% CHG solution reduced colony forming units on contaminated gloves, while at concentrations of CHG higher than 0.4%, there were no bacteria found. The potential for dilute surgical antiseptics to offer continuous intraoperative sterilization of surgical instruments or surgical teams' gloves may be a promising additional use of the splash basin in the future.

Although not well-studied in relation to splash basin contamination, both operative time and operating room traffic are known risk factors for increasing the likelihood of operating room contamination.[17,19,21] One study identified a direct relationship between time exposed to the OR environment and open tray contamination, even in a closed operating room environment with no traffic.[30] There is also a two-fold increase in airborne contamination reported while patients are prepped for surgery;[31] the forty-minute delay reported by Glait et al. between splash basin opening and incision appears to place splash basins at an avoidably high risk of contamination.[4] Additionally, staff leaving or entering the OR can change local air flow and expose the sterile field to contaminants.[19]

The splash basin should be opened as close to the time of first use as possible. Another logical best practice may be opening a new splash basin or replacing the basin fluid after given time periods have passed in cases, as is recommended for sterile gloves.[32] Threshold splash basin dimensions, levels of fluid debris (fat, blood), and operative times that significantly increase the risk of contamination are unknown. Limiting operating room traffic and placing splash basins in areas where passersby are unlikely to be in proximity also appears prudent in avoiding splash basin contamination.

Another factor that may influence the settling of microbes in the splash basin is airflow within the room. Ventilation systems may have been a sources of less typical splash basin contaminants in this systematic review that do not colonize human skin such as Kocuria species or Sphingobacterium multivorum.[33,34] Laminar airflow, as opposed to conventional turbulent ventilation, is meant to sweep airborne particles away from the operative wound.[35] Early results in lowering surgical site infection rates were promising but failed to control for confounders like antibiotic use.[36] A recent systematic review and meta-analysis drew into question the efficacy and cost-effectiveness of laminar airflow in preventing surgical site infections.[37] Importantly, big data analysis may fail to consider operation dependent factors such as correct set up of laminar airflow systems and modified operating room practices to maximize its efficacy.[38] Operating rooms should be oriented to reduce particulate matter settling on the sterile field regardless of laminar or turbulent airflow systems being used.

There are limitations of this systematic review. With widespread reports of splash basin contamination, there is also the possibility of abandoning the splash basin in favor of wiping instruments with a lap pad. However, there have been no studies comparing intraoperative rates of contamination with and without splash basin use. Also, some of our recommendations are rooted in studies that refer to operating room sterility rather than splash basin sterility. Until splash basin specific studies are conducted, these more general studies on operating room contamination seem logical to guide best practices.

In an era where postoperative complications can increase healthcare cost burden and negatively impact patient care, it is important to take all steps possible to ensure sterility during all surgical cases. Existing studies demonstrate that these basins can be a frequent source of contamination. However, there are many factors that can decrease the risk of contamination in these basins, namely shortened duration of use and incorporation of dilute surgical antiseptics. Surgeons and surgical staff should remain cognizant of these factors and adjust practices accordingly to decrease the risk of splash basin contamination.

ACKNOWLEDGEMENTS

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

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DOES THE PATIENT-REPORTED OUTCOMES MEASUREMENT INFORMATION SYSTEM CORRELATE TO LEGACY SCORES IN MEASURING MENTAL HEALTH IN YOUNG TOTAL HIP ARTHROPLASTY PATIENTS?

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ABSTRACT

Background: Mental health is becoming increasingly important in patient outcomes. The patient reported outcome measurement information system (PROMIS) was developed by the NIH to collect outcome data in rapid dynamic fashion on electronic platforms. The potential role of PROMIS in monitoring young total hip arthroplasty (THA) patients is under-investigated. The purpose of this study is to investigate correlations between PROMIS Depression or Anxiety with SF-12 mental component score.

Methods: We identified 223 hips (200 patients) who underwent primary THA over a 30-month period at a single institution. Patients without preoperative PROMIS or SF-12 mental scores, or >50yo were excluded. All data was collected preoperatively and included age, sex, BMI, ASA, PROMIS Depression, PROMIS Anxiety, and SF-12 Mental component score. We considered floor and ceiling effects as significant if >15% of patients responded with the lowest or highest possible score, respectively. Relationships between SF-12 and PROMIS were investigated using correlation (R), and were considered strong if R>0.7.

Results: Mean age was 41-years-old, mean ASA category was 2, mean BMI was 30kg/m2, and 54% were female. None of the PROMs showed any floor/ceiling effects at baseline. PROMIS Depression showed a strong correlation to SF-12 Mental (R=-0.72) while PROMIS Anxiety showed a moderate correlation to SF-12 Mental (R=-0.58). Negative linear relationships were observed because a lower PROMIS Depression/Anxiety values indicates less depressive/anxious feelings (inverse of SF-12).

Conclusion: PROMIS Anxiety and Depression correlate well with SF-12 mental. These PROMIS domains may be attractive alternatives to legacy mental health instruments in young THA patients.
Level of Evidence: III

Keywords: promis, patient-reported outcomes measurement information system, total hip arthroplasty, mental health, sf-12 mental

INTRODUCTION

As the link between mental health and clinical outcomes after orthopaedic surgery grows stronger,[1-4] the need for well-established gold standard patient-reported outcome measures (PROMs) has become exceedingly necessary.[5] Outcome measures are believed to provide an standardized and easily interpretable way for patients to communicate their mental health status to care providers. Unfortunately, over the last few decades, PROMs with varying scales have been proposed and used across medicine.[6-11] This creates barriers to efficient and effective patient care for physicians unfamiliar with the available PROMs, while also placing burden on patients who are required to complete multiple PROMs at every clinic visit, regardless of that provider's area of practice. Furthermore, many of the current mental health PROMs used in orthopaedic surgery are broad in scope, clumping all mental health aspects into one all-encompassing score.[12] To better understand how the various facets of mental health affect clinical outcomes, we must possess the ability to measure them accurately and separately.

There are few established PROMs that measure some characteristic of mental health in current orthopaedic practice.[13,14] One such PROM is the Short Form 12 Health Survey (SF-12), which is a 12-item health survey given to patients as a paper form to complete pre-operatively and throughout their follow-up. The individual item raw scores are transformed to a 0-100 scale, which is then standardized using linear T-score transformation with a general population mean of 50, and a standard deviation (SD) of 10.[15-18] A higher score on

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

Sources of Funding: This work was supported in part by the Curing Hip Disease Fund (JCC), the Jacqueline & W. Randolph Baker fund (JCC), and The Foundation for Barnes-Jewish Hospital (JCC, Award Reference 4060).

the SF-12 indicates that a patient has "better health". By weighing the separate item scores, a physical component score (PCS) and a mental component score (MCS) can also be obtained. Unlike item scores, these scores are calculated using all the questions for a comprehensive view of the patient's mental or physical health status. The SF-12MCS is considered one of the gold-standards of mental health PROMs for orthopaedic surgery due to its versatility and easy-to-understand scores.[13,19] Unfortunately, the SF-12MCS only gives a global summary of the patient's mental health, with a low score interpreted as meaning the patient has "frequent psychological distress, substantial social and role disability due to emotional problems."[15-18] Therefore a low score can't help in determining if the distress is more related to anxious feelings or those of depressive thoughts.[13]

Patient-Reported Outcomes Measurement Information System (PROMIS) was created by the National Institute of Health (NIH) to offer all healthcare providers a standardized global PROM that can be utilized for all patients, irrespective of their conditions or the physician treating them.[20,21] This new set of PROs utilize computer adaptive testing (CAT) and item-response theory (IRT) to quickly and accurately assess a patient's health status with the least number of questions possible.[22] Over 90 different PROMIS domains have been created so far ranging from generalized outcomes like the Global Health to highly detailed and specialized outcomes such as PROMIS-Cancer Fatigue. This presents healthcare providers a new opportunity to identify and monitor potential factors that may play a role in their patient's health. PROMIS Depression (PROMIS-DEP) measures negative mood, views of self, social cognition, and decreased positive affect and engagement. PROMIS Anxiety (PROMIS-ANX) measures fear, anxious misery, hyperarousal, and somatic symptoms related to arousal. PROMIS uses T-score standardization with all PROMIS-DEP and PROMIS-ANX scores calibrated for and centered on a general population mean of 50 and SD of 10. Subgroup means and SD have also been reported by the NIH and are available online at the HealthMeasures website.[23]

As with any new PROM, assessment of the validity and feasibility is paramount for its accurate use in various populations.[5,6,24] This can be achieved by validating the PROM in the general population and establishing the psychometric properties; a set of "quality criteria" have previously been proposed,[25] and more recently adapted for orthopaedic surgery.[24] These criteria have been used to demonstrate the validity of PROMIS across multiple patient populations[26-28] and medical specialties.[29-32] Nevertheless, some of those properties must be continually evaluated for a PROM to be deemed valid in a target population.[5,6] Little is known regarding the use of mental health domains of PROMIS in young patients undergoing primary THA, or their correlation to established gold standard mental health PROMs.

Due to the known association between mental health and outcomes after orthopaedic procedures, it is important to define the psychometric properties of PROMIS mental health domains, like PROMIS-DEP and PROMIS-ANX, as well as their relationship to SF-12 in individual patient populations. This may ensure better monitoring of various facets of mental health and facilitate future surgical decision-making and patient counseling. Therefore, in this study we 1) investigate the correlation of PROMIS-DEP and PROMIS-ANX with the SF-12 MCS, 2) provide validity for use of PROMIS-DEP and PROMIS-ANX in patients 50 years old and younger receiving a primary THA by analyzing baseline psychometric property values, and 3) establish baseline values for PROMIS-DEP and PROMIS-ANX in this cohort. We hypothesize that SF-12MCS will correlate strongly with PROMIS-DEP, moderately strong with PROMIS-A, and that both PROMs will demonstrate their validity. The reason for stronger correlation for depression but only moderately strong correlation for anxiety is because SF-12MCS identifies depressive symptoms better than anxiety symptoms.[13]

METHODS

This study was approved by our institutional IRB and all patients included in the study provided consent to be involved. We conducted a retrospective cohort study of hips that underwent a primary THA at our single academic institution for any diagnosis over a 30-month period between May 2016 and October 2018. The review of hips was conducted by one of 3 fellowship-trained hip arthroplasty surgeons. Those older than 50 years at the time of surgery or without scores for both the SF-12 MCS and at least one of the mental health PROMIS domains (Depression and Anxiety) were excluded. All demographics and PRO were collected as standard of care at the preoperative visit during check-in. After the patient provided consent, was scheduled for surgery, and agreed to participate in the study, the data was loaded into our research database. Demographics consisted of age at surgery, sex, operative side, BMI, and prior ipsilateral surgery. PROs collected preoperatively included PROMIS-DEP, PROMIS-ANX, SF-12MCS, SF-12PCS, UCLA activity score, WOMAC Pain, WOMAC Physical Function, and WOMAC Stiffness. PROMIS-DEP and PROMIS-ANX scores were obtained by patient input on a tablet computer device (iPad mini 16GB, Apple, Cupertino, CA) preloaded with the PROMIS-DEP (version 1.0) and PROMIS-ANX (version 1.0) computer adaptive tests

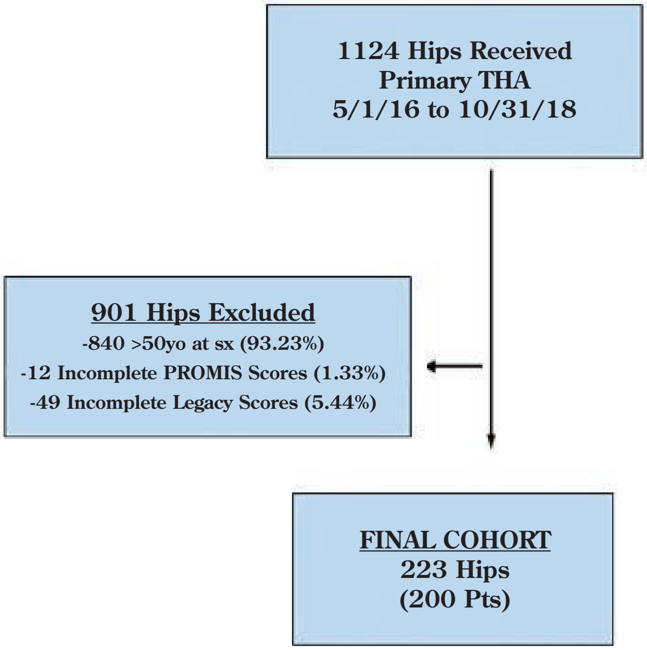

Figure 1. Flowchart demonstrating reasons for patient exclusions. THA, Total Hip Arthroplasty; Sx, Surgery; Pts, Patients; PROMIS, Patient-Reported Outcomes Measurement Information System.

(CATs) using an internally developed software while the remaining PROMs were collected via patient-completed paper questionnaire packets.

We assessed the data for descriptive statistics to summarize patient characteristics, and to ensure normal distribution before additional analysis. Presence of any apparent floor or ceiling effects were assessed using histograms; floor or ceiling effects were considered significant if 15% or more of the patients responded with the lowest or highest possible score, respectively.[25] We further analyzed all score distributions for the effect from demographic characteristics. Correlations between all PROMS were assessed using Spearman-rank correlation (R) and simple linear regression was conducted between PROMIS-DEP and PROMIS-ANX against SF-12MCS to investigate correlation, variation accounted for by the correlation, standard error (SE), significance, confidence intervals, general linear relationships, and floor or ceiling effects not identified on histograms. Residual plots were investigated to determine the presence of confounding variables. Correlation coefficients were interpreted as follows: 0 to 0.3 representing a negligible correlation, 0.3 to 0.5 representing weak correlation, 0.5 to 0.7 representing moderate correlation, and >0.7 representing strong correlation.[33] The amount of variation accounted for by the correlation was determined by the coefficient of determination (R^2). The value of R^2 ranges from 0.0 to 1.0 where 1.0 represents 100% of the variation seen in the sample was explained by the correlation. We established

Table 1. Demographic Characteristics of the Cohort

	Mean (SD)
Characteristic	Cohort (N= 223)
Age at Surgery	40.8 (8.7)
ASA	2 (0.5)
BMI	30.4 (6.4)
	No. (%)
Male Sex	97 (43.5%)
Right Side	109 (48.9%)
Prior I/L Sx	69 (30.9%)

No, Number; SD, Standard Deviation; Sx, Surgery; BMI, Body Mass Index; I/L, Ipsilateral.

Table 2. Diagnoses of the Cohort

Dx	No. (%)
Degenerative OA	144 (65.0%)
Hip Dysplasia	38 (17.0%)
AVN	28 (12.6%)
Post-Traumatic	6 (2.7%)
Epiphyseal Dysplasia	5 (2.2%)
Impingement	1 (0.4%)
Rheumatoid Arthritis	1 (0.4%)

Diagnoses of the cohort. No, Number.

through a priori power analysis that a sample size of 85 hips is necessary to show a weak correlation (R = 0.3) with 80% power and statistical significance. Construct validity was assessed by testing pre-determined hypotheses of how the PROMIS domains would correlate to PROMs measuring varying aspects of health and function. Interpretability was assessed with the baseline means, SD, and the coefficients of variation (CV, =SD/Mean) of the cohort to investigate how they relate to the general population, as well as to the same properties in SF-12MCS. Due to the demographic characteristics of our cohort, we chose to compare all our data to the general population values for PROMIS and forego detailed analysis based on the subgroup distributions. A p-value <0.012 was considered statistically significant according to Bonferroni correction.

RESULTS

Of the 1124 hips with primary THA, 223 total hips (in 200 patients) met inclusion criteria and were included in the final analysis (Figure 1). The mean age at surgery was 40.8 years old (±8.7 years), with a mean BMI of 30.4 (±6.4). From the 223 hips included, 97 (43.5%) were male, 109 (48.9%) had surgery on the right hip, and 69 (30.9%)

Table 3. Correlation of All PROMs

	R		
PROM	PROMIS-DEP	PROMIS-ANX	SF-12MCS
SF-12MCS	-0.71	-0.58	1.00
SF-12PCS	-0.11	-0.18	0.01
UCLA Activity Score	-0.19	-0.12	0.21
WOMAC Pain	-0.17	-0.20	0.22
WOMAC Physical Function	-0.22	-0.23	0.29
WOMAC Stiffness	-0.18	-0.22	0.18

Correlation of pre-operative scores for PROMIS-DEP, PROMIS-ANX, and SF-12MCS against WOMAC Pain, WOMAC Physical Function, WOMAC Stiffness, UCLA activity score, and SF-12PCS. R, Correlation coefficient; SD, Standard Deviation; PROM, Patient Reported Outcome Measure; PROMIS-DEP, Patient-Reported Outcomes Measurement Information System Depression; PROMIS-ANX, Patient-Reported Outcomes Measurement Information System Anxiety; SF-12MCS, Short Form 12 Health Survey Mental Component Score; SF-12PCS, Short Form 12 Health Survey Physical Component Score; WOMAC, Western Ontario & McMaster Universities Osteoarthritis Index.

Table 4. Cohort Scores, All Hips and by Age Subgroup

	Mean (SD)				
PROM	All Hips	18-34	35-44	45-50	P-value
PROMIS-DEP	49.5 (10.5)	50.5 (10.4)	47.6 (12)	50.2 (9.3)	0.360
PROMIS-ANX	54.3 (9)	54.3 (9.2)	53.4 (9.5)	54.8 (8.3)	0.336
SF-12MCS	52.1 (11.6)	51.2 (11.9)	52.3 (11.5)	52.5 (11.5)	0.819

Characteristics of pre-operative scores for PROMIS-DEP, PROMIS-ANX, and SF-12MCS. SD, Standard Deviation; PROM, Patient Reported Outcome Measure; PROMIS-DEP, Patient-Reported Outcomes Measurement Information System Depression; PROMIS-ANX, Patient-Reported Outcomes Measurement Information System Anxiety; SF-12MCS, Short Form 12 Health Survey Mental Component Score.

had surgery on their index hip prior to receiving THA (Table 1). The majority (144 hips, 65%) presented with degenerative osteoarthritis as their sole diagnosis, 28 (12.6%) presented due to avascular necrosis and 6 (2.7%) presented post-trauma (Table 2).

Regression analysis revealed that PROMIS DEP demonstrated a strong correlation with SF-12MCS at baseline (R=-0.71, 95% CI -0.67 to -0.88) while PROMIS ANX only had a moderate correlation (R=-0.58, 95% CI -0.59 to -0.89) with SF-12MCS at baseline (Figures 2A and 2B). The moderate R^2 value for PROMIS DEP and SF-12MCS (R^2=0.50) demonstrates that the correlation and regression account for 50% of the variance between scores. Although these 2 PROMs are measuring roughly half of the same parameters, PROMIS-DEP is likely obtaining information that the SF-12MCS does not. The R^2 value for PROMIS ANX and SF-12MCS (R^2=0.33) was even lower, indicating that these PROMIS-ANX is likely capturing information that SF-12MCS is not.

Correlations of PROMIS-DEP, PROMIS-ANX, and SF-12MCS with SF-12PCS, UCLA activity score, WOMAC Pain, WOMAC Physical function, and WOMAC Stiffness are shown in Table 3. When comparing the correlations for PROMIS-DEP, PROMIS-ANX, and SF-12MCS (each of these against any one specific legacy PROM for pain or physical function), all R values fall within the same tier of correlation grading and also demonstrate overlapping confidence intervals, signifying no significant difference

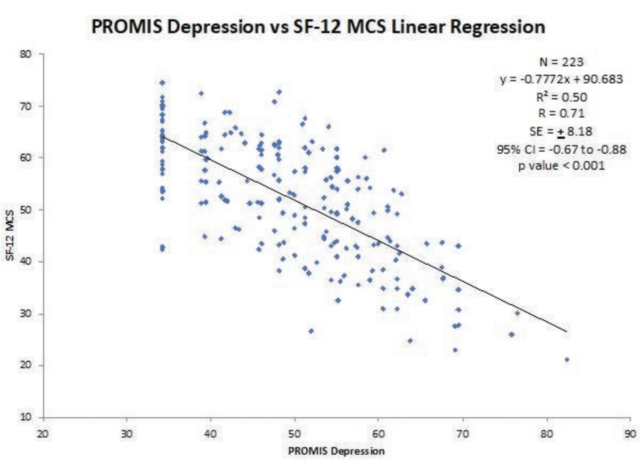

Figure 2A. Scatter plot of pre-operative PROMIS Depression scores versus SF-12 Mental scores with linear regression line which yielded R^2=0.5008. R^2, Goodness of fit measure; R, Correlation Coefficient; SE, Standard Error; SF-12 MCS, Mental Component Score; PROMIS, Patient-Reported Outcomes Measurement Information System.

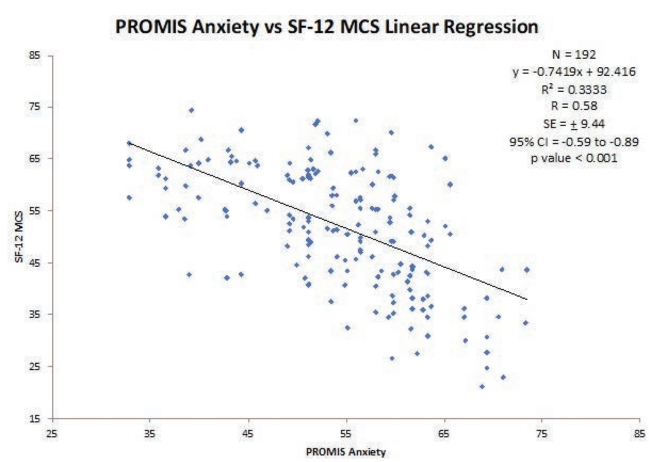

Figure 2B. Scatter plot of pre-operative PROMIS Anxiety scores versus SF-12 Mental scores with linear regression line which yielded R^2=0.333. R^2, Goodness of fit measure; R, Correlation Coefficient; SE, Standard Error; SF-12 MCS, Mental Component Score; PROMIS, Patient-Reported Outcomes Measurement Information System.

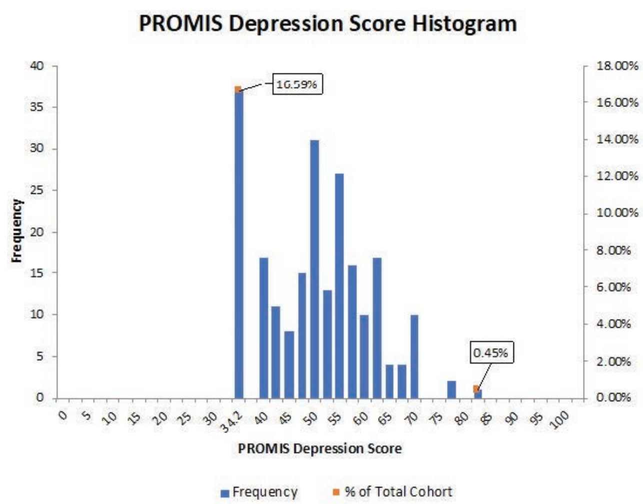

Figure 3A. Histogram of PROMIS Depression scores. Orange dots signify the percentage of hips from the cohort that obtained that respective score. Those with > 15% were considered to demonstrate a floor or ceiling effect. PROMIS, Patient-Reported Outcomes Measurement Information System.

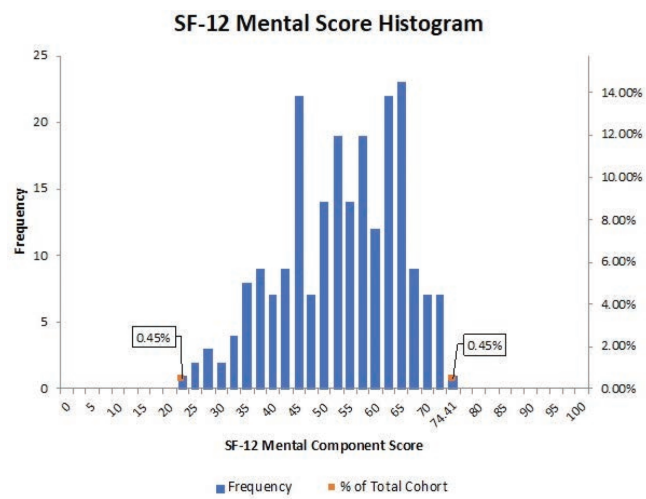

Figure 3C. Histogram of SF-12 Mental Component scores. Orange dots signify the percentage of hips from the cohort that obtained that respective score. Those with > 15% were considered to demonstrate a floor or ceiling effect. PROMIS, Patient-Reported Outcomes Measurement Information System.

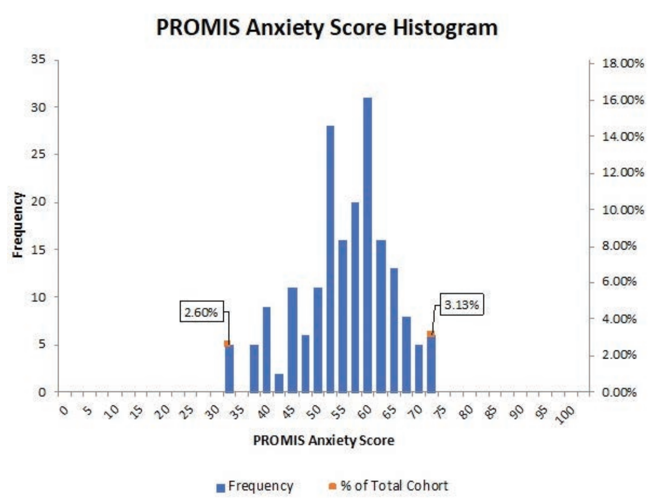

Figure 3B. Histogram of PROMIS Anxiety scores. Orange dots signify the percentage of hips from the cohort that obtained that respective score. Those with > 15% were considered to demonstrate a floor or ceiling effect. PROMIS, Patient-Reported Outcomes Measurement Information System.

between the 3 mental scores and their various correlations to physical function and pain PROMs (Table 3).

At baseline, all 3 of the PROMs demonstrated means within 1 SD of 50 (PROMIS-DEP=49.5, PROMIS-ANX=54.3, SF-12MCS=52.1, Table 4). No ceiling effects were seen in any PROM, and only PROMIS DEP showed a floor effect with 16.59% (37/223) of hips achieving the lowest possible score (34.2) (Figure 3A). Distribution was otherwise normal for all PROMs, as seen in the histograms (Figures 3B and 3C) and confirmed with Shapiro-Wilk analysis. Demographic characteristics analyzed show no effect on score distribution. Scores were also stratified by age groups and showed no significant differences (Table 4).

DISCUSSION

Recent research has demonstrated the importance of considering mental health in patients undergoing surgery. Nonetheless, very little information is currently available on the effects that mental health status can have on clinical outcomes of patients undergoing orthopaedic surgery. Furthermore, the availability of PROMs that measure different aspects of mental health, or global mental health is limited. Current gold-standard PROMs of mental health include the SF-12MCS and the EQ-5D, both of which give a single score that encompasses the entirety of the patient's mental health. To our knowledge, this is the first study to analyze the correlation of PROMIS mental health domains with SF-12MCS scores in patients <50-years-old receiving primary THA.

Our objectives in this study were to investigate the correlation of PROMIS-DEP and PROMIS-ANX with the SF-12MCS , to validate PROMIS-DEP and PROMIS-ANX for use in patients 50 years old and younger receiving a primary THA by analyzing baseline psychometric property values, and to establish baseline values for PROMIS-DEP and PROMIS-ANX in this cohort. Based on our findings, we believe that PROMIS-ANX is valid for use in this cohort to establish a baseline anxiety status and that the average patient in this cohort falls within an acceptable range of normal anxiety when compared to the general population. With regards to PROMIS-DEP, the data suggests that it is partially valid for use in this population and may still be useful for monitoring some patients, especially those with initially high scores. Despite showing stronger correlation than PROMIS-ANX, a lack of floor effect places some limitation to the validity of PROMIS-DEP for use in this population as discussed later. Nevertheless, PROMIS-DEP still demonstrated a mean in our population that is within an acceptable range of the normal general population. Although these findings support the use of PROMIS mental health domains as an alternative to legacy mental health measures in young patients undergoing THA, additional work is needed to obtain follow-up scores in this population to fully validate PROMIS-DEP and PROMIS-ANX.

The strong correlation of PROMIS-DEP to the SF-12MCS lends to its validity, while the moderate goodness-of-fit demonstrates that PROMIS-DEP and SF-12MCS are measuring many, but not all, of the same parameters. The weak and negligible correlations to the remaining PROMs provide further validity, showing that PROMIS-DEP is indeed capturing information about the patient's depressive symptoms and not using other health aspects as surrogates. Unfortunately, PROMIS-DEP did demonstrate a floor effect, which places some limitations to its use in patients with very low scores preoperatively and should be the subject of future research.

Meanwhile, the moderate correlation with small R^2 for PROMIS-ANX and SF-12MCS demonstrates that these 2 PROMs are measuring somewhat different parameters of mental health. This finding was expected and agrees with reports that SF-12MCS does a better job at picking up depressive symptoms more than anxiety symptoms.[13] PROMIS-ANX was able to demonstrate correlations to PROMs of physical health that were comparable to SF-12MCS and PROMIS-DEP. It also showed no floor or ceiling effects, making it an effective tool for establishing baseline anxiety status. Some groups have demonstrated the validity of PROMIS-ANX by utilizing the EQ-5D in other patient populations but due to the lack of availability of a true gold-standard legacy measure for anxiety in orthopaedic populations, we were limited in the PROMs used for correlation and validation.

To utilize these PROMs in our specific populations, it's necessary to establish baseline values and to investigate their interpretability when compared to the general population. Previous literature has shown that the average patients presenting for primary THA have depression and anxiety symptoms at rates similar to or less than the general population, indicated by their SF-12MCS scores.[34,35] Both PROMIS domains had means within 5 points (1/2SD) of the general population means and smaller SDs than SF-12MCS. This shows that PROMIS domains may have the ability to detect smaller changes in health status and likely have a smaller MCID than SF-12MCS, although actual MCID values must still be established in this cohort. It also shows that when it comes to feelings and thoughts of anxiety or depression, this cohort performs similarly to the general population. The CV for PROMIS-DEP (0.21) and PROMIS-ANX (0.17) compare well with the general populations (0.2), signifying that PROMIS-DEP exhibits distribution in this cohort that is nearly identical to the general population, and PROMIS-ANX exhibits less variation in this cohort when compared to the general population. Taken together with the easy-to-understand scoring system and standardized means and SD, PROMIS-DEP and PROMIS-ANX prove to be easily interpretable PROMs. A cursory analysis of our PROMIS values stratified by age and compared to values of PROMIS for the appropriate subgroups, rather than general population values, further supported the above findings.

Limitations

Two large limitations exist that constrain our abilities to fully validate these PROMs in our cohort. First, the lack of follow-up scores prevents us from performing other important validation criteria- reliability and responsiveness, or from establishing true MCID values. Second, the lack of a gold-standard mental health PROM in orthopaedic surgery for anxiety limited our ability to evaluate the validity of PROMIS-ANX, although this has been done previously in other populations.

CONCLUSION

Our findings support the use of PROMIS mental health domains as an attractive alternative to current mental health legacy scoring instrument in young patients undergoing THA, given their moderate to strong correlations with SF-12MCS, demonstrated validity, and easily interpretable scores. Further work is necessary to obtain follow-up scores in this cohort and to fully validate PROMIS-DEP and PROMIS-ANX for use in this cohort.

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TOTAL KNEE ARTHROPLASTY: A QUANTITATIVE ASSESSMENT OF ONLINE PATIENT EDUCATION RESOURCES

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ABSTRACT

Background: Patients often turn to the online resources to learn about orthopedic procedures. As the rate of joint arthroplasty is projected to increase, the corresponding interest in relevant online education material will increase as well. The American Medical Association (AMA) and National Institutes of Health (NIH) recommend that publicly available online health information be written at the 6th grade or lower reading level to be fully understood by the average adult in the United States. Additionally, educational resources should be written such that readers can process key information (understandability) or identify available actions to take (actionability). The purpose of this study was to quantify the readability, understandability, and actionability of online patient educational materials regarding total knee arthroplasty (TKA).

Methods: The most common Google™ search term utilized by the American public was determined to be "knee replacement". Subsequently two independent online searches (Google.com) were performed. From the top 50 search results, websites were included if directed at educating patients regarding TKA. Non-text websites (audiovisual), articles (news/research/industry), and unrelated resources were excluded. Readability was quantified using the following valid objective algorithms: Flesch-Kincaid Grade-Level (FKGL), Simple Measure of Gobbledygook (SMOG) grade, Coleman-Liau Index (CLI), and Gunning-Fog Index (GFI). PEMAT was utilized to assess understandability and actionability (0-100%; score ≥70% indicates acceptable scoring). The relationship between search rank with FKGL and PEMAT scores was quantified.

Results: A total of 34 (68%) unique websites met inclusion criteria. The mean FKGL, SMOG, CLI, and GFI was 11.8±1.6, 11.1±1.2, 11.9±1.4, and 14.7±1.6, respectively. None of the websites scored within the acceptable NIH/AMA recommended reading levels. Mean understandability and actionability scores were 54.9±12.1 and 30.3±22.0. Only 5.9% (n=2) and 9.2% (n=1) of websites met the ≥70% threshold for understandability and actionability. Only 29.4% (n=10) sources used common language and only 26.9% (n=9) properly defined complicated medical terms. Based on website type, the mean understandability scores for academic institution, private practice, and health information publisher websites were 57.2±8.8%, 52.6±11.1%, and 54.3±15.3% (p=0.67). Readability (rho: -0.07; p=0.69), understandability (rho: -0.02; p=0.93), and actionability (rho: -0.22; p=0.23) scores were not associated with Google™ search rank.

Conclusion: TKA materials scored poorly with respect to readability, understandability, and actionability. None of the resources scored within the recommended AMA/NIH reading levels. Only 5.9% scored adequately on understandability measures. Substantial efforts are needed to improve online resources to optimize patient comprehension and facilitate informed decision-making.

Level of Evidence: III

Keywords: patient education, knee arthroplasty, health literacy

INTRODUCTION

Osteoarthritis (OA) of the knee is a significant health problem, with up to 14 million people in the United States (US) reporting symptoms.[1] OA is a leading cause of disability, as joint pain can produce sequelae, including depressed mood, poor sleep, and loss of independence.[1,2] The volume of primary total knee arthroplasties in the US is projected to have an 85% increase by the year 2030, surmounting to approximately 1.26 million cases per year.[3]

When considering an elective surgical procedure, patients often turn to the internet for additional information. In 2019, 90% of US adults utilized the internet, with 72% of adults accessing the internet for health information.[4]

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

Sources of Funding: No sources of funding declared.

This includes the TKA specific population, consisting of older patients who are at increased risk for lower health literacy.[5] However, despite online patient education materials being recognized as an important component of health literacy,[6] studies continue to demonstrate variable quality and validity of online information. Furthermore, inconsistent, and poorly written material may negatively impact understanding, shared decision-making, and overall outcomes.[5,7-11]

The American Medical Association (AMA) and National Institutes of Health (NIH) recommend that publicly available online health information be written at the 6th grade or lower reading level to be fully understood by the average adult in the United States. Currently the quality of TKA patient education materials is poorly understood. Past literature has investigated the readability of TKA online patient education materials.[12-15] However, readability assessments are subjected to linguistics, syllables, and syntax, which limits their measuring ability to effectively assess a resource's capacity to convey data such that readers can process and understand the information. This limitation has been previously recognized and the Patient Educational Materials Assessment Tool (PEMAT) was developed to assess the ability of readers to process and explain key messages (understandability) and identify what they can do based on the information presented (actionability).[6] The aim of this study was to utilize PEMAT and validated readability algorithms to quantify the readability, understandability, and actionability of online TKA patient education resources.[6] We hypothesize that the existing TKA resources will score favorably on the readability, understandability, and actionability metrics.

METHODS

Educational Material Identification

The most common TKA search term was determined by utilizing Google™ trends (trends.google.com).[16] This trend analysis tool collects the individual Google™ search inputs in the United States, and normalizes the one-year search data. Subsequently, terms can be compared resulting in geographic and quantity-based values ranked 0-100 based on a well designed Google™ algorithm. A value of 100 indicates peak popularity of the term. The following terms were compared from 2/2019-2/2020: "total knee arthroplasty", "total knee surgery", "total knee replacement", "knee arthroplasty", and "knee replacement". Google™ reported "knee replacement" was 28.1 times more likely searched by the general public compared to "total knee replacement", the second most common TKA input. (Figure 1)

The Google™ search engine was the search engine of choice because at the time of this study Google™ searches comprised a majority (88-92%) of the internet search market share.[17,18] Two searches of the term "knee replacement" were independently performed by two reviewers on 2/17/20 (TRG) and 2/18/20 (MKS). Prior studies have reported that approximately 70% or more "clicks" originate from the first 10-50 search results,[19-21] with, previous PEMAT studies targeting the first 10 to 50 websites.[22-26] Therefore, the searches were entered to imitate real user experience. From the independent searches, each reviewer subsequently recorded the first 50 websites in order of search result.

The two sets of search results were consolidated, and duplicates were removed. Each website was meticulously assessed with strict inclusion and exclusion criteria applied. Inclusion criteria consisted of websites that contained primary content educational information focused on total knee arthroplasty. Exclusion criteria included news articles, primarily audio-visual resources, personal experiences/blogs, references specifically written for health care professionals, peer-reviewed journal articles, advertisements of product or service without patient education, articles unrelated to TKA and articles not directed at patients as the primary consumer. Primarily audiovisual resources were excluded because these could not undergo readability analysis.

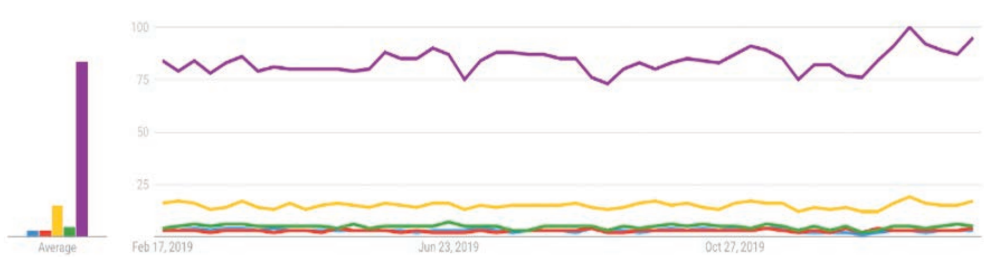

Figure 1. Trends based on google search terms formulated by trends.google.com. Value ranked 0-100 based on Google™ algorithm. A value of 100 indicates peak popularity of the term. Study terms demonstrated that "knee replacement" was 28.1 times more likely to be searched by the general public compared to "total knee arthroplasty".

Content Analysis

Content analysis was performed on every included resource via two qualitative reviews consisting of the following categories: i) discussion of operative management ii) discussion of non-operative management iii) advertisement of a physician or group who provided the described management iv) discussion of general background information of the disease (anatomy, pathology, prognosis, risk factors) v) discussion of work-up or activities related to diagnosis and/or preoperative management vi) discussion of postoperative management vii) discussion of complications and/or risks of operative management. For this study, an advertisement was defined as any website that included information directing the reader towards a specific institution or group for management of TKA.

Subgroup analysis based on type of practice that created the resource was performed. This included the following groups: academic institution, private practice, or health publisher.

Statistical Analysis

Readability

Objective quantification of the patient education resources was performed by employing the following validated algorithms: Flesh-Kincaid Grade Ease (FKGE), Flesch-Kincaid Grade-Level (FKGL), Simple Measure of Gobbledygook (SMOG) grade, Coleman-Liau Index (CLI), Gunning-Fog Index (GFI), and Automated Readability Index (ARI). These algorithms were accessed using an open-source readability software (https://webfx.com/tools/read-able/check.php). A larger numerical FKGE score signifies the text material is grammatically simpler to read. FKGL, SMOG grade, CLI, GFI, and ARI readability scores represent grade level per the United States education system. Selected algorithms have been utilized in previous studies to assess the readability of other surgical online materials.[10,22,23,27-29] Text unrelated to patient education, including copyright, references, and links independent of the main text were excluded from the readability analysis.

Understandability and Actionability

Understandability and actionability of each website were analyzed by applying the validated Patient Education Material Assessment Tool (PEMAT), a reliable instrument from the Agency for Healthcare Research and Quality (AHRQ).[6,30,31] The PEMAT tool specifies independent understandability and actionability scores for each educational material on a scale from 0-100%. A larger percentage represents a higher level of understandability or actionability for the reader. The PEMAT developers have established a threshold of 70% as the minimum score required for a resource to have adequate actionability and understandability.[6] Therefore, a resource having a PEMAT score less than 70% is considered poorly understandable or poorly actionable.[6] Two reviewers (MKS, TRG), individually conducted separate understandability and actionability analysis on the included websites using the PEMAT-P form.[6,30-32] As previously applied by the PEMAT developers,[6,31] interrater reliability was calculated using Cohen's Kappa.

Search Rank Analysis

Google search rank was averaged from two independently conducted searches of "knee replacement". Spearman's rho was used to assess the correlation between website search rank and its readability, understandability, and actionability. Statistical significance was defined as $p<0.05$.

RESULTS

Following the two independent searches and the removal of duplicate websites, a total of 52 unique online materials were identified, while 34 (65.4%) websites ultimately met the inclusion criteria. Three (5.8%) websites were excluded as primary literature, five (9.6%) were primarily audiovisual materials, and seven (13.5%) were excluded as news articles, two (3.8%) websites were excluded as primarily advertisements, and one (1.9%) was excluded as other/miscellaneous.

Of the 34 included online educational resources, 15 (44.1%) included background information (anatomy, pathology, prognostic factors), 15 (44.1%) discussed nonoperative management and 31 (91.1%) discussed operative management. Less than half the websites (n=15, 44.1%) discussed the preoperative workup of TKA, while 29 (85.3%) discussed the postoperative course. Risks and complication of operative management were discussed in 21 (61.8%) of the websites. Overall, 17 (50.0%) included an advertisement for a physician or group who provided the described management. Based on website type: 13 (38.2%) were from an academic institution, 12 (35.3%) from private practice, and 9 (26.5%) from a health publisher.

Readability

The mean FKGE was 45.9±8.3. Readability grade-levels per score ranged from 10.7 to 14.2. The mean FKGL, SMOG, CLI, GFI, and ARI representing grade level were 11.8±1.6, 11.1±1.2, 11.9±1.4, 14.7±1.6 and 12.1±1.7, respectively (Table 1). None (n=0) of the websites scored within the AMA/NIH recommended levels (≤ 6th grade reading level). (Table 1)

Understandability and Actionability

Mean understandability and actionability scores were 54.9±12.1 and 30.3±22.0. Only 2 (5.9%) websites met the threshold for adequate (≥70%) understandability. Only

1 (2.9%) met the threshold for actionability. (Figure 2) Interrater reliability demonstrated substantial agreement (kappa = 0.80+/-0.002).

There were 10 (29.4%) sources that used common language and 12 (35.3%) defined complicated medical terms. The most frequently missed understandability criteria was the lack of a comprehensive summary with 30 (88.2%) missing this valuable component. The second most frequently missed criteria was a lack of clear titles/captions (n=26, 76.5%). While 94.1% (n=32) scored well regarding layout and design, only 73.5% (n=25) of websites used visual aids. Additionally, under word choice and style, only 10 (29.4%) websites used common, everyday language and only 9 (26.9%) appropriately used and defined medical words.

Based on website type, the mean understandability scores for academic institution, private practice, and health information publisher websites were 57.2±8.8%, 52.6±11.1%, and 54.3±15.3% (p=0.67), respectively. (Figure 3)

Search Rank

Google search rank was not associated with the online material's readability (rho: -0.07; p=0.69), understandability (rho: -0.02; p=0.93), and actionability (rho: -0.22; p=0.23) scores.

DISCUSSION

This study investigated the readability, understandability, and actionability of online resources regarding the diagnosis and treatment of total knee arthroplasty. While readability assessments on TKA have been performed previously, this is the first study to utilize the validated PEMAT algorithm to commonly accessed online TKA patient education materials.[12-15] Our results demonstrated that these resources were not sufficiently formulated for the American public based on readability, understandability, and actionability measures. Additionally, this study demonstrated no difference in measures between academic institution, private practice, or health information publisher websites. Overall, the findings of this study corroborates with other studies, confirming an existing concern on the lack of online patient materials that are both readily accessible to patients.[6,33-41] As there was no association between Google rank and any of the measures utilized in this study, patients must be made aware that "top hits" are not necessarily equivalent with highest quality or utility.

Though there are concerns about the quality and reliability of health information found online,[6,32,33,35,37,40-47] patient education material websites have been increasingly recognized as a crucial part of health literacy in the internet era.[6,46,47] Health literacy is the capacity to "obtain, process and understand basic health information and services needed to make appropriate health decisions."[48]

Table 1. Flesch-Kincaid Grade Ease

Score	School Level	Interpretation	Number of Websites (n, %)
100-90:	5th Grade	Easy to read and understand	0 (0%)
90-80:	6th Grade	Easy for conversational English consumers	0 (0%)
80-70:	7th Grade	Fairly easy to read	0 (0%)
70-60:	8th/9th Grade	Understood by most 13–15-year-olds	1 (2.9%)
60-50:	10th/12th Grade	Fairly difficult to read	8 (23.5%)
50-30:	College	Difficult to read	21 (61.8%)
30-0:	College Graduate	Very difficult to read (University graduate level)	4 (11.8%)

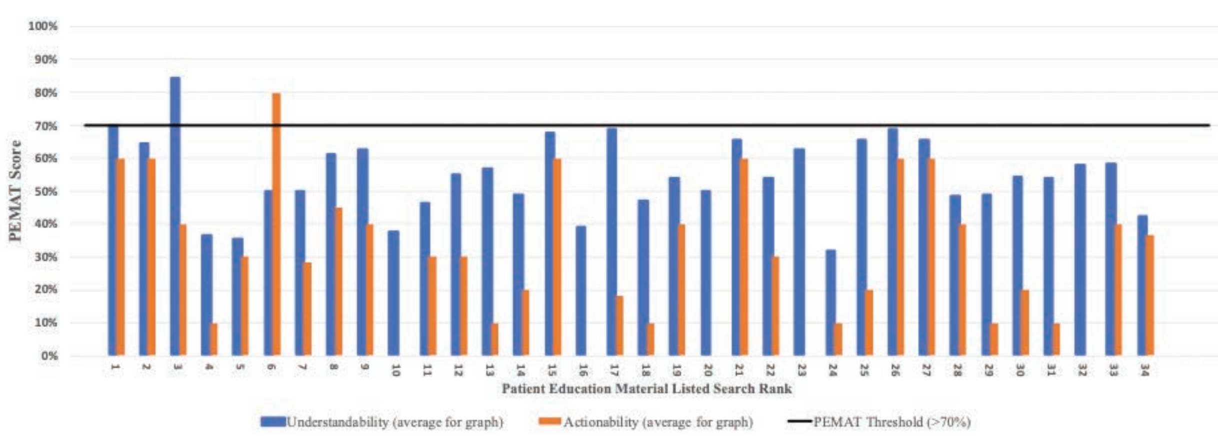

Figure 2. Knee Replacement Patient Educational Material PEMAT Scores

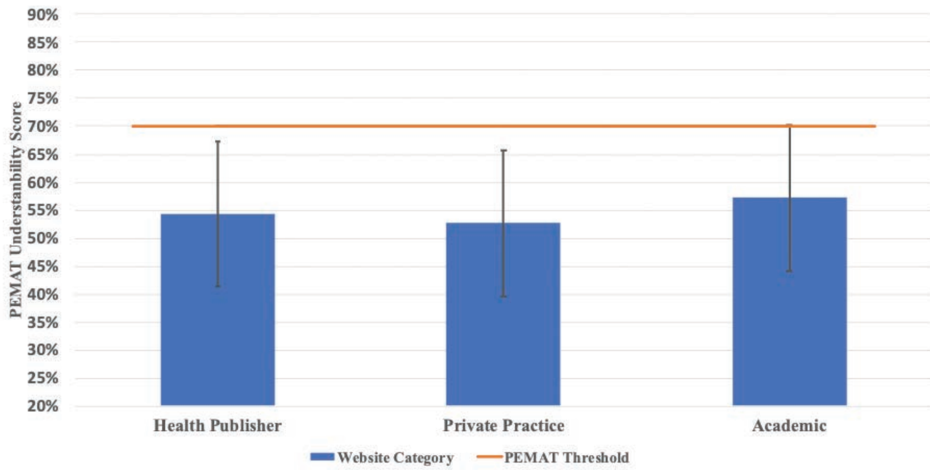

Figure 3. Mean Understandability per Website Category

While personal health literacy is a common public health concern,[5] it has been shown to have detrimental impacts on cost as well as patient outcomes including adherence, length of stay, and complication rates.[6,7,12,49,50] Therefore, it is crucial to investigate and emphasize the critical importance of health literacy in surgical specialties, especially those involving elective procedures.

Previous studies have demonstrated that health literacy impacts patient expectations following orthopedic procedures.[49-51] Hadden et al. investigated the effect of health literacy by evaluating 200 patients who underwent a total joint arthroplasty procedure (THA/TKA). They reported that patients with higher health literacy reported higher expectations for walking following the arthroplasty procedure, whereas patients with lower health literacy reported lower expectations.[50] Mendenez and colleagues reviewed audio-recordings of 84 upper extremity clinic visits. They found that patients with limited health literacy were less likely to engage in question-asking behavior during the visits with the surgeon.[52]

Considering best practices to optimize organizational health literacy is crucial in the orthopaedic field. This is especially true in patients undergoing TKA, as this patient population is consistently older, and therefore at a higher risk of not fully understanding basic health information and services.[46,50,53] Furthermore, limited health literacy results in an increased risk for the inability to make appropriate health decisions both preoperatively and postoperatively. As increasing numbers of older individuals access the internet for health information, organizations will need to strive to provide accurate, accessible, and high-quality online patient education materials that are easy to read and understand by the public.[5]

This current study demonstrated that the included websites scored inappropriately above the NIH and AMA's recommended reading level (6th grade reading level or lower).[12-15] Utilizing common readability index tools, none of the included websites were written below a 6th grade reading level, with all being at the 10th grade or higher. Previous studies analyzing the readability of TKA materials have reported similar results with readability scores too advanced for the general public.[13,15,54] A study by Schnaekel et al. found that the mean FKGL of nine arthroplasty materials were written at an 11th grade level.[13] Similarly, Bahadori et al. investigated the readability of arthroplasty-related smartphone apps.[15] The mean FKGL level was 9.7, with only 3 apps (20%) meeting the NIH/AHA readability threshold. Finally, a study investigating the readability of online patent education materials from major implant manufacturers found that the mean grade level was 11.3, with only 2.2% (n=13) of articles at the recommended 6th grade or lower reading level.[12]

While readability instruments measure the complexity of the vocabulary and syntax, it does not directly measure the understandability and actionability. Importantly, the ability to process key information (understandability) and identify key actions (actionability) are both crucial to the functional application of health literacy. Therefore, the PEMAT was established to compensate for this limitation of previous instruments utilized to measure patient education materials. Utilizing this reliable and valid instrument with a threshold of 70% for a text to be considered adequately understandable and actionable by readers.[5] Only 5.9% (n=2) of the included TKA materials met the threshold for understandability while only 2.9% (n=1) met the threshold for actionability. These scores are similar to those reported in other medical and surgical subspecialities.[10,22,23,27-29]

There has been a lack of literature comparing academic, private practice, and health publisher patient educational resources. Rozental and colleagues published a study that compared academic and private practice patient educational resources. They reported that although private practice websites were more complete and informative compared to academic websites, both lacked in many informative and patient education aspects.[55] However, they did not investigate if the resources were suitable to the general public or if they were designed in order for patients to understand the material and take action when necessary. This current study demonstrated no difference in PEMAT understandability scores.

The TKA patient resources included in this study have several themes when evaluating the understandability criteria that was missed. These included missing summaries, lack of visual aids, and unclear titles. Frequently missed actionability criteria included failing to address the patient directly, failing to breakdown instructions into explicit steps, and failing to provide a tangible action tool, such as a checklist. To address these deficits, website authors should consider incorporating PEMAT guidelines (accessible at https://www.ahrq.gov/ncepcr/tools/self-mgmt/pemat2.html) to ensure development of patient-appropriate resources.

Limitations

There are several limitations that should be considered. Due to constant algorithm variabilities, Google™ search results consistently change; therefore, the top 50 websites could be different at various times and geographic search locations. To minimize variability, the authors cleared all cookies and cache prior to the search. Another limitation includes the choice of search engine, search term, and country of origin, as these factors can influence the provided search results. However, the authors utilized the most common search engine with the most common term searched by the public. Limitations with readability measures should be addressed as well. The readability scores can be skewed by certain healthcare vocabulary. Words with increased characters, including "arthroplasty", can inherently increase the grade level of the content. Therefore, this aspect may inflate all the grading scores used in this study. However, readability is known to have its limitation in all healthcare and medical content.[56] Another limitation is the subjectivity of the PEMAT grading and implicit bias could not be fully eliminated. To limit this bias and subjectivity, two authors independently performed the grading, which demonstrated substantial interrater reliability, consistent with prior studies utilizing PEMAT.[31]

CONCLUSION

Overall, total knee arthroplasty online patient educational materials scored poorly with respect to readability, understandability, and actionability. None of the online resources scored at the AMA and NIH recommended reading level. Additionally, only 5.9% (n=2) and 2.9% (n=1) of websites met the threshold for adequate (≥70%) understandability and actionability. Optimization of the most accessible TKA websites is necessary and special attention on simplifying and/or defining key medical terms. Providers, health care institutions, and medical societies should lead this effort, as ensuring accessible, high-quality materials is a crucial component of patient care and overall outcomes. Additionally, while studies have demonstrated an association between mass media and health behavior,[57] further research is required to interpret the impact of online patient education materials on arthroplasty related health behaviors and treatment decision-making.

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IS THERE A TIME-DEPENDENT CONTAMINATION RISK TO OPEN SURGICAL TRAYS DURING TOTAL HIP AND KNEE ARTHROPLASTY?

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ABSTRACT

Background: Periprosthetic joint infection (PJI) after total hip and knee arthroplasty (TJA) is a devastating complication and intraoperative contamination can be a source for PJI. Currently, many measures are performed intraoperatively to reduce the risk of contamination. The primary purpose of this study was to determine if there is a time-dependent risk of contamination to open sterile surgical trays during TJA cases.

Methods: A prospective intraoperative culture swab study was performed. Standard sterile operating room trays without instruments were utilized as the experimental trays. These were opened simultaneously with all other surgical instrumentation needed for the procedure. These trays were left on an isolated Mayo stand next to the scrub tech's table and swabbed at 30-minute intervals. The first swab was performed immediately after opening all sets and the last swab performed on closure of the incision. A new section of the grid-lined tray was swabbed for each data point and the culture analysis was conducted by our institutions' microbiology lab for both quantitative and qualitative analysis. Operating suite room temperature and humidity data was also gathered.

Results: Twenty-three consecutive primary TJA cases in high air turnover rooms were included. 13 of the 23 (57%) cases demonstrated culture positive bacterial growth on at least one time point. Of the 109 independent swabs collected, 19 (17%) had bacterial growth. The most common bacterial species isolated was Staphylococcus epidermidis. There were no statistically significant associations between time (p= 0.35), operating room (OR) temperature (p = 0.99), and OR humidity (p = 0.07) and with bacterial growth.

Conclusion: In spite of isolating an organism in 57% of cases, we could not identify a time-dependent increase in bacterial contamination throughout our operative cases. We were unable to associate OR environmental temperature and humidity to bacterial growth.

Level of Evidence: II

Keywords: arthroplasty, operating room, bacteria, infection, knee, hip, pji, prosthetic joint infection

INTRODUCTION

Infection following total joint arthroplasty is a devastating complication. Contamination intraoperatively is thought to be a main cause of acute periprosthetic joint infections (PJI). PJI typically necessitates subsequent surgery, and has high morbidity to the patient.[1] This poses a very significant burden on both the patient and the treating surgeon to minimize infection risk.

Arthroplasty surgeons use protocols to mitigate contamination on the day of surgery including: performing operations in high air turnover rooms, clipping skin day of operation, meticulously prepping skin with both alcohol and non-alcohol preparations, carefully draping patients in a specific fashion, using occlusive iodine impregnated dressing to cover skin before incision, wearing hooded gowns, changing gloves immediately after draping, avoiding OR traffic, and operating efficiently so as to minimize incision time.[2] While intuitively these steps should lower potential contamination, little data have been published with regards to these steps reducing postoperative infection. Further, infection rates have remained relatively constant despite these steps.[2] There have been many studies that have investigated intraoperative risk factors associated with PJI. Time of procedure has been shown by multiple studies to be associated with the development of PJI.[3,4] However, these studies do not specify where the source of the infection originated from. It is reasonable to assume that longer operative times lead to more opportunities for contamination of the sterile field, but there is limited data on if surgical trays are the source of contamination leading to PJI.

We sought to identify additional potential interventions that may decrease the infectious risk to patients.

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

Sources of Funding: Dedicated department research funding was used to fund this project.

One variable that was identified was selective opening of operating room trays based upon when they are needed in the procedure. Previous studies have shown that there is a time dependent rate of contamination of trays intraoperatively, but this has been specific to spine fusion procedures.[5-7] Little to no data has been published specific to joint arthroplasty, a unique surgical procedure in which deep infection has particularly devastating consequences including potential need for a two-stage revision arthroplasty and long-term IV antibiotics. It is uncertain as to if contamination of trays occurs in arthroplasty rooms, rooms that already take precautions to reduce air contamination and potential settling of debris on open surgical trays. The purpose of this study was to swab and culture this potential contamination site and determine if delaying the opening of trays until they are necessary can help to mitigate bacterial contamination loads. Our hypothesis is that a temporal relationship between bacterial contamination of surgical trays and case time will be identified.

METHODS

Control Set Preparation and Swabbing

After obtaining institutional review board exemption status, we selected one senior total joint arthroplasty surgeon and obtained culture results from his operating room. Twenty-three consecutive primary total joint arthroplasty cases were included in this analysis. Standard sterile operating room trays without instruments were utilized. These were opened simultaneously with all other surgical instrumentation needed for the procedure. These trays were left on an isolated Mayo stand next to the scrub nurse's table and swabbed at 30-minute increments by a research assistant not actively scrubbed into the case. The first swab was performed immediately after opening all sets and the last swab performed on closure of the incision. A new section of the grid-lined tray was swabbed for each data point and the culture analysis was conducted by our institutions' microbiology lab for both quantitative and qualitative analysis. Operating suite room temperature and humidity data was also gathered.

Microbiological Analysis

For the bacterial analysis portion, we utilized a modified protocol described by Shams et al.[8] The samples were collected using the BD ESwab collection kit (Becton Dickenson) The swab was removed and moistened with sterile saline. The tray samples were collected by applying gentle but firm pressure using back and forth vertical S-strokes with one side of the swab and back and forth horizontal S-strokes with the other side of the swab, using templates to standardize surface sampling. After placing the swabs into collection tubes, breaking

Table 1. Outlines Each Surgical Case With the Species of Bacteria Found

Case #	T1 (CFU)	T2 (CFU)	T3 (CFU)	T4 (CFU)	T5 (CFU)
1	*NGTD	NGTD	1000 /10 (M. *luteus*)	NGTD	10
2	NGTD	NGTD	NGTD	100 (M. *oleivorans*) /10 (S. *capitis*)	NGTD
3	NGTD	NGTD	NGTD	NGTD	NGTD
4	NGTD	100 (S. *acidaminiphila)* /20	**NQ (S *hominis*)	NGTD	NGTD
5	NGTD	NGTD	NGTD	NGTD	10 (C. *tuberculosis*)
6	NGTD	NQ (S. *epidermidis*)	NGTD	NGTD	NGTD
7	NGTD	NGTD	NGTD	NGTD	
8	NGTD	NGTD	NQ	NGTD	NGTD
9	NGTD	NGTD	NGTD	NGTD	NGTD
10	NGTD	NGTD	NGTD	NGTD	NGTD
11	NGTD	NGTD	NGTD	NGTD	NGTD
12	NGTD	NQ (M. *testaceum*)	NGTD	NGTD	NGTD
13	NGTD	NGTD	NQ (S. *epi)*	10/10 (C. *jeikeium*)	NGTD
14	NGTD	10 (S. *capitis)*	NQ (S. *hominis)*	NQ (S. *epi*)	NGTD
15	NGTD	NGTD	NGTD	NGTD	NGTD
16	NGTD	NGTD	NGTD	NGTD	NGTD
17	NGTD	NGTD	NGTD	NQ (M. *luteus*)	
18	NGTD	NGTD	NGTD	NGTD	
19	NGTD	NGTD	NGTD	NGTD	NGTD
20	NGTD	NGTD	NGTD	NGTD	
21	NGTD	NQ (S *epidermidis*)	NGTD	NGTD	
22	30 (M. *luteus*)	NGTD	NGTD	NGTD	NGTD
23	10 (S *epidermidis*) /10 (S. *hominis*)	NQ (S. *epidermidis*)	NGTD	NGTD	

*No Growth to Date (Ngtd)
**Nq Represents That Bacteria Was Noted on the Culture Analysis, But These Were Unable to be Quantified.

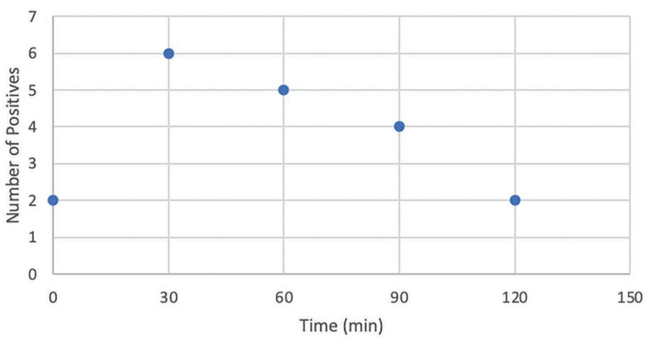

Figure 1. Frequency of positive cultures as a function of time.

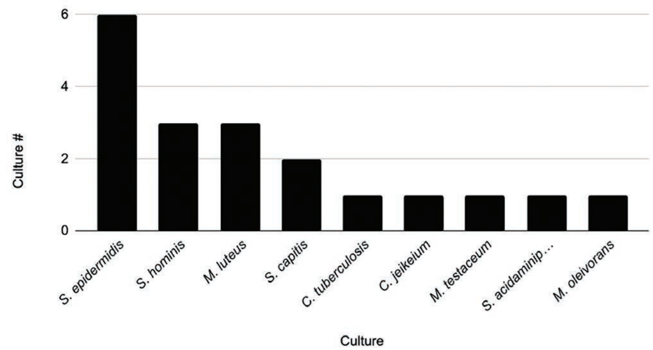

Figure 2. Frequency of isolated bacterial contaminants.

off the shafts and replacing the caps, the swabs were delivered to the laboratory, refrigerated, and processed within 24 hours. The tubes were vortexed for 5 seconds.

The samples were spread 100μL each of a 1:10 and 1:100 dilution in Tryptic soy broth (TSB) per University of Iowa micro lab standard operating protocol in both a non-selective and selective agar using an L-shaped cell spreader. The agar plates were incubated at 35° for 48 hours, and the colonies counted and recorded on plates with between 20 and 250 colonies. The number of colony forming units (CFUs) per sample, based on the dilutions performed were recorded. The isolated organisms were identified to species level using the MALDI-TOF mass spectrometry (Bruker). The isolates were banked at -80 degrees and subsequently destroyed after 48 hours of culture analysis.

Statistical Analysis

Rates of contamination was reported with descriptive statistics. This was then analyzed from a statistical perspective with Mann-Whitney U test and Wilcoxon Sign Ranks tests. Room temperature and humidity were separately analyzed to evaluate for significance. Categorical variables were evaluated with chi-square test or Fisher's exact test. A p-value < 0.05 was considered statistically significant.

RESULTS

Twenty-three consecutive total joint arthroplasty cases from one orthopaedic surgeon were analyzed with swabs sent for culture and quantitative analysis. In addition to culture results, additional data points including room temperature and humidity were also analyzed. The complete data sets are included in Table 1. The numerical values represent the number of colony forming units observed under microscopic analysis. In some of these analyses, there were two separate bacterial colonies that were noted, and these are noted by the duplicate measurements. Additionally, the bacterial colonies that speciated out on culture analysis are also included. For some of the cases, there are only four data points that are included implying that the case had been completed in less than 120 minutes.

Of these 23 cases, 13 of the cases (57%) demonstrated culture positive bacterial growth on at least one time point. The time-points in which each positive culture was obtained and detected is outlined in Figure 1, with the highest number of positive cultures being at 30 minutes. Of the 109 independent swabs collected, 19 (17%) had bacterial growth. The most common bacterial species isolated was *Staphylococcus epidermidis*. OR temperatures varied from 62 to 69 F and humidity varied from 38 to 55% relative humidity. There were no statistically significant associations between time (p= 0.35), OR temperature (p = 0.99), and OR humidity (p = 0.07) and bacterial growth.

As outlined in Figure 2, our research team found that the most commonly isolated species in our study was S. epidermidis but this was only present in 6 cultures out of 109. The next most common bacteria isolated was *Staphylococcus hominis* and *Micrococcus luteus* and was present in 3 of the 109 cultures. Other bacteria isolated were *Microbacterium oleivorans*, *Stenotrophonomonas acidaminiphila*, *Corynebacterium tuberculosteatricum*, *Microbacterium testaeum*, and *Corynebacterium jeikeium* each of which were only isolated in 1 culture of the 109. As for the quantitative number of bacteria grown, the most CFU found were 1000, and the least was 10.

DISCUSSION

The purpose of this study was to identify a temporal relationship of case length and OR tray contamination. Our hypothesis was that longer case length would be associated with higher frequency of OR tray contamination. Although, there was contamination of OR trays in 57% of cases, it did not have a temporal relationship. This went against our original hypothesis and previous studies that have shown time dependent increases in bacterial contamination as a basis of time spent in the operating rooms. Despite variances in operating room temperature and relative humidity, there was no association with presence of bacterial growth or bacterial load. Additional data is needed to determine if a temporal relationship exists for OR tray contamination in total joint arthroplasty cases.

Dalstrom et al. did reveal the time dependent nature of tray contamination in a controlled experimental setting and did show that covering the trays with a surgical towel was an effective way to prevent contamination. With other studies displaying the association with increased surgical time and infection rates we were surprised to find no association between time and contamination.[9,10] Although there is an abundance of data that has found the association between increased operating time and the prevalence of PJI, there is the need for investigation for further interventions to lower the rate of PJI.

There have been studies that have not shown a time-dependent risk for surgical site infections, specifically for total hip arthroplasty.[11] This suggests that there may be a difference in the risk of longer procedures and the risk of contamination for total knee arthroplasty and total hip arthroplasty. Regardless, it is known bacterial contamination of sterile surfaces occurs during total knee and hip arthroplasty, and there have been multiple interventions that have improved contamination rates. It is still yet to be discovered the if there is a relationship between surgical tray contamination and the rate of PJI.

Further investigation is warranted for the time-relationship between length of surgical case and contamination of sterile OR trays. Our data suggest that opening all surgical trays at the beginning of the case does not have a temporal relationship with contamination and remains to be a safe practice for total knee and hip arthroplasty.

Limitations

This study was cut down from the original cohort size of 100 patients based upon a lack of a time dependent relationship between time in OR and bacterial contamination in preliminary data analysis during our preliminary data analysis. If this had been carried out to completion, it is possible that a time dependent relationship could have been observed. An additional possible weakness is the fact that cultures were limited to 48 hours to decrease chance of contaminants. This was based upon our institutions' microbiology policy and also based upon similar studies conducted previously.[12] There is always a chance that some species might have been isolated if culture were kept for longer time periods.

CONCLUSION

In summary, this study did not find a time-dependent relationship with contamination or OR trays during a TJA. Additionally, operating room temperature and humidity did not correlate with detection of tray contamination. The bacteria that were isolated also are known to be common causes of PJI. Investigating the relationship between surgical tray contamination and rate of PJI remains necessary. Also, additional data is warranted regarding staggered tray opening and rate of contamination during total knee and hip arthroplasty to ensure a change in practice is not warranted.

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PATIENT RESILIENCE INFLUENCES OPIOID CONSUMPTION IN PRIMARY TOTAL JOINT ARTHROPLASTY PATIENTS

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ABSTRACT

Background: Resilience and depression may influence opioid consumption in patients undergoing primary hip and knee arthroplasty (TJA); however, data evaluating these relationships are limited.

Methods: We retrospectively identified 119 patients undergoing TJA who completed preoperative questionnaires to measure resilience (Brief Resilience Scale) and depression (PHQ-9) from 2017 to 2018 at a single institution. Patients were stratified into high, normal, and low resilience groups as well as no, mild, and major depression groups. Opioid use was recorded in morphine milligram equivalents (MMEs). Nonparametric statistical testing was performed with significance level at P < 0.05.

Results: Higher levels of resilience correlated with less postoperative inpatient opioid use (P = 0.003). Patients with high resilience were less likely to use preoperative opioids compared to those with low resilience (OR = 6.08, 95% CI [1.2-30.5]). There was no difference in postoperative outpatient opioid prescriptions between resilience groups. Lower levels of depression correlated with less postoperative inpatient opioid use, though this did not reach statistical significance (P = 0.058). Additionally, there was no significant difference in preoperative opioid use or postoperative outpatient opioid prescriptions between depression groups.

Conclusion: Patients with higher levels of resilience are less likely to use opioids before TJA and utilize lower amounts of opioids while inpatient following surgery. Depression correlated with higher postoperative inpatient opioid use; however, the present findings regarding this relationship are inconclusive. Resilience is a psychological trait that may impact opioid use in patients undergoing TJA and should be viewed as a modifiable risk factor.

Level of Evidence: III

Keywords: resilience, opioid, total joint arthroplasty

INTRODUCTION

Patients undergoing total joint arthroplasty (TJA) have high rates of opioid consumption pre- and postoperatively. Approximately 40% of patients undergoing TJA fill an opioid prescription in the 3 months preceding surgery.[1,2] Over 60% of patients fill an opioid prescription within the first month after surgery; 18-25% of patients continue to fill opioid prescriptions at 3 months postoperatively, and approximately 15% will fill an opioid prescription at 1 year following TJA.[1,2]

Multiple risk factors for persistent opioid consumption following TJA have been identified, including younger age, female sex, preoperative opioid use, and mental health disorders including depression and anxiety.[1-5] Additionally, preoperative opioid use has been linked to greater postoperative inpatient opioid use.[6] Presence of more than one of these characteristics may result in a synergistic effect begetting significant increases in duration and quantity of opioid consumption following TJA.[7] Recently, the influence of psychologic traits, such as a resilience, on pain perception following orthopedic surgery has been examined.[8,9] Helmhorst et al.[8] went as far as proclaiming resilience to be "the ultimate analgesic after musculoskeletal surgery." However, data regarding the influence of resilience on opioid consumption after TJA is limited.

The purpose of the present study to investigate the potential relationship between resilience, depression, and duration and quantity of opioid consumption in patients undergoing elective primary TJA.

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Disclosures: JQT and QA have no conflicts of interest related to this study. CNC has the following disclosures: J of Arthroplasty: Editorial or governing board. NON has the following disclosures: MicroPort, Link, Smith & Nephew: Paid consultant; DePuy, Wright Medical, Smith & Nephew: Research support; MAOA: Board or committee member. JEO has the following disclosures: DePuy: Paid consultant, research support; AAHKS: Board or committee member. TSB has the following disclosures: PLOS One: Editorial or governing board; AAHKS: Board or committee member.
Sources of Funding: No sources of funding declared.

Instructions: Use the following scale and circle one number for each statement to indicate how much you disagree or agree with each of the statements.

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

1. I tend to bounce back quickly after hard times..	1	2	3	4	5
2. I have a hard time making it through stressful events……………………………………	1	2	3	4	5
3. It does not take me long to recover from a stressful event……………………………………	1	2	3	4	5
4. It is hard for me to snap back when something bad happens………………………..	1	2	3	4	5
5. I usually come through difficult times with little trouble………………………………	1	2	3	4	5
6. I tend to take a long time to get over set-backs in my life…………………………….	1	2	3	4	5

Figure 1. Brief Resilience Scale

NAME:________________________ DATE:____________

Over the last *2 weeks*, how often have you been bothered by any of the following problems? *(use "✓" to indicate your answer)*	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself—or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed. Or the opposite—being so figety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead, or of hurting yourself	0	1	2	3
add columns		+	+	
(Healthcare professional: For interpretation of TOTAL, please refer to accompanying scoring card). TOTAL:				

10. If you checked off *any problems*, how *difficult* have these problems made it for you to do your work, take care of things at home, or get along with other people?	Not difficult at all	______
	Somewhat difficult	______
	Very difficult	______
	Extremely difficult	______

Figure 2. Patient Health Questionnaire-9

METHODS

Institutional Review Board approval was obtained. A retrospective chart review of patients who underwent elective primary total hip arthroplasty (THA) or total knee arthroplasty (TKA) by one of three fellowship-trained arthroplasty surgeons from January 1, 2018 to December 31, 2018 was performed. Patients were identified using Current Procedural Terminology (CPT) codes 27447 and 27130. Inclusion criteria were patients ≥18 years of age undergoing primary THA or TKA, completion of preoperative questionnaires including the Brief Resilience Scale (BRS) and Patient Health Questionnaire-9 (PHQ-9) that were administered from June through August of 2017, and a minimum follow-up of 3 months. Exclusion criteria were patients who underwent revision or reoperations within 90 days as well as chronic opioid users (defined as those with at least six consecutive months of preoperative opioid usage or who had seen a chronic pain specialist) due to potential factors unrelated to hip or knee pain possibly influencing opioid usage.

Opioid use was recorded in morphine milligram equivalents (MMEs), which were calculated using an opioid equianalgesic chart.[10] Opioid consumption was identified at five time points: preoperative, perioperative, intraoperative, inpatient postoperative, and outpatient postoperative. Preoperative was defined as within three months before surgery. Perioperative was defined as the time from admission to incision. Intraoperative was defined as the time from incision to leaving the operating room. Inpatient postoperative was defined as the time from leaving the operating room to hospital discharge. Outpatient postoperative was defined as the time from hospital discharge to three months following surgery.

Prolonged preoperative opioid consumption was defined as at least six continuous months of opioid use at any time before surgery. Number of patient call-ins pertaining to pain management or opioid refills were recorded, as were length of hospital stay (in hours) and type of anesthesia.

Study Instruments

Instruments administered to patients included the BRS to measure resilience and the PHQ-9 to measure depression. BRS (Figure 1) is a six-item questionnaire that has demonstrated positive correlation with social support and optimism, negative correlation with self-blame and pessimism, and successful internal consistency and test-retest reliability. The score ranges from 1.00-5.00 and can be stratified into three groups: low resilience (1.00-2.99), normal resilience (3.00-4.30), and high resilience (4.31-5.00).[11,12] PHQ-9 scale (Figure 2) has been proven as a reliable and valid measure of both diagnosing and assessing the severity of depression symptoms. The score ranges from 0-27 and can be stratified into three groups: no depression (0-4), mild depression (5-9), and major depression (10-27).[13,14]

Study Cohort

Included in the time period were 119 total patients, 58 TKA patients and 61 THA patients. Demographics

Table 1. Demographics for Patients by Resilience Groups

	High resilience (n = 43)	Normal resilience (n = 67)	Low resilience (n = 9)	P-value
Age (median, IQR)	65 (54-72)	65 (55-69)	61 (60-63)	0.583
Gender (% female)	39.5%	56.7%	55.5%	0.211
Race (% Caucasian)	97.6%	97.0%	77.7%	0.056
BMI (median, IQR)	32.30 (27.93-37.54)	32.17 (28.46-37.15)	32.93 (25.12-34.37)	0.819
CCI (median, IQR)	0 (0-2)	1 (0-2)	1 (1-4)	0.126
Preop opioid use (% yes)	11.6%	19.4%	44.4%	0.059
Prolonged opioid use (% yes)	23.2%	23.8%	33.3%	0.806

SD, standard deviation; BMI, body mass index; CCI, Charlson comorbidity index.

Table 2. Demographics for Patients by Depression Groups

	No depression (n=77)	Mild depression (n = 20)	Major depression (n = 22)	P-value
Age median, IQR)	66 (58-71)	59.5 (51.5-69)	62 (52-65)	0.074
Gender (% female)	49.3%	55.0%	50.0%	0.929
Race (% Caucasian)	97.4%	100.0%	86.3%	0.094
BMI (median, IQR)	31.63 (28.28-35.26)	30.26 (26.23-37.39)	34.14 (31.82-40.12)	0.109
CCI (median, IQR)	0 (0-2)	1 (0-2.5)	0.5 (0-2)	0.330
Preop opioid use (% yes)	18.1%	15.0%	22.7%	0.834
Prolonged opioid use (% yes)	20.7%	30.0%	31.8%	0.428

IQR, interquartile range; BMI, body mass index; CCI, Charlson comorbidity index.

Table 3. Perioperative Inpatient and Postoperative Opioid Use by Resilience Groups

	High resilience (n = 43)	Normal resilience (n = 67)	Low resilience (n = 9)	P-value
Periop opioid (% yes)	39.5%	49.2%	44.4%	0.601
Intraop opioid (% yes)	60.4%	62.6%	55.5%	0.908
Anesthesia type (%)				0.586
General	23.2%	26.8%	11.1%	
Regional Converted to General	9.3%	4.4%	11.1%	
Regional	25.5%	26.8%	44.4%	
Regional + Monitored	41.8%	41.7%	33.3%	
Postop inpatient, MME/h (median, IQR)	2.12 (0.93-3.40)	2.91 (1.87-3.78)	3.11 (2.58-3.85)	0.053
High vs. Normal				.051
High vs. Low				.035
Normal vs. Low				.430
Length of stay, hours (median, IQR)	27 (24-47)	26 (24-47)	28 (21-47)	0.956
Initial postop prescription, MME (median, IQR)	500 (480-500)	500 (500-500)	500 (320-500)	0.402
Total postop refill, MME (median, IQR)	0 (0-300)	0 (0-200)	300 (0-600)	0.158
Number of call-ins (median, IQR)	0 (0-1)	0 (0-1)	1 (0-2)	0.319

MME/h, morphine milligram equivalent/hour; MME, morphine milligram equivalent; IQR, interquartile range.

including age, sex, race, and body mass index (BMI) were recorded. Charlson Comorbidity Index (CCI) was also calculated for each patient (Table 1 and Table 2). Preoperatively, high resilience was identified in 36% of patients, normal resilience in 56%, and low resilience in 8%. Major depression was identified in 18% of patients and mild depression in 17%.

Statistical Analysis

We used the Spearman's rank-order correlation test to evaluate correlations between BRS, PHQ-9, and opioid MME's. The Wilcoxon sum rank test and Kruskal-Wallis test were used to compare continuous scores between different groups. Chi-square statistics and the Fischer exact test were used to compare categorical variables. All statistical analysis was done by SAS 9.4 (SAS Institute Inc., Cary, NC, USA) with significant level at $P < 0.05$.

RESULTS

Patients with high resilience were significantly less likely to use preoperative opioids within 3 months of surgery compared to those with low resilience (OR = 6.08, 95% CI [1.21-30.47]) (Table 3). Further, patients

Table 4. Perioperative Inpatient and Postoperative Opioid Use by Depression Groups

	No depression (n=77)	Mild depression (n = 20)	Major depression (n = 22)	P-value
Periop opioid (% yes)	41.5%	45.0%	59.0%	0.366
Intraop opioid (% yes)	59.7%	50.0%	77.2%	0.807
Anesthesia type (%)				0.899
General	22.0%	20.0%	36.3%	
Regional Converted to General	6.4%	5.0%	9.0%	
Regional	27.2%	35.0%	22.7%	
Regional + Monitored	44.1%	40.0%	31.8%	
Postop inpatient, MME/h (median, IQR)	2.58 (1.44-3.57)	3.02 (1.95-4.03)	3.16 (1.91-3.57)	0.418
Length of stay, hours (median, IQR)	26 (24-42)	26.5 (24-51.5)	25 (21-70)	0.870
Initial postop prescription, MME (median, IQR)	500 (500-500)	500 (500-500)	500 (500-500)	0.972
Total postop refill, MME (median, IQR)	0 (0-300)	0 (0-262.5)	0 (0-0)	0.289
Number of call-ins (median, IQR)	0 (0-1)	0 (0-1)	0 (0-1)	0.946

MME/h, morphine milligram equivalent/hour; MME, morphine milligram equivalent; IQR, interquartile range.

Table 5. Correlations between Resilience, Depression, and Postoperative Opioid Use

Variable		Correlation (Spearman)	P-value
BRS vs.			
	Postop inpatient, MME/h	-0.26	0.003
	Initial postop prescription in MME	-0.07	0.427
	Total postop refill in MME	-0.06	0.480
PHQ-9 vs.			
	Postop inpatient, MME/h	+0.17	0.058
	Initial postop prescription in MME	-0.02	0.826
	Total postop refill in MME	-0.08	0.372

BRS, brief resilience scale; MME/h, morphine milligram equivalent/hour; MME, morphine milligram equivalent ; PHQ-9, patient health questionnaire-9.

with low resilience tended to have higher rates of opioid use relative to those with normal resilience, who had higher rates than those with high resilience; this closely reached significance (44.4% vs. 19.4% vs. 11.6%, respectively, P = 0.059). There was no significant difference in rates of prolonged preoperative opioid use between patients in high resilience, normal resilience, and low resilience groups (23.2% vs. 23.8% vs. 33.3%, P = 0.806) (Table 1).

The percentages of patients who received opioids in the perioperative (39.5% high resilience, 49.2% normal resilience, 44.4% low resilience, P = 0.601) and intraoperative (60.4% high, 62.6% normal, 55.5% low, P = 0.908) periods were not significantly different between resilience groups (Table 3). During the inpatient postoperative period, patients with high resilience consumed significantly fewer opioids than patients with low resilience (2.12 MME/h vs. 3.11 MME/h, P = 0.035) (Table 3). Similarly, higher preoperative BRS scores strongly correlated with decreased inpatient opioid use (r = -.026, P = 0.003) (Table 5).

No significant differences existed between resilience groups for median postoperative outpatient opioid MME's for either initial prescriptions (500 high resilience, 500 normal resilience, 500 low resilience, P = 0.402) or total refills (0 high, 0 normal, 300 low, P = 0.158). Also, length of stay (P = 0.956), number of call-ins (P = 0.319), and anesthesia type (P = 0.586) did not significantly differ between groups (Table 3).

When comparing patients by depression symptoms, major, mild, and no depression groups did not demonstrate significantly different preoperative, perioperative, or intraoperative opioid consumption (Tables 2, 4). Lower preoperative PHQ9-9 correlated with less postoperative inpatient opioid use (r = +.17, P = 0.058) (Table 5). No significant differences existed between depression groups for initial postoperative prescription MME (P = 0.972), postoperative outpatient refill MME (P = 0.289), length of stay (P = 0.870), number of call-ins (P = 0.946), or anesthesia type (P = 0.899) (Table 4).

DISCUSSION

Primary total hip and knee arthroplasty are common elective orthopedic procedures with high opioid usage. Therefore, it is imperative to identify risk factors associated with increased opioid consumption in order to prevent abuse, addiction, and overdose. Data evaluating the effects of mental health disorders, such as depression, and psychological traits, such as resilience, are limited.

We found that resilience contributes to both pre- and postoperative opioid use in patients undergoing TJA. Patients with low resilience were six times more likely to use opioids in the months leading up to surgery compared to those with high resilience. Additionally, higher baseline resilience scores correlated with decreased inpatient opioid use after surgery (P = 0.003). These trends align with literature that shows that preoperative opioid use is a risk factor for higher postoperative inpatient opioid use.[6] While we did not find that patients with major or mild depression significantly used more opioids than those without depression, the presence of more depressive symptoms correlated with more postoperative inpatient use (P = 0.058). Though this did not reach statistical significance, it may have with a greater sample size and still demonstrates a clinically important point that depression may affect opioid usage.

Current literature proves that preoperative opioid consumption before TJAs negatively impacts outcomes. Studies have shown that patients who use opioids before surgery have worse postoperative pain and function as well as higher rates of nonhome discharge, 30-day readmission, and periprosthetic joint infections. Additionally, preoperative opioid users are more likely to have prolonged postoperative opioid use and require TJA revision surgery.[15-19] Postoperative opioid use has proven similarly detrimental. Adverse effects from postoperative inpatient opioids lead to increased complications, longer length of stay, and higher rates of nonhome discharge.[20] Therefore, the present study proves valuable since findings showed that patients with lower resilience are more likely to use preoperative opioids and have greater postoperative opioid consumption.

This study has several limitations. First, as a retrospective study, it depends on accurate documentation of medical records, which may not be fully reliable. Second, this study could only analyze opioid prescriptions prescribed by providers at our institution, so patients may have had others from outside institutions not included. Further, analyzing prescriptions filled may not be the most accurate way to measure opioid consumption since patients don't necessarily utilize their prescriptions. Finally, the sample size was limited, and future studies with larger patient populations from multiple institutions would provide more concrete, generalizable results.

In conclusion, the present study demonstrates that psychological traits, such as resilience, and possibly mental health disorders, such as depression, may influence opioid consumption in patients undergoing total joint arthroplasty. Patients with higher resilience utilize fewer opioids before and after surgery, which may result in improved outcomes following surgery. Furthermore, patients who scored higher on the depression scale trended toward higher opioid use while inpatient after surgery; however, our study lacked enough power to definitively conclude the presence or absence of a relationship between depression and opioid usage. Though some work has expressed that resilience can be improved,[21-22] future studies are still needed to understand potential interventions for improving resilience prior to elective TJA in order to minimize patient opioid use and optimize patient outcomes.

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EFFICIENCY BENEFITS OF LIVE FLUOROSCOPY IN HAND CLINICS

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ABSTRACT

Background: Postoperative imaging protocols for common hand procedures typically consist of 2-3 plain radiographs at defined intervals dependent on the surgery. Radiographs typically verify reduction, hardware position, and/or evaluate for complications, but also generate costs and alterations in clinic flow. We hypothesize the use of mini-fluoroscopic images will provide comparable clinical data with less cost and improved clinic flow. The objectives of the study were to determine if clinic-based fluoroscopic imaging is feasible for post-operative hand patients and if fluoroscopic imaging results in improved clinic flow (less waiting and more time with provider) and theoretical cost savings using mini-fluoroscopy instead of traditional radiographs.

Methods: With institutional review board exemption, the prospective use of mini-fluoroscopic evaluation of post-operative hand surgery patients was compared to traditional radiographs using time-based cohort analysis. Patients who underwent percutaneous pinning of phalanges/metacarpals, ORIF (open reduction and internal fixation) of phalanges/metacarpals or ORIF of distal radius fractures were included to evaluate common hand surgery patients. Each cohort consisted of a 3-month data collection period with prospective measures of clinic flow (wait times, appointment times, time with provider) and estimated cost compared between the groups.

Results: 24 patients met inclusion criteria for data analysis; 11 patients in the mini-fluoroscopy group and 13 patients in the traditional radiograph group. Appointments using mini-fluoroscopy were 24 minutes shorter (53 vs 77 minutes) from patient check-in to check out time. Check-in time to rooming was 10 minutes quicker (9 vs. 19 minutes) using mini-fluoroscopy. Traditional hand radiographs have a face-value of $734 per appointment/series for a total theoretical savings of $9540 (n=13).

Conclusion: The use of mini-fluoroscopy during orthopedic hand surgery post-operative visits provides a feasible, quick, cost effective way to evaluate patients postoperatively, ultimately, resulting in quicker patient appointments and greater time spent with providers.

Level of Evidence: III

Keywords: fluoroscopy, hand surgery, radiograph, mini c-arm

INTRODUCTION

The use of mini C-arm fluoroscopy is increasingly utilized part of orthopedic surgery, especially in hand practices. Mini C-arm use in the operating room and in the Emergency Department has been well documented with numerous benefits including real-time feedback on anatomy and a potential decrease in radiation exposure during procedures as compared to conventional radiographs, however the actual radiation exposure during mini C-arm use remains debated.[1-3] In addition to the technical aspects of providing medical and surgical care to patients, patient satisfaction as well as patient access to care has become increasingly important in recent years. A major factor in patient satisfaction relates to patient wait times and patient flow in clinic.[4,5]

Postoperative imaging protocols for common hand procedures typically consist of two or three plain radiographs at defined intervals depending on the operative procedure. These images are typically used to verify reduction, placement of hardware, and/or evaluate for post-operative complications, but also generate potential costs and alterations in clinic flow due to travel to radiology for x-rays. The cost associated with routine evaluation with standard-view plain radiographs following orthopedic procedures has been called into question due to the absence of significant clinical findings on the majority of these standard radiographs.[6] The use of mini C-arm in an outpatient orthopedic pediatric clinic has already been reported and lauded as a significant improvement in both quality and efficiency of outpatient pediatric care.[7]

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

Sources of Funding: No sources of funding declared.

The objective of this study was to evaluate the use of a mini C-arm in an outpatient orthopedic hand clinic at a large tertiary Medical Center. We sought to determine if the use of live fluoroscopic imaging in outpatient postoperative follow-up visits was feasible as well as determine whether this resulted in improved clinic flow and cost savings associated with the use of live fluoroscopic imaging in an outpatient hand clinic.

METHODS

Institutional Review Board approval/exemption was obtained for the prospective use of mini-fluoroscopy in the evaluation of post-operative patients within the orthopedic surgery hand clinic. Postoperative hand surgery patients were included in this evaluation as these patients routinely receive standard view plain radiographs as part of their surgical follow up. Inclusion criteria included: Adult patients (age >18 years) who underwent percutaneous pinning of the phalanges/metacarpals, open reduction and internal fixation (ORIF) of the phalanges/metacarpals or ORIF of distal radius fractures. Pediatric patients were excluded secondary to patient behavioral compliance that may affect the overall consistency of results between groups. Over a 6-month period, two 3-month, sequential periods comprised the comparison cohorts: the first 3 months representing traditional radiographs obtained for post-operative patients and the following 3 months utilizing post-operative patients evaluated with a mini C-arm (Orthoscan, Scottsdale, AZ) as part of their routine postoperative follow-up. The standard radiograph versus mini C-arm groups were compared with regard to clinic flow which included wait times, overall appointment duration, and time spent with treating provider. Additionally, groups were compared regarding estimated cost of plain radiographs versus mini C-arm imaging during their clinic appointment. Findings in each group were compared using a student's T-test with a threshold of $P = 0.05$ set for statistical significance.

RESULTS

Time Savings Analysis

A total of 24 patients met inclusion criteria within the data collection time period; 13 patients in the traditional plain radiograph group and 11 patients in the mini-fluoroscopy group. Time from check-in at the reception desk to check-out was 24 minutes shorter in the mini-fluoroscopy group when compared to the traditional radiograph group (53 minutes versus 77 minutes, $P=0.04$). Check-in time to ready-for-provider time was 10 minutes quicker in the mini-fluoroscopy group compared to the traditional radiograph group (9 minutes versus 19 minutes, $P=0.04$). The time waiting in the exam room for the provider was slightly improved in the fluoroscopy group however this did not meet statistical significance when compared to traditional radiographs (1 minute versus 4 minutes, $P>0.05$). These findings are summarized in Table 1.

Table 1. Average Clinic Times

Time Metric	Standard Radio-graphs (n=13)	Mini-C Arm (n=11)	Difference	P-Value
Check-in to Check-out	77 minutes	53 minutes	-24 minutes	0.04
Ready-for-provider	19 minutes	9 minutes	-10 minutes	0.04
Exam Room Wait-time	4 minutes	1 minutes	-3 minutes	0.29

Amount of time required for completion of each state of between stages of a clinical encounter between the standard radiograph and Mini-C Arm groups.

Cost Savings Analysis

At the study institution, a standard radiograph series of the hand includes a PA and lateral view. The billed, non-negotiated, rate for these radiographs was $734 dollars during the study period. This billed charge represents and includes overhead cost, technologist and ancillary labor costs as well as the radiologist interpretation fee. The 13 patients in the traditional radiographs generated a billed cost of $9542 as part of the post-operative clinic evaluation. The only cost to the mini-c group would have been attributed to overhead equipment cost which, in this evaluation, incurred no cost secondary to donated equipment during the study period. Mini c-arm imaging systems vary widely in cost but are acquired with an initial $25,000 to $60,000 up-front cost. Image storage on hospital secured servers represents a relatively minor potential cost of $270 per year per terabyte of data.

DISCUSSION

This study identified that there were significant time reductions in the clinic visit improving efficiency with the use of mini fluoroscopy as compared to traditional radiographs in addition to a theoretical cost-savings. Optimization of clinic flow has been cited previously as an avenue for clinical practice improvement. Rohleder et. al. performed an in-depth clinic flow analysis of an orthopedic outpatient clinics and found that radiology wait times contributed significantly to patient overall wait time and length of clinic appointment.[4]

This study's time-related findings are well in-line with the findings otherwise documented in the literature including Fenellli et al. who documented the use of fluoroscopy on pediatric forearm fractures evaluated an outpatient clinic and ultimately cited a decreased patient visit time of 23 minutes when fluoroscopy was used compared to plain radiographs.[7] Swindells et al. retrospectively looked at the use of traditional radiographs versus mini C-arm at the discretion of treating surgeons, and demonstrated that treating physicians preferred using live fluoroscopy citing 114 uses out of 131 opportunities and noted decreased radiation exposure and wait times for the patients from one minute in the mini C-arm group to 25 minutes in the plain radiograph group.[8,9] These findings are all highly consistent with the time savings noted within the orthopedic hand clinic evaluated in this study.

A proportion of the 24 minute reduction in overall appointment time can be attributed to the increase speed (10 min improvement) at which patients are checked in and then placed in an exam room without having to present to radiology. However, this increased efficiency does not account for the 24-minute decrease in overall appointment length. We theorize that this overall improvement was partially fueled by the fact that many patients' questions and concerns were addressed during the in-vivo evaluation of their hand using the mini C-arm. We ultimately believe that this likely acted as a catalyst to prompt questions and produce a more streamlined interaction with the provider in the exam room.

Standard hand PA and lateral radiographs at the study institution are charged at $734 which represents a charged rather than a collected or negotiated rate. This fee represents both a facilities fee and radiology reading fee associated with the films. Within the traditional plain radiograph group these 13 patients would have saved a total estimated $9542 as compared to only overhead costs which would have been incurred in the mini C-arm group. It is worth noting that in the study intuitions' typical orthopedic hand clinic, x-rays are obtained immediately prior to the visit and are reviewed by the surgeon and/or mid-level provider as part of the clinic visit. The evaluation, treatment decisions, and discharge of the patient are usually completed prior to a radiology read being available and ultimately, making the radiologist's read unnecessary and less valuable to the overall clinic visit. In a 2007 study published in the Journal of Hand Surgery, authors found that the use of mini-fluoroscopy decreased their department's need for post-operative formal x-rays by over 90% and cited the main advantages being logistical in regard to clinic flow as well as economic as a significant decrease in charges was achieved.[9]

It is worth some discussion regarding the goals of imaging and role of traditional radiographs versus mini C-arm evaluation. The goal of post-operative imaging, simple stated, is to evaluate for bony healing and detect complications, either bony or hardware related. The standard views obtained in traditional radiograph series allow comparison over time, however, this is dependent upon satisfactory performance by technologist and any difference in view (ex. rotational differences) limit the longitudinal comparison benefit. Mini C-arm images allow for both standard longitudinally comparable views which are deemed satisfactory in real-time but also allows for directed evaluation of hardware etc. by changing rotation and deviating from standard views for example rotating a hand to evaluate for prominent hardware or potential screw disengagement. With the increased number of images obtained, there is some controversy regarding the radiation exposure to the patient and surgeon in plain radiographs versus mini C-arm images with multiple studies showing that surgeon control of obtaining images provides a minimal amount of radiation exposure.[1,3,9-11] Some investigators have raised concerns that the overall radiation exposure the surgeon's hands is underestimated within the literature while other have acknowledged this and countered that the minimal dose for a single image and best practice techniques make this exposure negligible and that the benefits of mini C-arm use outweigh risks.[1,3,11]

Multiple patients commented on the additional perceived time spent with the provider as they were escorted to a fluoroscopy suite, evaluated by their treating provider under live fluoroscopy and had results and findings explained in real-time. Although this was not quantified within the study we do believe this represents a well-documented phenomenon within orthopedics where increased time spent with patients correlates to improve patient satisfaction.[12] While our satisfaction findings were anecdotal, other studies have found that increasing the amount of time spent with the patient or perceived time spent with the patient lead to overall improvement in patient satisfaction when visiting an outpatient orthopedic clinic.[12]

This study is not without limitations and the first and most prominent limitation is the small sample size. The narrow selection criteria which included only specific postoperative patients made the overall number of adult patients meeting the criteria relatively limited. However, we do believe that this small scale evaluation will remain consistent as applied to a larger scale and thought the narrow inclusion criteria was important to maintain standardization between the two compared groups. Another limitation lies in the fact that this study was performed at a large academic institution. At a more streamlined private or smaller institution the benefits over using traditional plain radiographs may prove smaller if this process is already more streamlined, however, these results are consistent with multiple sources published throughout the literature. Lastly, there is a limitation in the estimated cost savings of using a mini C-arm over traditional radiographs as the overhead involved in maintaining a mini C-arm was not calculated into these findings and the overhead involved in maintaining traditional radiograph equipment could not be separated from standard published charge rates.

The use of mini-fluoroscopy during orthopedic hand surgery postoperative visits provides a feasible, quick, cost effective way to evaluate patients postoperatively, ultimately, resulting in improved patient flow via quicker patient appointments without sacrificing time spent with providers. We believe this validates a proof of concept and the utility of mini-fluoroscopy within an outpatient hand clinic, which will ultimately prompt further evaluation and more large-scale adaptation to confirm these findings.

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DELAYED ONSET POST-OPERATIVE NEUROLOGIC DEFICIT IN A PATIENT WITH MUCOPOLYSACCHARIDOSIS TYPE VI: A CASE REPORT

Christopher Lindsay, MD[1]; Joshua Holt, MD[1]; Stuart Weinstein, MD[1]

ABSTRACT

Background: Mucopolysaccharidoses (MPS) are lysosomal storage disorders characterized by abnormal deposition of glycosaminoglycans (GAGs) in tissues. In type VI MPS, otherwise known as Maroteaux-Lamy syndrome, the defect is in the enzyme N-acetylgalactosamine-4-sulfatase. Thoracolumbar kyphosis results from GAG deposition, leading to incompetence of posterior ligamentous structures as well as poor trunk control. Though neurologic symptoms from canal compression due to deformity and hypertrophy of tissues have been described, occasionally requiring surgical decompression, there has not been a prior report of late onset of symptoms in a previously neurologically intact patient following surgery to correct spine deformity.

Methods: The case reviewed is a 14 year old girl with mucopolysaccharidosis type VI underwent anterior release and posterior instrumentation for correction of severe progressive lumbar kyphosis. Postoperatively she developed delayed onset of profound lower extremity weakness and underwent urgent wide laminectomies and resection of thickened ligamentum flavum. At 1 year follow-up, she had near complete neurologic recovery.

Conclusion: Patients with mucopolysaccharidoses are at significant risk for neurologic compromise both as part of the natural history of the disease, and as a risk of deformity correction. The surgeon must consider the pathologic thickening of tissues surrounding the spinal cord when planning surgery.

Level of Evidence: IV

Keywords: mucopolysaccharidosis, scoliosis, kyphosis, deformity, outcomes

INTRODUCTION

Mucopolysaccharidosis (MPS) type VI, otherwise known as Maroteaux-Lamy syndrome, is one of several known lysosomal storage disorders characterized by accumulation of glycosaminoglycans (GAGs) in lysosomes and abnormal deposition in tissues.[1] In the case of MPS VI, the defect is in the enzyme N-acetylgalactosamine-4-sulfatase (also known as arylsulfatase B, or ASB) which degrades dermatan sulfate.[2,3] Like all MPS diseases except MPS II (which is X-linked), MPS VI is inherited in autosomal recessive fashion.[1] The incidence is estimated between 1 in 238,000 to 1 in 300,000, and makes up about 4.2% of the documented US cases of MPS.[1,4] The clinical presentation is heterogenous, but includes dysmorphic facies, cardiopulmonary disease, stunted growth, and progressive skeletal and joint deformities.[1]

Advancements in treatment, including hematopoietic stem cell transplants and enzyme replacement therapy, have dramatically improved life expectancy for MPS patients,[5,6] but these treatments do not prevent most musculoskeletal manifestations, including spine pathology. Thoracolumbar kyphosis results from GAG deposition leading to incompetence of posterior ligamentous structures as well as poor trunk control. This is quite common in MPS I (Hurler syndrome) and occurs in up to 90% of those patients.[5,7] It is also described in MPS II, IV, and VI and many authors have published their experiences with kyphotic deformity and correction in patients with MPS.[5,8-11] Deposition of GAGs in the meninges, PLL, and ligamentum flavum, leads to stenosis of the spinal canal, both in the upper cervical spine and in the thoracolumbar spine at the apex of the gibbous deformity.[7,11] Neurologic symptoms from this compression is known to develop in 12-40% of patients with MPS, and does occasionally require surgical decompression.[11]

Herein we present a case of a young girl with MPS type VI with no pre-operative neurologic signs or symptoms, who developed delayed neurologic compromise after combined anterior release and posterior spinal fusion for a lumbar kyphotic deformity, treated with return to the operating room for wide laminectomy and decompression.

The patient's parents did provide consent for data concerning this case to be published as a case report. Our institutional IRB considers case studies of three or

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

Sources of Funding: No sources of funding declared.

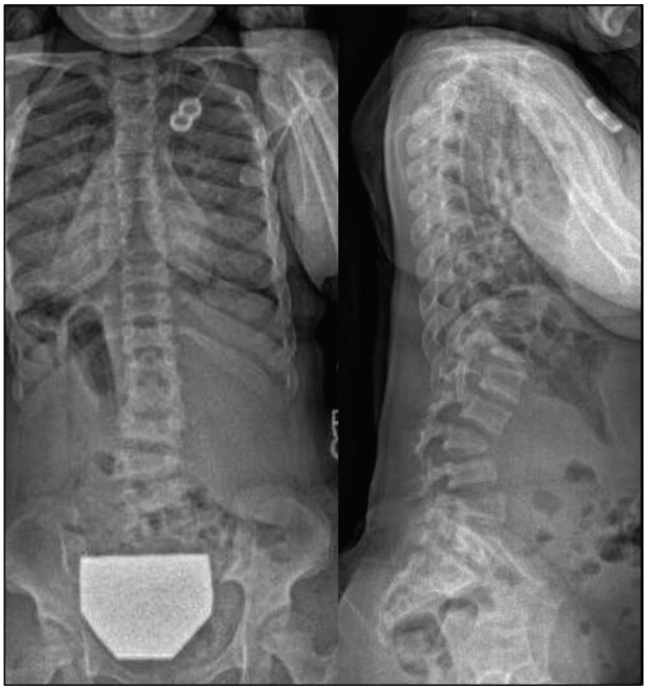

Figure 1. Preoperative AP and lateral scoliosis films. Preoperatively there was 38 degrees of lumbar kyphosis with hypoplastic L2. Planned surgery included anterior releases from T12 to L4 with subsequent posterior instrumentation.

fewer patients as exempt, per section 12.G of the Human Subjects Office's SOP manual.

The Case

A 14-year-old female with history of mucopolysaccharidosis type VI (Maroteaux-Lamy syndrome) presented to the senior author (SLW) for evaluation of progressive thoracolumbar kyphosis and worsening back pain. She had a history of prior cervical laminectomy at C1-C3, as well as bilateral carpal tunnel and trigger finger release. Due to severe, symptomatic progressive kyphosis centered at L2-3 (Figure 1), the patient was indicated for anterior release and posterior correction and instrumentation in a single, two-part procedure. She had failed conservative management and bracing was felt unlikely to improve her symptoms and deformity. Preoperative bolster films demonstrated partial correction of the deformity (Figure 2). Anterior releases were planned, not for the purpose of a more aggressive correction, but because in the senior author's opinion, without releases, there would be increased force on the posterior hardware in pathologic bone. In addition, most of the pre-operative stenosis was anterior on MRI (Figures 3, 4). Multiple level anterior release with meticulous ligation of unilateral segmental vessels has been extensively documented as safe, especially when using neuromonitoring technology.[12,13] Risks, benefits and alternatives were discussed with family and the patient's parents signed the consent

Figure 2. Lateral scoliosis film with a bolster, demonstrating good flexibility with partial correction of the deformity.

Figure 3. Preoperative sagittal T2 weighted MRI scan demonstrating mild to moderate stenosis near the apex of the gibbous deformity, but no areas of severe stenosis in the thoracolumbar spine.

document. There was no pre-operative neurologic deficit.

After induction of general anesthesia, the patient was placed in the right lateral decubitus position and neuromonitoring with sensory (SSEP) and motor evoked potentials (MEP) was initiated. After positioning, MEPs were noted to be normal on the left side but distally on the right were negligible to absent at baseline. A standard thoracoabdominal anterior approach was carried out, and anterior releases were performed at disc spaces of each level from T12 to L4. Throughout the anterior procedure, neuromonitoring was unchanged. After uncomplicated anterior release, the patient was flipped prone. MEPs were then detected in all extremities. Pedicle screws were placed bilaterally from T10

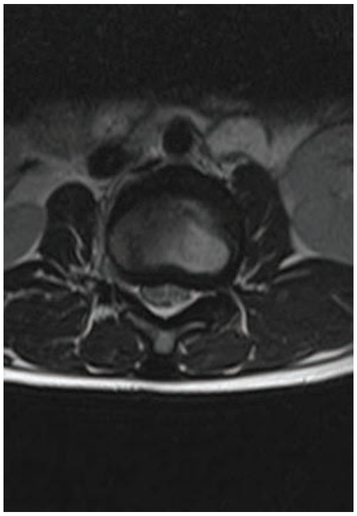

Figure 4. Preoperative axial T2 weighted MRI at the apex of the gibbous (T1-2), showing mild to moderate stenosis.

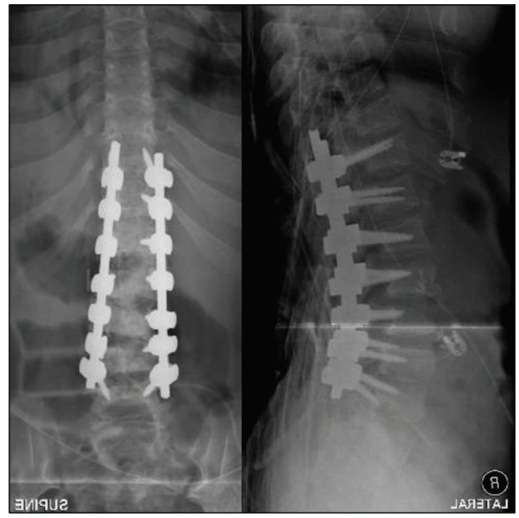

Figure 5. Postoperative supine films with excellent correction of lumbar kyphosis and no hardware complications.

to L4. Rods were placed, and kyphosis was reduced using cantilever technique. Throughout reduction, all MEPs remained normal and intraoperative wake-up test demonstrated volitional movement of both lower extremities, so the correction was not felt to be overly aggressive. Satisfied with the correction (Figure 5) and the successful wake-up test, the wound was closed. The patient was transported to the pediatric ICU (PICU) for close monitoring. She was extubated uneventfully the day of surgery and was noted to have full symmetric strength in lower extremities.

On post-operative day 1 and 2, the patient reported some paresthesias in lower extremities and on exam had trace weakness in tibialis anterior (TA), extensor hallucis longus (EHL), and gastrocsoleus complex (GSC). On post-operative day 3, she exhibited ascending weakness in the right lower extremity with new weakness in hamstrings and flexor hallucis longus (FHL), and profound weakness in TA and EHL. An MRI and CT were obtained (Figures 6-10), showing multiple levels of central stenosis and misposition of one screw at L4 on the left (non-affected side). Over the next 24 hours, she had gradual progression of the weakness in the right lower extremity. Gradual onset and unilateral weakness without hyperreflexia was most consistent with a cauda equina syndrome.

In the absence of relevant literature, and after discussion with several experienced colleagues, both within

Figure 6. Sagittal MRI postoperatively is limited by metal artifact, but demonstrates most significant compression at T10-11, L1-2 and L2-3 levels.

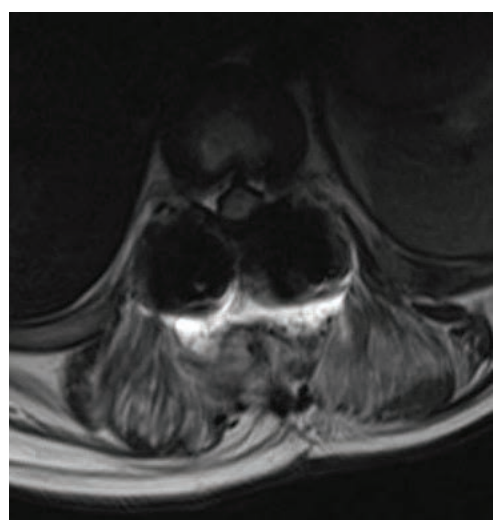

Figure 7. Axial cut of postoperative MRI, also limited by metal artifact at T10-11, but demonstrates significant stenosis.

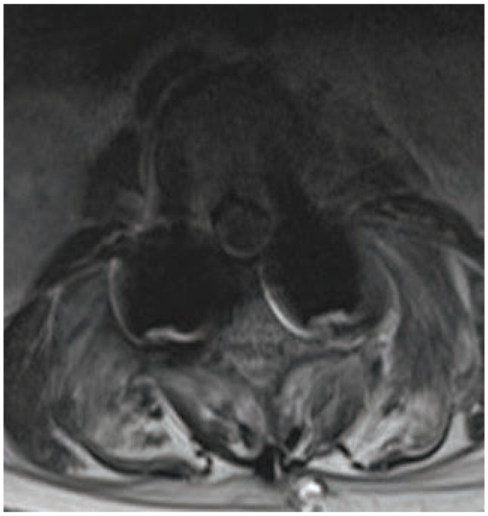

Figure 8. Most severe level of stenosis on axial MRI cuts postoperatively at L1-2 level.

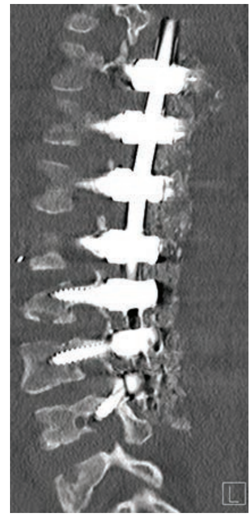

Figure 9. Postoperative sagittal CT demonstrating misplaced screw at L4 pedicle on the left. Screw with noted inferior and medial breach. This is notably on the contralateral side of the patient's symptoms.

and outside our institution, the decision was made to perform urgent laminectomies with extensive central decompression. The mispositioned L4 screw was replaced, but not thought to play a part in the neurologic symptoms. Wide laminectomies were performed from T9 to L5, and dramatically thickened ligamentum flavum was encountered with buckling of the tissues throughout. The ligamentum was carefully dissected off the dura. After this dissection was completed, the dura was noted to also be thickened and have undulating indentations from the hypertrophied ligamentum flavum (Figure 11), however at this point was completely decompressed posteriorly. As SSEPs were improving during the case, and clinically, the canal was felt to be adequately decompressed, the correction was not reversed. The patient returned to PICU postoperatively and was started on 0.1 mg/kg dexamethasone every 6 hours.

Post-operatively, the patient continued to have profound weakness (0-1/5) in TA, and EHL, with 3/5 strength in hamstrings, GSC, and FHL on the right. She also had weakness to a lesser extent on the left with 1-2/5 in TA and EHL and 4/5 in hamstrings, GSC, and FHL. By her 6-week postoperative appointment, she had about a 15-20% improvement in strength. Over the next 6 months, the patient exhibited gradual but steady improvement. At one-year post op, the patient made al-

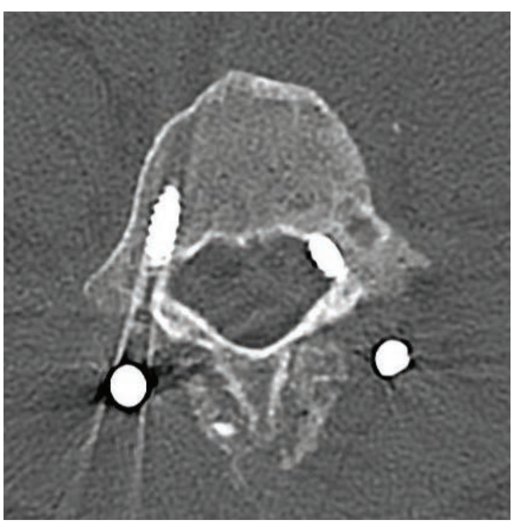

Figure 10. Axial cut of postoperative CT demonstrating misplaced screw at L4 pedicle on the left. Screw with noted inferior and medial breach. This is notably on the contralateral side of the patient's symptoms.

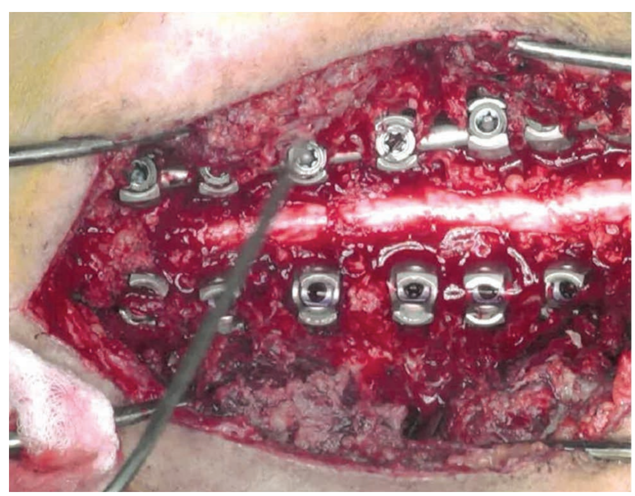

Figure 11: Representative picture after decompression with extensive laminectomies. Centrally, undulating indentations in the dura can be seen after removal of the thickened ligamentum flavum.

most complete neurologic recovery, with nearly normal strength, 4+/5 in TA, GSC, EHL, FHL on the left, GSC on the right, otherwise 5/5.

DISCUSSION

Spinal stenosis is common in mucopolysaccharidoses, and neurologic compromise is described in the natural history of the disease.[5,11] In this case report we describe, to our knowledge, a previously unreported complication in a patient with MPS VI who developed critical stenosis after correction of thoracolumbar deformity, related to pathologic thickening of the ligamentum and dura. In this case, our patient did have a prior cervical spine decompression due to cervical myelopathy, so her spinal cord was known to be at risk. During the case however, neuro monitoring did not show any changes in motor potentials. Though there were some irregularities in SSEPs, the intraoperative wake-up test was normal, and the case was uncomplicated. Indeed, the patient was not found to have significant neurologic compromise until post-op day 3.

Post-operative neurologic changes are not new in MPS. There is a reported series (Pauchard et al., 2014)[14] of two patients with Hurler syndrome and one patient with Morquio syndrome who experienced similar post-operative neurologic compromise within a week of correction of thoracolumbar kyphosis. One of these was treated expectantly, one with hardware removal and casting, and one (thought to be due to epidural hematoma) was taken back for laminectomy, but unfortunately did not experience neurologic recovery and died from the resulting quadriparesis. The conclusion of these authors was that surgeons must be cognizant of "spinal cord fragility" in patients with MPS.[14] Although MPS type VI is less prevalent, these patients are known to have similarly tenuous neurologic status, which is not improved by enzyme replacement.[15]

In conclusion, with modern enzyme replacement therapies, patients with mucopolysaccharidoses can survive many decades. Spinal deformity is common among these patients, and deformity correction is desirable to maintain function and quality of life. The surgeon must be cognizant of the risks of neurologic compromise, and consider pathologic thickening of the meninges, PLL, and ligamentum when performing surgical deformity correction. Caution should be used regarding degree of correction, and sagittal and coronal alignment goals should likely be less aggressive than for healthy patients. If any intraoperative concern is encountered, or large correction needed, prophylactic laminectomy and resection of thickened ligamentum may be considered. These risks should be discussed as part of the informed consent process with families of patients.

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