THE IOWA ORTHOPAEDIC JOURNAL

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INSTRUCTIONS FOR AUTHORS

Any article relevant to orthopaedic surgery, orthopaedic science and the teaching of either will be considered by The Iowa Orthopaedic Journal for publication. Articles will be enthusiastically received from alumni, visitors to the department, members of the Iowa Orthopaedic Society, residents and friends of the University of Iowa Department of Orthopaedics. The journal will be published annually in May or June. The deadline for receipt of articles for the 1988 journal is February 1, 1988.

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3. Legends for all illustrations submitted, listed in order and typed double-spaced.

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   b. Original drawings or charts.
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Preparation of illustrations: Number all illustrations and indicate top plainly. Write the author's name on the back of each illustration. Send prints unmounted or mounted only with rubber cement; paste or glue will damage them. Drawings, charts, and lettering on prints usually should be done in black; use white on black backgrounds. Put dates or initials in legends, not on prints. Make lettering large enough to be read when drawings are reduced in size. When submitting an illustration that has appeared elsewhere, give full information about previous publication and credit to be given, and state whether or not permission to reproduce has been obtained.
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Editors' Note

This journal has as its primary purpose education, and those who participate in its production undoubtedly learn the most. The journal also seeks to reflect the activity of the residents, faculty, alumni, and visitors to the department in a forum that allows the dissemination of scientific thought. As such we have included historical and philosophic articles as well as scientific and general review articles. The contents of this edition provide testament to its goal of educational excellence. This reflects the authors' dedication to the highest standards in education, and we thank them for their contributions.

We would also like to thank Drs. Cooper, Clark and Weinstein for their guidance, and Paul Etre for his administrative assistance. We extend a special thanks to Nancy Grubb for her cooperation and superb secretarial help throughout the year.

We hope that you, the reader, benefit from our efforts and welcome your response and constructive criticism.

TCM
MCM
1987 Graduating Senior Residents

We would like to congratulate the senior residents and give them our best wishes as they carry the Iowa Orthopaedic tradition across the country (and world).

Brian D. Adams, M.D.

Brian grew up in Wahoo, Nebraska. He did his undergraduate work at Creighton University and received his M.D. degree from the University of Nebraska School of Medicine. After two years of orthopaedic residency at Creighton, he joined the University of Iowa program. Next year Brian and his wife Debbie will be in California where Brian will do his hand-surgery fellowship at Loma Linda University.

John J. Hugus, M.D.

John was raised in South Bend, Indiana. He attended Dartmouth College where he received his A.B. degree, and he received his M.D. degree from the University of North Carolina School of Medicine. Next year John will do a traveling spine fellowship with Dr. Frymoyer in Vermont, Dr. Crock in England, and Dr. Taylor in Sydney, Australia.

Thomas A. Malvitz, M.D.

Tom's hometown is Otsego, Michigan. He received his B.S. degree from Western Michigan University and his M.D. degree from the University of Michigan Medical School. Tom, his wife Margie, and sons Michael and Stephen will move to Grand Rapids where Tom will join Kent Orthopaedics.

Randall R. Wroble, M.D.

Randy was born and raised in Chicago. He received his A.B. degree from Cornell University (N.Y.), his M.S. in Chemistry from the University of Colorado, and graduated from the University of Illinois School of Medicine. Randy, his wife Deborah, and their daughter Leigh will be in Cincinnati next year where Randy will do a Sports Medicine fellowship at the Cincinnati Sports Medicine Clinic.
PRELIMINARY RESULTS OF UNCEMENTED P.C.A. TOTAL HIP REPLACEMENT

*Stanley H. Dysart, M.D., CPT USA
+*John J. Callaghan, M.D., MAJ, USAR
+*Carlton G. Savory, M.D., COL, USA

From The Orthopaedic Service
Walter Reed Army Medical Center
Washington, D.C.

*Orthopaedic Service, Walter Reed Army Medical Center
Washington, D.C. 20307-5001

+ Uniformed Services University of the Health Sciences
Bethesda, Maryland

No benefits of any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

INTRODUCTION

Evaluation of cemented total hip arthroplasty has revealed mechanical failure caused by aseptic loosening to be the most significant and concerning long-term problem. Stauffer documented 11.3 percent acetabular component and 29.9 percent femoral component loosening at ten-year follow-up of the Charnley prosthesis\textsuperscript{32}. One and one half to 19 percent long-term (ten-year) revision rates for aseptic loosening have been reported\textsuperscript{21,31,33,34}. Cemented total hip arthroplasty in patients younger than sixty have demonstrated even higher loosening and revision rates\textsuperscript{7,9,13,28}. In addition, revision cemented total hip arthroplasty demonstrates less durability than primary arthroplasty\textsuperscript{4,22,27} with Pellicci reporting 29 percent failure at eight-year follow-up\textsuperscript{27}. These findings have stimulated research in two areas: 1) the improvement of cemented total hip arthroplasty by femoral stem design modification\textsuperscript{10,11}, centrifugation of cement\textsuperscript{3}, better cementing techniques\textsuperscript{19,27}, and metal backing of acetabular components\textsuperscript{5,20,24,26} and 2) biologic ingrowth fixation with animal studies\textsuperscript{1,5,15} and early clinical trials\textsuperscript{14,23,29} reporting encouraging results. The purpose of this paper is to present a preliminary minimum two-year follow-up of a prospective, consecutive series of patients who underwent uncemented primary total hip arthroplasty with the Porous Coated Anatomic (PCA) total hip system by Howmedica.

MATERIAL AND METHODS

A protocol was approved by the human use committee at Walter Reed Army Medical Center to implant PCA total hip arthroplasties in patients who had agreed to the procedure and signed informed consent detailing its experimental nature. Only two cemented primary total hip replacements were performed during this time period.

Forty-seven patients underwent fifty primary uncemented total hip arthroplasty procedures between October 1983 and December 1984 at Walter Reed Army Medical Center. All procedures in this series were performed through the direct lateral approach as described by Scheck\textsuperscript{32} and Hardinge\textsuperscript{17}, with the anterior one-third of the gluteus medius tendon elevated, along with its more anterior muscular attachment and the proximal vastus lateralis, as a subperiosteal sleeve from the greater trochanter and proximal femur. Ages ranged from twenty-two to eighty-one years. The age and sex distribution are illustrated in Figure 1. Diagnoses are listed in Figure 2.

AGE OF PATIENTS

![Age and sex distribution of the forty-seven patients studied.](image)

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H. Dysart, J. Callaghan, G. Savory

DIAGNOSIS

<table>
<thead>
<tr>
<th>Condition</th>
<th>HIPS</th>
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<tbody>
<tr>
<td>Osteoarthritis</td>
<td>24</td>
</tr>
<tr>
<td>Rheumatoid</td>
<td>7</td>
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<tr>
<td>Osteonecrosis</td>
<td>9</td>
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<td>Ankylosing Spondylitis</td>
<td>2</td>
</tr>
<tr>
<td>CDH</td>
<td>3</td>
</tr>
<tr>
<td>Post-Traumatic</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>50</td>
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Figure 2
Diagnosis of the forty-seven patients (fifty hips).

Harris hip ratings were obtained preoperatively and at three-month, six-month, one-year and two-year follow-up. Overall results, pain, limp, and use of ambulatory aids were individually analyzed. All forty-seven patients were evaluated at one year and the forty-six living patients were evaluated at two years. Anteroposterior and Lauenstein lateral radiographs were obtained postoperatively and at three months, six months, one year and two years. A single radiology technician experienced in orthopaedic radiographs performed or supervised all radiographs on a single radiograph machine.

RADIOGRAPHIC ANALYSIS

Various anteroposterior radiograph measurements, as illustrated in Figure 3, were used to evaluate results. Vertical subsidence of the femoral component was measured as the change in the distance from the superior medial extent of porous coating to the most proximal point on the lesser trochanter. A difference of five millimeters or more was considered to indicate subsidence. Migration of the acetabular component was measured as: 1) the change in the vertical distance between the inferior margin of the acetabular cup and the inferior margin of the teardrop and 2) the change in the horizontal distance between Kohler's line and the acetabular cup. A change of more than two millimeters in one or both of these dimensions was considered acetabular migration. The acetabular lateral opening, or cup angle, was formed by the horizontal line drawn through the teardrops and the plane of opening of the cup. The cortical index was measured as the ratio of the width of the intramedullary canal over the outside shaft diameter at the level of the prosthesis tip. Loss of proximal density and calcar rounding were determined subjectively by comparing sequential radiographs. Femoral lines and sclerosis and acetabular lines were recorded at one and two-year follow-up using DeLee's zones for the acetabulum and Gruen's zones for the femur. Loose femoral and acetabular beads were recorded for each follow-up film. Anteroposterior and lateral radiographs were evaluated for fit of the femoral stem in the femoral canal. On the anteroposterior projection, fit was considered excellent if the stem contacted the cortical bone at some point on both the medial and lateral surface, good if the stem was within two millimeters of the cortex medially and laterally, and poor if there was greater than two millimeters of distance between the stem and cortex either medially or laterally. Fit was considered excellent on the lateral projection if the stem came within two millimeters of the cortex in two of the three possible contact points: proximal anterior, distal anterior, and posterior because of the posterior bow of the prosthesis. Fit was considered good if there was contact within three millimeters of the cortex in two of the three points, and poor if there was no contact within three millimeters in two of three contact points. Heterotopic bone was graded according to the classification of Brooker.

RESULTS

A. Overall Results:

Sequential Harris hip ratings are demonstrated in Figures 4A-E. There was gradual improvement in overall ratings over the first year but little change between the one and two-year follow-up. Mean male score was 94 and mean female score as 93 at two years. There was no statistically significant difference in scores versus diagnosis, sex, or decade of life, however the mean score in rheumatoid hips was 88 and in osteoarthritic hips 95. Results were excellent in 74 percent, good in 20 percent, fair in 4 percent, and poor in 2 percent. The fair and poor results were in Charnley class C patients, the low scores because of activity level, not pain.

B. Pain:

The mean preoperative pain score was 94 and declined to 42 three months postoperatively. Mean pain scores did
not change appreciably over the remaining follow-up. Eighteen percent of hips had slight anterior thigh pain with weightbearing or prolonged activity at one year and 16 percent at two years. In no case was the thigh pain disabling and no patient used medication to control the pain.

C. Limp:

Sequential limp scores of these fifty hips performed through the direct lateral approach are listed in Figures 5A-D. Twenty-four percent of patients had a moderate or
H. Dysart, J. Callaghan, G. Savory

severe limp at one year and twenty-eight percent at two years. These results were compared to the six (one moderate and no severe) and twelve-month (no moderate or severe) limp scores of the first twenty-two consecutive hips performed through the posterolateral approach at a later date. The hips performed through the posterolateral approach had statistically significant less limp when compared to the direct lateral approach (p < .00001 at six months and p < .01 at one year). Limp did not improve in the lateral approach hips after one year.

D. Use of Ambulatory Aids:
At one year 70 percent of patients used no support, 18 percent used a cane for long walks, and 12 percent used a support all the time. At two years 76 percent of patients used no support, 14 percent used a cane for long walks and 10 percent used a support all of the time.
RADIOGRAPHIC RESULTS

A. Femoral Lines:
Femoral lines were defined as a lucency adjacent to the prosthesis with an increased density less than three millimeters thick adjacent to this lucency as illustrated in Figure 6. The distribution of these lines at two years on the anteroposterior and lateral radiographs are illustrated in Figure 7. The femoral lines were progressive (not present at one year but present at two years or present at one year but extending within the same zone or into other zones at two years) in 41 percent of hips.

![Figure 6](image)
Typical lines observed around the femoral component.

![Figure 7](image)
Two-year distribution of femoral lines on anteroposterior and lateral radiographs.

B. Acetabular Lines:
A typical acetabular line is pictured in Figure 8. The distribution of acetabular lines is illustrated in Figure 9 for two-year follow-up radiographs. Acetabular lines were progressive in 8 percent of hips.

![Figure 8](image)
Typical acetabular line.

![Figure 9](image)
Two-year acetabular line distribution.

C. Femoral Sclerosis:
Femoral sclerosis was defined as an increase in density (of greater than three millimeters) adjacent to the prosthesis or adjacent to a lucency as illustrated in Figure 10.
D. Loose Beads:

Loose acetabular beads and loose femoral beads (Figure 12) occurred in 36 percent and 55 percent of hips respectively. They were progressive (not present on postoperative radiographs but present at later follow-up or present initially with additional beads present later) in 18 percent of acetabular components and 28 percent of femoral components.

E. Other Radiographic Findings:

In the anteroposterior projection the femoral fit was excellent in 36 percent, good in 30 percent and poor in 34 percent. In the lateral projection the fit was excellent in 38 percent, good in 34 percent, and poor in 28 percent. Sixty-five percent of hips had loss of proximal femoral density and 69 percent had calcar rounding. No marked progression of proximal femoral density loss occurred between one and two years. There was a decrease in the cortical index of greater than 10 percent (i.e. .5 initially and .45 at follow-up) in eight hips (16 percent) at two years, probably representing cortical hypertrophy. Het-
erotic bone was present in 81 percent of hips with 57 percent Grade I, 16 percent Grade II, 8 percent Grade III and 0 percent Grade IV. Two patients demonstrated endosteal scalloping in zone II of the femur. One patient had femoral subsidence after a fracture fourteen months postoperatively. One patient had acetabular cup position change. This patient had no pain but walked with a moderate limp.

COMPLICATIONS

Two orthopaedic complications occurred in this series. One patient had an intraoperative nondisplaced proximal femoral fracture which was treated with a single cerclage wire. Two-year follow-up Harris hip rating was 96 with the patient experiencing slight thigh pain with activity and no limp. The second patient, noted above, incurred a femoral fracture fourteen months postoperatively after a minor fall. He was treated for six months in a spica cast and the fracture healed. One year postoperatively (before the fracture) his hip rating was 91 and at two-year follow-up his rating was 85. At last follow-up he used a cane most of the time and had slight thigh pain and limp. The radiograph at two years demonstrated subsidence of the femoral component with no progression since the fracture. The fracture had healed.

There were no infections in this series of patients. No revisions have been performed and there are no impending revisions. One patient died eighteen months postoperatively of unrelated causes. He had a hip rating of 76 at one-year follow-up and slight thigh pain which his wife claimed persisted until his death six months later.

DISCUSSION

The strength of the present study is that it is prospective, involves a consecutive series of patients, includes sequential clinical and biplane radiographic follow-up, and includes all patients during the follow-up period. In addition, all surgery was performed through the same approach and by, or supervised by, two orthopaedic surgeons (C.G.S. and J.J.C.) with special training in total joint reconstruction. Finally, all radiographs were reviewed by two authors (S.H.D. and J.J.C.) with agreement reached between the two in all cases. The study can be criticized because of its relatively small numbers with few statistically significant correlations (Table 1).

The overall Harris hip ratings were good or excellent in all cases except for three patients who were Charnley class C and hence unable to perform at a normal or near-normal activity level. Harris hip ratings plateaued at one year and we would predict from this study minimal improvement in hip scores after one year in patients with uncemented prostheses. Evaluation of postoperative pain did not appreciably change between three-month and two-year follow-up, however there was actually some increase in the number of patients with slight pain between the one and two-year follow-up. Thigh pain was present in 18 percent of cases at one year and did not change appreciably by two-year follow-up (16 percent). Thigh pain was not disabling and usually occurred after prolonged activity and never at rest. No statistically significant correlation could be made between the thigh pain and any of the radiographic findings (Table 1).

Over the two-year follow-up we became very concerned about the excessive limp of the patients (24 percent moderate or severe at one year and 28 percent at two years). Limp did not improve between one and two-year follow-up. As this finding became apparent we switched to the posterolateral approach with the thought that the elevation of the gluteus medius and minimus in the direct lateral approach contributed to the limp. Our early data comparing the direct lateral with the posterolateral approach is already statistically significant with the posterolateral approach having markedly less limp ($p < .00001$ at six months and $p < .01$ at one year). We anticipate that this correlation will continue with further follow-up as there was no change in limp between one and two years in the patients with the direct lateral approach. The etiology of this correlation was suggested during the reoperation of three hips, one cemented hip and two uncemented bipolar replacements where the lateral approach was used at the initial surgery. At revision, the subperiosteal medius flap had completely separated off from the greater trochanter (though the suture remained attached to bone through the original drill holes). We strongly recommend that this approach be avoided in primary arthroplasty.

As documented, many of the radiographic changes were progressive between the one and two-year follow-up. However, we did not appreciate any obvious proximal femur density loss between one and two years, which has been a concern with the uncemented replacements. The femoral fit and thigh pain did not statistically correlate with the radiographic changes (Table 1).

Though not statistically significant, we feel some correlations warrant mention. Excellent femoral fit on the anteroposterior radiograph did show a trend toward correlation with less femoral hip sclerosis than in those hips without excellent fit ($p < .08$). There was also a tendency for correlation of less femoral lines on the lateral projection when the lateral fit was excellent ($p < .09$). There was a trend ($p < .06$) toward correlation of poor anteroposterior fit and thigh pain. The femoral sclerosis and distal cortical hypertrophy (change in cortical index) would suggest distal stress transfer, however these findings did not correlate with proximal density loss (Table 1). Excellent and good fit did show a trend ($p < .18$) to correlate with tip hypertrophy. The most disturbing radiographic finding was the progressive bead loosening (two to fourteen beads) in 18
The clinical results of uncemented Porous Coated Anatomic total hip replacements are encouraging at two-year follow-up with 94 percent good or excellent results. The 6 percent fair and poor results were because of limited activity in Charnley C patients, rather than pain. Sixteen percent of patients do have slight anterior thigh pain at two years with weightbearing or prolonged activity. There are definitely more patients with a moderate or severe limp in this series than in patients with cemented prosthesis, however this is partially related to the direct lateral approach. The thigh pain, the progressive radiographic changes and loose beads are of concern and need further follow-up. Long-term durability, stem strength, and biocompatibility can only be assessed with longer follow-up.

BIBLIOGRAPHY


Preliminary Results of Uncemented P.C.A. Total Hip Replacement

DO THE BELLS TOLL FOR IDIOPATHIC LOW BACK PAIN?* 
ONE AUTHOR’S OPINION

Dan M. Spengler, M.D. 
Professor and Chairman 
Department of Orthopaedics and Rehabilitation 
Vanderbilt University Medical Center 
Nashville, Tennessee 37232

Low back pain (LBP) represents a common clinical symptom which affects over 80 percent of humans at some point in life. Because of the prevalence of low back pain, one could persuasively argue that this symptom may characterize a normal phenomenon rather than reflect a symptom related to a pathological process. Several authors have emphasized that a specific anatomical source of "pain" cannot be identified in 80 percent of patients who report low back symptoms.

As physicians well-grounded in scientific thought processes, we readily recognize that treatment is usually only successful when a specific diagnosis can be made. We also accept the tenet, "primum non nocere," in most clinical settings. For example, the common cold is a similar enigma with multiple treatments available to minimize the nuisance. In spite of the commonness of the cold, no one has to my knowledge recommended mucosectomies or fusion of the nares as treatment. Both of these procedures are absurd. How, therefore, can thoughtful clinicians recommend treatment strategies which include steroid dose packs, dependency-inducing narcotics and tranquilizers, passive modalities, adjustments, exploratory surgeries, and spinal fusions for low back pain? None of these strategies have ever been shown to be either valid or reliable in the treatment of low back pain. Moreover, significant complications can be encountered with all of these treatments so that the risk-benefit ratio tilts strikingly toward risk.

To discuss this controversy, let us first examine the natural history of idiopathic LBP. Fortunately, several excellent studies have been presented which allow insight into the natural history of LBP. Deyo's recent article suggests (perhaps even proves) that most individuals with LBP should be back to work in two days. Other authors have also shown that the majority of self-employed individuals who encounter LBP are nearly always back to productivity in six to seven days. Individuals who receive compensation and/or who are involved in litigation rarely, if ever, follow the natural history curve. Indeed, these individuals often miss nearly three weeks of work on average—a fourfold increase. Factors other than tissue damage (nociception) certainly affect the functional outcome in LBP patients. Haddad has recently reported an astounding bit of information which certainly supports clinical observations. In a five-state study of thousands of compensation claimants, Haddad reported that 77 percent of claimants who did not enlist or accept an attorney returned to work. Ninety percent of the claimants who engaged or accepted an attorney never returned to work. Such data, if verified, cast an ominous cloud over the value of our current workers' compensation/tort system. Individuals who drop out of the work force may initially be delighted with the instant gratification of the modest financial windfall and lack of responsibility. Over the long haul, however, an extreme toll is taken from individuals who do not work. Loss of self esteem, family discord, lack of focus in life, and loss of friends represent only a few of the adverse long-term consequences. Clearly, this traditional approach needs to be critically examined to create incentives for productivity and achievement as contrasted to the current state of incentives for exhibiting illness behavior (disincentives).

Another interesting observation regards the minimal impact of low back pain in third world countries. Having spent one year at a Vietnamese hospital where I treated primarily Vietnamese civilians, I evaluated only one patient who presented with complaints of back pain and did not have spinal tuberculosis. This particular working male had a classic lumbar disc herniation. He returned to work as a roofer approximately three weeks following an uneventful lumbar disectomy. Why was low back pain so strikingly absent as a presenting symptom in this population?

We physicians also contribute to the problem. Our behavior will of necessity change in the future as precious health care resources are more carefully allocated. Certainly, we must continue to be patient advocates, but we cannot hide behind the cloak of altruism. Over-treatment of individuals with idiopathic LBP represents an improper deployment of vital resources. In addition, patients with

*This discussion focuses on idiopathic LBP, and assumes that proper evaluations have been performed to exclude identifiable sources of pain.
Do the Bells Toll for Idiopathic Low Back Pain?

LBP are far better served by being directed back to productivity as soon as possible, certainly within days\(^2\). Patients who are not able to comply with this approach should be carefully assessed to exclude a significant source of nociception, e.g. tumor, disc herniation, infection, referred pain.

Treatment strategies which have not been validated through controlled studies should not be implemented. The major emphasis of treatment must be to educate the patient about the natural history of back pain and insist that he or she be an active participant in becoming “well”. Thus, treatments which on the surface appear benign (e.g. hot packs, massage, ultrasound) really reinforce dependency and therefore adversely affect long-term outcome. Patients who wish to procure and/or pursue safe non-scientific approaches can certainly do so, but they must be financially responsible for these types of entertainment, not third-party payors.

Yes, the future is bright for the patient with low back pain. Scientists are continually expanding our knowledge of pain. Perhaps what we learn about low back pain in the future will diminish its adverse impact on society. In the interim, however, we must remain true to our conscience and avoid allocating valuable health care resources for a condition which fortunately has a limited clinical course with a generally positive outlook.

REFERENCES


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Iowa Orthopaedic Journal.
UNILATERAL CERVICAL FACET SUBLUXATION/DISLOCATION*

Charles R. Clark, M.D.**
William E. Wessels, Jr., M.D.***

INTRODUCTION

The treatment of unilateral facet subluxation/dislocation of the cervical spine is controversial. The literature is somewhat confusing with respect to the optimal management of this condition. Treatment options to achieve reduction include traction, closed manipulation, and open reduction and fusion. The indications for the various treatment modalities are unclear. Some of the major controversy centers around the role of manipulation in the management of this condition and the necessity for open reduction. It is not clear whether residual subluxation or dislocation is an acceptable treatment outcome. Because of these concerns, a retrospective study of unilateral facet subluxation/dislocations of the cervical spine was undertaken in attempt to answer these questions and to identify a rational and safe approach to the management of these injuries.

MATERIALS AND METHODS

A computer-generated list of 313 cervical spine injuries treated between 1979 and 1983 by the Departments of Neurosurgery and Orthopaedic Surgery at the University of Iowa Hospitals and Clinics was reviewed. Patients with unilateral subluxation/dislocations between C3 and C7 were included in the study. Included in this group are those with unilateral facet subluxation, perched-facet or dislocation, with or without associated fracture of the articular process or pedicle. Patients with associated fractures of the spinous process or lamina of the same level were included. Lesions involving C1, C2 and cases of multiple level cervical injury were excluded. In addition, patients with associated fracture of the body and patients with no follow-up data after discharge were excluded. Patients were then evaluated by a personal examination. Where this was not possible, data was obtained from the most recent recorded exam and radiographs, and a personal phone interview. Follow-up examination consisted of a history, physical examination and radiographic assessment. The three primary areas of clinical assessment were presence of pain, neck motion, and neurologic status. Radiographs were reviewed to determine the extent of original injury, displacement, angulation, motion on dynamic flexion-extension radiographs, and disc space height.

RESULTS

Twenty-two patients met the above criteria. There were sixteen male and six female patients ranging in age from twenty-one to eighty years with a mean of 36.7 years. The level of injury included: three patients with C3-4 injury, two with C4-5 injury, six with C5-6 injury and eleven with C6-7 injury. Fourteen of the subluxations were on the right side and eight on the left. Ten patients had a delay in diagnosis ranging from one to seventy-seven days with a mean delay of 20.6. Reasons for delay included: missed on original radiographs in six patients, alcohol ingestion in two patients, multiple other injuries in one patient, and one patient presented late. The mechanism of injury included a fall or diving injury in five patients, a motor vehicle accident in sixteen patients, and one patient was struck by a falling object. Associated injuries included head injuries in six patients, extremity fractures in one patient and brachial plexus injury in another patient. Treatment included skeletal traction with an attempt at closed reduction in twenty-one patients and one patient had a closed manipulation (without traction). Eight patients underwent subsequent surgical stabilization. Five patients underwent posterior spinous process wiring, two patients had facet fusions and one patient underwent a decompressive laminotomy/foraminotomy.

Six patients were neurologically intact throughout their course of treatment. One patient had a brachial plexus lesion with no discernable root or cord injury. The weakness was unchanged throughout the patient’s course. Fifteen patients had signs of nerve root deficit including motor weakness or sensory loss. At follow-up, eleven of these were improved, three were unchanged, and one patient who originally presented with a nerve root lesion was quadraplegic following an open reduction and fusion. (Note: two patients, not included in the study because of insufficient follow-up, presented with complete cord lesions.)

Residual displacement of the original subluxation/dislocation was analyzed. Patients were divided into three groups: reduced, dislocated, or subluxated. Five patients

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**Department of Orthopaedic Surgery, University of Iowa Hospital, Iowa City, Iowa 52242.
***Department of Surgery, Division of Orthopaedic Surgery, University of North Carolina, Chapel Hill, North Carolina 27514.
(23 percent) were reduced at the time of last follow-up (Fig. 1). Nine patients (41 percent) had residual subluxation and eight patients (36 percent) had no reduction of their original displacement.

**Figure 1**
Twenty-three year old male who sustained a unilateral C3-4 perched facet in a motor vehicle accident.

Pain was evaluated and graded as follows: none, mild (occasional aching requiring no medication), moderate (pain which is relieved with non-narcotic medication), and severe (pain which is not relieved with non-narcotic medication). At follow-up there were fifteen patients (72 percent) with no pain. Three patients (14 percent) had mild pain, three patients (14 percent) had moderate pain and there were no patients with severe pain. (One patient had died and was not included in the pain follow-up.)

Pain was then compared to the degree of displacement. Of the five patients who were reduced, three had no pain, one had mild pain and one patient was deceased. Of the nine patients with residual subluxation seven patients had no pain, one patient had mild pain, and one patient had moderate pain. Five of eight patients unreduced at final
follow-up had no pain, one had mild pain, and two had moderate pain. Therefore, only three (18 percent) of the seventeen patients who had either residual subluxation or dislocation had moderate pain and no patients in this group had severe pain.

Residual displacement was then compared with neurologic status. Five patients with reduction included two patients who were neurologically intact throughout their course (Fig. 2), two patients who had improvement of a neurologic deficit, and one patient who had worsening of a neurologic deficit (quadriplegic after an open reduction). Nine patients with residual subluxation included three patients who were neurologically intact throughout (Fig. 3), three patients who had a neurologic deficit which was unchanged and three patients who had improvement of their neurologic deficit. Of the eight patients with no reduction, one had been neurologically intact throughout, one had a neurologic deficit which was unchanged and six had improvement of their neurologic deficit.

**DISCUSSION**

Simultaneous flexion and rotation of the neck has generally been accepted as the mechanism of unilateral facet dislocation. Beaston demonstrated that the interspinous ligament and capsule of the dislocated facet joint needed to be ruptured to produce a unilateral dislocation in isolated cervical spine specimens. He also found that the annulus and posterior ligaments were only minimally damaged. This limited disruption of ligaments prevents the vertebral bodies from overriding more than half of their anteroposterior dimension, an important clinical point in recognizing a unilateral dislocation. In a bilateral dislocation all the major ligaments (i.e., both facet joint capsules, posterior ligaments, intervertebral disc, and sometimes the anterior longitudinal ligament) are thought to be disrupted resulting in gross instability. Because of this instability, the vertebral bodies typically override half of their anteroposterior dimension or greater.

Previous reports stated that about half of the patients with unilateral dislocations were involved in a motor vehi-
Twenty-one year old female who sustained a unilateral C5-6 dislocation following a fall.

Lateral radiograph demonstrating the double facet image above the level of the dislocation.

The diagnosis of a unilateral facet subluxation/dislocation is often overlooked. Braakman found a delay in diagnosis of a unilateral C5-6 dislocation. This compares favorably with our study in which we found 73 percent were a result of a motor vehicle accident and 23 percent were secondary to falls. The most common sites of injury have been reported as the C4-5, C5-6, and C6-7 levels, with over 80 percent of all injuries occurring at these levels. Once again our results were similar with 86 percent of the injuries occurring at these three levels. The most common level in our study was C6-7, comprising 50 percent of our patients.

O'Brien and Braakman reported that neurologic deficit included root lesions in 24 to 27 percent and complete cord lesions in 8 to 20 percent of patients. We found neurologic deficits in sixteen (73 percent) of our twenty-two patients with fifteen of these being root lesions. Among cervical lesions, unilateral dislocations have accounted for 13 to 18 percent in various series.

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**C. R. Clark, E. Wessels, Jr.**

Greater than two weeks in 40 percent of patients. Ten patients (45 percent) in our series had delayed diagnosis. The average delay was approximately three weeks. We found that the major factors leading to a delay in diagnosis included improper interpretation of radiographs (60 percent), associated alcohol intoxication (20 percent), and multiple trauma (10 percent). One patient in our series presented late for treatment.

The key to recognition of a unilateral dislocation is careful scrutiny of the lateral radiograph. Displacement of vertebral bodies and the projection of the dislocated facet through the dislocated body (giving a "bat wing" or "bow tie" appearance) are the classic radiographic features. The anteroposterior view of the cervical spine may show a tilt of the column away from the lesion and rotation of the spinous processes toward the dislocation. Various authors, particularly Beaston, have promoted the use of right anterior and posterior oblique views to determine the site of the lesion. Tomography of the cervical spine can be helpful to locate the dislocation and to delineate any associated fractures. Particular attention must be paid to the radiographs of those patients whose neurologic deficit seems out of proportion to the radiologic picture or whose neurologic status either plateaus or declines. Myelography, computed tomography and possibly magnetic resonance imaging are useful to detect an associated herniated disc.

The goals of treatment of any neck injury are to restore or maintain neurologic function and to provide a stable pain-free neck in a safe and timely manner. Braakman contends that reduction is necessary to relieve root symptoms and to restore normal spinal column anatomy and he felt this was a procedure associated with low risk. However, he does state that there is a tendency to spontaneous stabilization regardless of whether the reduction is carried out or not and that unreduced unilateral dislocations rarely show neurologic deterioration. Indeed the need for complete reduction is controversial. We found that seventeen (77 percent) of our twenty-two patients had residual displacement at follow-up. Despite this, nine of these patients (53 percent) had improvement of their neurologic deficit and fourteen (82 percent) of these patients had no or only mild pain. None of the patients in our series with residual displacement had severe pain or worsening of neurologic function. The single patient in our series who had worsening of their neurologic function had an open reduction of the dislocation and no residual displacement. Therefore, we question the absolute necessity for complete reduction of these injuries and certainly appreciate there may be considerable risk with reduction.

Reduction by manipulation remains an area of controversy. Braakman reported it was often used in the 1930's but generally fell out of use with the introduction of traction and operative reduction. Evans and Burke both strongly recommend the use of closed manipulation under general anesthesia. Both felt it was a safe, rapid method of obtaining a reduction but there has been little support for it in the American literature. One patient in our series had a reduction obtained by manipulation. This patient has done well, however we are concerned about the potential risk associated with this maneuver.

Our current approach to unilateral cervical facet subluxation/dislocation is based on the findings of this series and our review of the literature. Patients are initially placed in skeletal traction and weight is added at five-pound increments every twenty minutes with repeat neurological examination and serial lateral radiographs following each increase. This sequence is continued up to one-third of the patient's body weight or a maximum of sixty pounds, whichever is less. The only manipulation which is permissible is slight, gentle extension of the neck to "unlock" the facet joints. If reduction is achieved, stabilization should be obtained with a cervical orthosis, halo vest, or posterior cervical fusion. If reduction is not achieved or if significant neurologic deficit is present further radiographic investigation (myelography and/or computerized tomography with contrast) should be carried out to rule out retropulsed fragments of the vertebral body or intervertebral disc prior to consideration of surgical intervention. We agree with McAfee and Bohlman that anterior decompression and fusion offers the best chance for neurologic recovery if there is evidence of disc disruption or retropulsed vertebral body fragments. If, however, contrast radiography reveals an intact intervertebral disc without evidence of anterior compression, we prefer posterior stabilization if surgery is felt necessary. This allows good visualization of the dislocated facet, decompression and/or reduction. Surgery is performed with the patient in skeletal traction. The patient undergoes an awake endotracheal intubation and is carefully log-rolled into position with skeletal traction being maintained. Lateral radiographs are obtained to verify alignment and a neurologic exam is performed prior to the induction of anesthesia. Spinal cord monitoring is performed throughout the procedure. We have found surgery to be safe and reliable when this procedure has been followed.

**CONCLUSIONS**

As a result of this review of unilateral facet subluxation/dislocations in the cervical spine, the following conclusions and recommendations for treatment are made:

1) The treatment of unilateral facet subluxation/dislocation has been a perplexing problem for the orthopaedic surgeon. Our approach is presented above.

2) Careful scrutiny of the plain radiograph is essential for prompt diagnosis. Additional radiographic studies may be necessary for confirmation or clarification.

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3) A delay in diagnosis is frequent in this condition and may contribute to the morbidity associated with it.

4) The need for complete reduction of the subluxation/dislocation is controversial. All seventeen patients in our series with residual displacement were functioning well and none had worsening of their neurological deficit or severe pain. Therefore we question the absolute necessity for complete reduction of these injuries.

5) Reduction by manipulation is controversial. If considered, it is perhaps prudent to perform with the patient awake.

BIBLIOGRAPHY


THE ROLE OF BACK SCHOOL

Nancy C. Selby, L.P.T.

Reprint requests to: Nancy Selby, L.P.T., Spine Education Center, 6161 Harry Hines Blvd., Suite 312, Dallas, Texas 75235

Patient education has been fostered by physicians for years, but mostly one-on-one rather than with a formal program. Studies have shown that emergency room visits as well as doctor visits can be reduced through appropriate education1. This frees the physician to have the time to treat those patients who really need his/her expertise.

The concept of back school was introduced in the late 1950's by Dr. Harry Fahrni who designed an educational program for his patients suffering from back pain. This was followed about ten years later by a program designed for Volvo workers by Alf Nachemson and a physical therapist, M. Bergquest-Ullman. The focus was the industrial back injury2. Arthur White, M.D. established the California Back School in 1974 and has continued to promote the concept of training and education for these difficult patients.

Since then back schools have sprung up all over the United States. They range from sound/slide programs available to patients waiting for the physician to examine them, to comprehensive, formal programs involving several sessions. The common denominator is education for the individual suffering from back pain.

Physical therapists have been universally selected as the professionals most qualified to present the information as well as to determine appropriate self-help techniques and exercises.

Although this educational process can certainly be done effectively with one patient and one physical therapist, it is not cost effective for either. Small classes therefore may be more beneficial. Dialogue between patients helps alleviate anxiety and tends to make them less self-conscious about asking questions they may consider nonessential or silly.

The format we have found successful utilizes classes with a maximum of eight participants, scheduled in two sessions held approximately one week apart. An individual session with the therapist is scheduled six weeks after the second session.

Back school components may vary, but most cover anatomy as part of the core program. The majority of these patients are very frightened because they are unable to understand what is happening to them. The use of a plastic spine model is an effective training tool to help promote understanding of the actual makeup of the spine, nerves, joints, and discs. This understanding eliminates many of the myths associated with back pain i.e., "my back's gone out”.

Once patients have a basic grasp of spinal anatomy, these concepts can be reinforced by using visual aids which should be colorful and fun, as well as informative. Disc pressure and posture can be incorporated into the general information in preparation for the most important component of all—body mechanics. Body mechanics are important in sitting, standing, bending, stooping, reaching, pushing, pulling, lifting, sleeping, eating,—basically what we do every day, all day, no matter where we are. Many of the patients unknowingly use such poor body mechanics that they become spine abusers.

Therefore, the emphasis for any back school should be the modification of body mechanics both on and off the job3. The use of slides to introduce these concepts is helpful because it allows the patient to visualize various situations. Correct and incorrect examples may be presented and options may be discussed with the therapist. It is also essential that the therapist identify both job and home activities that are relevant for each group.

Although visual aids can be an effective training tool, they cannot take the place of actual participation using props to duplicate the activities of daily living. Since posture does affect the pressure on the lower spine4, full length mirrors are extremely helpful. Each class member is asked to stand and look at themselves from the side and several options are introduced for changing standing posture. The use of a low stool to prop one foot up will decrease the lordosis; slightly flexed knees while tightening the abdominals and tucking in the buttock will accomplish the same task.

Options are important to the modification process. Therefore, they should be offered to the participants whenever possible. The positions that we concentrate on during the first session are primarily those involving home activities since many of these patients are off work at the time. Sleeping positions, brushing teeth, getting in and out of a chair, bed, or car, sitting postures, child care, food preparation, and other simple household tasks are emphasized.

First aid for back pain is also introduced. Many of the patients are experiencing muscle spasms. Ice massage,
aspirin or anti-inflammatories and stretching are effective first aid techniques for the discomfort.

Each patient is given a simple exercise program during the first session — only three exercises that involve stretching and strengthening, and are encouraged to start a walking program. The exercises are outlined by the therapist. Both flexion and extension are promoted depending on the type of back problem. The patients are then sent home to work on their body mechanics and exercise program, and return the following week for additional instruction.

The second session covers more job related activities and labor related jobs at home. For example, lifting, pushing, pulling, etc. are covered. Stress, sex, nutrition, and recreational activities as they relate to back pain are also discussed. Three or four additional exercises are given to the patient, again emphasizing stretching and strengthening. The laboratory is then used to practice these techniques further.

All participants are provided with a packet of information reinforcing the concepts they have learned. They return in six weeks and are encouraged to contact the back school if they have any difficulty with the activities. The doctor receives a progress report based on the therapist’s observations.

Back school benefits the patient and the physician. The patients have as much time as they need to ask questions. They learn to modify their daily activities so they are more comfortable both at home and at work. They can control their back pain most of the time. The physician enjoys increased success in treating patients with back pain and a reduction of panic calls at inappropriate times. Educated individuals are willing to take more responsibility for their own back care. The use of back school is a valuable tool the physician can use to evaluate and treat the patient while returning him/her to function.

REFERENCES

GLUTEUS MAXIMUS ISLAND FLAP REPLACEMENT FOR IRREPARABLE PARASPINAL MUSCLE DAMAGE

A PRELIMINARY REPORT

H.V. Crock, A.O., M.D., M.S., F.R.C.S., F.R.A.C.S.
B.M. Jones, M.S., F.R.C.S.
23 Lexham Gardens
London, England W85JJ

Surgical approaches to the lumbar spine most commonly involve separation of the paraspinal muscles and the use of self-retaining retractors. Where posterior fusion is added to procedures for exploration of the spinal canal, the paraspinal muscles may be forcibly retracted. In many cases, quite large volumes of muscle tissue may be excised to allow adequate exposure of the proposed graft beds, especially in patients with bulky sacrospinalis muscles.

Descriptions of surgical techniques for laminectomy for disc prolapse, spinal canal decompression, and the various posterior or posterolateral spinal fusion procedures rarely focus attention on the handling or fate of the paraspinal muscles.1,3

The paraspinal muscles may be extensively damaged in the course of surgical approaches to the lumbar spine. Pathological changes ranging from intramuscular fibrosis to dense chondrifying metaplasia of infarcted muscle tissue and varying grades of myositis ossificans are all too frequently found in patients who have had multiple spinal operations.

Attention to the care of these muscles during surgery should be of prime concern.

In this short preliminary communication, we present one solution to the management of irreparable damage to the lumbar paraspinal muscles in a patient who had had eleven lumbar spine operations.

A forty-six year-old white female presented with progressive loss of power in her legs, chronic constipation, and impaired bladder function, with severe back and bilateral leg pain.

This unfortunate lady had submitted previously to eleven operations on her lumbar spine. The procedures included partial laminectomy, posterior lumbar interbody fusion at L4-5 level, anterior lumbar interbody fusions at L4-5 and L5-S1, posterior instrumentation with Knodt rods from L3 to S2, and intertransverse alar fusions from L3 to sacrum. These procedures were followed by removal of Knodt rods, then bilateral lateral release of abdominal muscles and paraspinal muscles to facilitate scar tissue closure over the laminal remnants.

Leaving aside any critical analysis of decision making and of the preceding multiple surgical procedures, we advised this patient to submit to yet another complex operation—based on our assessment of her clinical problems in October 1986.

She had developed arachnoiditis of the cauda equina and her lumbar paraspinal muscles from L3 to the level of the sacrum had been irreparably damaged. We recommended radical excision of the damaged paraspinal muscles, extensive spinal canal decompression, dural splitting over the area of the arachnoiditis, and closure of the spinal defect with a free vascularised muscle flap. The plan had been to use a free vascularised latissimus dorsi flap.

After excising the scarred, chondrified tissues down to the level of the spinal canal, the surgical decompression of the bony canal was followed by dural splitting and separation of the thickened arachnoid from the inner surface of the dural sac. Some ossification was noted along one of the filaments of the cauda equina. No attempt was made to dissect the arachnoid membrane.

Attempts were then made to isolate satisfactory vessels for anastomosis to the artery and veins of the planned latissimus dorsi free flap. The subcostal vessels were too small and access to the lumbar vessels for anastomosis proved impractical. A massive gluteus maximus island flap was then designed (Figures 1-4) sutting the margins of the muscle to remnants of muscle and dense scar tissues around the edges of the defect in the spine.

Figure 1
A schematic drawing to show the extent of the spinal canal decompression in this patient with bilateral intertransverse alar fusions from L3 to sacrum. The dorsal sac was opaque and firm. The relationship of branches of the superior gluteal vessels on the outer surface of the right ilium are shown.
Gluteus Maximus Island Flap Replacement

On review in February 1987 the back wound had healed and the transposed muscle was supple.

Early recovery of bladder function has occurred and the level of this patient's physical activity has improved compared with her preoperative condition.

DISCUSSION

The gluteus maximus muscle may be rotated locally in dealing with indolent buttock ulcers and a range of other problems in the region of the perineum and sacrum. We believe this is the first account of the use of a massive gluteus maximus muscle flap, based on the superior gluteal vessels, to close a large defect in the lumbar spine following irreparable damage to the paraspinal muscles.

REFERENCES

PRIMARY TUMORS OF THE SPINE

Robert F. McLain, M.D.
James N. Weinstein, D. O.
Department of Orthopaedics
University of Iowa Hospitals and Clinics
Iowa City, Iowa 52240

INTRODUCTION

Primary tumors of the spine are uncommon lesions, accounting for less than 10 percent of all bone tumors. Primary neoplasms are far less common in the spine than are metastatic lesions, particularly in adult patients. Nevertheless, a wide variety of primary tumors may arise from the bone and soft tissue components of the spinal column. Simply identifying the presence of a tumor may require a high index of suspicion, since the most common early symptom is back pain — an almost universal complaint. Symptoms of night pain, pain at rest, or a neurologic deficit should prompt the consideration of a spinal neoplasm. Because of the difficulties associated with operative procedures about the spine, early detection and treatment is imperative. Patients presenting with large soft tissue masses, bowel obstruction, or dense neurologic deficits have missed their best opportunity for curative therapy. Their prognosis is much poorer than those identified earlier.

We have reviewed all cases of primary tumors of the spine treated at the University of Iowa between 1935 and 1985, with the purpose of identifying specific clinical features that might aid in differentiating benign and malignant lesions of the spine, thereby aiding treatment. We also sought to compare the long-term results of treatment of primary benign and malignant tumors of the spine, with respect to local recurrence and survival. Outcomes were compared both on the basis of tumor types and the extent of surgical resection.

MATERIALS AND METHODS

The charts and radiographs of 103 patients with the diagnosis of primary tumor of the spine were reviewed. Twenty-one patients were excluded because of inadequate documentation, previous treatment at another facility, or incomplete evaluation for metastatic or disseminated disease. Original histologic specimens were reviewed for all cases in which surgical material was obtained, representing seventy-nine of eighty-two cases (96 percent).

Patients in this series were seen and treated at the University of Iowa Hospital between 1935 and 1985. Surgical and medical treatment differed significantly over the five decades reviewed, and patients were cared for by three different surgical services. Operative records and pathology reports were reviewed in order to determine the type of treatment utilized and the extent of the initial surgical excision. Original radiographs were available in 45 percent of our cases, while detailed radiographic reports were available for all of the cases included. Cases lacking clear descriptions of radiographic findings or available radiographs were not included.

Of the eighty-two patients included in this series there were forty-two men and forty women. Patients ranged in age from 2.5 to eighty-nine years. There were thirty-one patients eighteen years or younger. Mean follow-up was 9.7 years in benign lesions, and 3.8 years in patients with malignancy.

RESULTS

The clinical presentation varied considerably from patient to patient, but pain was the primary complaint of most patients (Tables 1 & 2). Only thirteen patients denied pain on presentation. Overall, 84 percent of patients presented with some complaint of pain, either localized back pain (60 percent), or radicular pain (24 percent). There was no difference between the benign and malignant groups with respect to pain symptoms.

<table>
<thead>
<tr>
<th>Patterns of Presenting Symptoms</th>
<th>Number</th>
<th>Percent</th>
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<tbody>
<tr>
<td>Back pain</td>
<td>25</td>
<td>30.5</td>
</tr>
<tr>
<td>Radicular pain</td>
<td>8</td>
<td>9.8</td>
</tr>
<tr>
<td>Weakness</td>
<td>7</td>
<td>8.5</td>
</tr>
<tr>
<td>Back pain and weakness</td>
<td>15</td>
<td>18.3</td>
</tr>
<tr>
<td>Radicular pain and weakness</td>
<td>8</td>
<td>9.8</td>
</tr>
<tr>
<td>Mass</td>
<td>4</td>
<td>4.9</td>
</tr>
<tr>
<td>Pain and mass</td>
<td>9</td>
<td>11.0</td>
</tr>
<tr>
<td>Pain, weakness and bowel and bladder dysfunction</td>
<td>4</td>
<td>4.9</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>2</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Forty-one percent of patients complained of a subjective sense of weakness on initial presentation. Weakness was the only complaint in seven patients, but was a component
of the presentation in twenty-seven others. Several patients presented with paraparesis or paraplegia.

At the time of the initial clinical examination, an objective neurologic deficit could be identified in 55 percent of patients with malignancies, but only 35 percent of patients with benign lesions (p < .1). Rapidly progressive neurologic deficits were more common with malignancy, due either to pathologic fracture or rapid tumor expansion.

A palpable mass was detectable in 16 percent (thirteen) of cases reviewed. Of these, only four were painless, and all four of these proved to be malignant.

The interval from onset of symptoms to diagnosis was frequently prolonged, particularly in the case of benign lesions. The mean interval to diagnosis for patients with malignancy was 10.4 months, and for those with benign lesions, 19.3 months. Overall, 74 percent of all patients were diagnosed within one year of the onset of their symptoms. The most common cause for delay in diagnosis was the patient's delay in seeking medical attention.

Plain radiographs demonstrated the lesion in eighty-one cases, (99 percent). The only case in which plain radiographs were unable to demonstrate the lesion involved a Ewing's sarcoma of the thoracic spine which presented with signs of cord compression prior to radiographic changes in the bone. Cortical disruption and/or soft tissue mass were common in both benign and malignant lesions and could be identified in 61 percent of cases. Myelography was utilized in 33 percent of cases. CT scanning was used in only 10 percent of cases due to its recent development.

All spinal segments were involved (Table 3). The cervical spine was least frequently involved and no malignant lesions were identified there.

### Table 3

<table>
<thead>
<tr>
<th>Segment</th>
<th>Benign</th>
<th>Malignant</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Thoracic</td>
<td>12</td>
<td>21</td>
<td>33</td>
</tr>
<tr>
<td>Lumbar</td>
<td>6</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Sacrococcygeal</td>
<td>7</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>51</td>
<td>82</td>
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</tbody>
</table>

Sixty-six percent of all lesions arose in the vertebral body. Of these, 76 percent proved to be malignant. Of those lesions arising in the posterior elements only 36 percent proved to be malignant. Overall, 80 percent of all malignant tumors and 42 percent of all benign tumors were found to occur in the vertebral body (p < .0005).

There was a significant correlation between age at diagnosis and the incidence of malignancy. The mean age at diagnosis was 48.7 years for patients with malignancy and 20.9 years for patients with benign tumors (p < .0001). Of the thirty-one patients aged eighteen or younger, 68 percent had benign and 32 percent had malignant lesions. Of the fifty-one patients older than eighteen, 80 percent had malignant tumors (p < .0001).

### Table 4

<table>
<thead>
<tr>
<th></th>
<th>Benign</th>
<th>Malignant</th>
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<tr>
<td>Mean age at diagnosis</td>
<td>20.9</td>
<td>48.7</td>
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<tr>
<td>Age greater than 18 years</td>
<td>32%</td>
<td>80%</td>
<td>.0001</td>
</tr>
<tr>
<td>Neurologic deficit</td>
<td>35%</td>
<td>55%</td>
<td>.1</td>
</tr>
<tr>
<td>Anterior location</td>
<td>42%</td>
<td>80%</td>
<td>.0005</td>
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Histologic material was obtained in seventy-nine of eighty-two cases. No biopsy was performed in three cases in which radiographic changes were classic for benign neoplasm. Two of the seventy-nine specimens reviewed were obtained from metastatic lesions at sites distant to the spine. A needle biopsy was performed in eight patients, and was the only biopsy in two. The other six went on to open biopsy or an attempt at surgical excision, as was performed in the remaining seventy-one patients. Needle biopsy provided the correct diagnosis in six of eight cases in this series. Open biopsy provided the correct diagnosis in every case.

### Table 5

<table>
<thead>
<tr>
<th>Tumor Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteoblastoma</td>
<td>7</td>
</tr>
<tr>
<td>Osteochondroma</td>
<td>7</td>
</tr>
<tr>
<td>Giant Cell Tumor</td>
<td>5</td>
</tr>
<tr>
<td>Aneurysmal Bone Cyst</td>
<td>4</td>
</tr>
<tr>
<td>Hemangioma</td>
<td>3</td>
</tr>
<tr>
<td>Osteoid Osteoma</td>
<td>2</td>
</tr>
<tr>
<td>Eosinophilic Granuloma</td>
<td>2</td>
</tr>
<tr>
<td>Angiolipoma</td>
<td>1</td>
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</tbody>
</table>

Seventeen different tumor types were identified: eight benign and nine malignant. Osteoblastomas and osteochondromas were the most common benign tumors, making up nearly half of this group (Table 5). Solitary plasmacytomas and chordomas were the most prevalent.
malignant tumors (Table 6). Of the six giant cell tumors identified in this series, five were benign and one was felt to have malignant histologic characteristics at initial excision.

### Table 6

<table>
<thead>
<tr>
<th>Malignant Tumors</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solitary Plasmacytoma</td>
<td>15</td>
</tr>
<tr>
<td>Chordoma</td>
<td>14</td>
</tr>
<tr>
<td>Chondrosarcoma</td>
<td>6</td>
</tr>
<tr>
<td>Lymphoma</td>
<td>5</td>
</tr>
<tr>
<td>Ewing's Sarcoma</td>
<td>4</td>
</tr>
<tr>
<td>Osteosarcoma</td>
<td>3</td>
</tr>
<tr>
<td>Fibrosarcoma</td>
<td>2</td>
</tr>
<tr>
<td>Malignant Giant Cell Tumor</td>
<td>1</td>
</tr>
<tr>
<td>Angiosarcoma</td>
<td>1</td>
</tr>
</tbody>
</table>

**TREATMENT AND OUTCOME**

Surgical treatment was divided into five groups according to the extent of the initial surgical excision: none, biopsy only, curettage, partial resection, or complete excision. In addition to surgical treatment, forty-two patients received radiotherapy as part of their initial treatment.

**Benign Tumors:**

The overall five-year survival rate for patients with benign tumors of the spine was 86 percent. There was no significant relationship between the extent of initial excision and either survival or recurrence rate, except in the case of benign giant cell tumors. When compared to other benign lesions, giant cell tumors demonstrated an aggressive tendency towards local recurrence, with two of the five patients eventually dying from extensive recurrences and cord compromise. Aside from the giant cell tumor patients, the only patient to die from a benign spinal neoplasm presented with a massive sacral osteoblastoma which was unresectable.

Local recurrence was seen in 21 percent of patients undergoing surgical treatment of their lesions, but half of these recurrences occurred in the giant cell tumor group. Sixty-six percent of local recurrences were apparent within the first year. One patient with a benign giant cell tumor suffered a malignant transformation following biopsy and irradiation.

**Malignant Tumors:**

Among the malignant lesions, survival varied with the extent of the initial surgical excision and tended to vary with tumor type.

Overall survival was greatest in the chondrosarcoma and solitary plasmacytoma groups (Table 7), and least for those patients with osteosarcoma and lymphoma. The only neoplasm associated with greater than 50 percent five-year survival was the solitary plasmacytoma. In order to eliminate any bias introduced by the relatively few long-term survivors in each group, survival data was truncated to a maximum of sixty months when survival exceeded sixty months. No statistically significant difference was seen between the various tumor groups, though the group of patients with solitary plasmacytoma did show a strong trend toward longer survival (p < .06).

### Table 7

| Survival in patients with malignancy, by tumor type. (Survival scores truncated to 60 months) |
|---------------------------------|-----------------|-----------------|
| Tumor Type                      | N   | Mean Survival (Months) |
| Solitary Plasmacytoma           | 15  | 38.27 (months)         |
| Chondrosarcoma                  | 4   | 28.00              |
| Chordoma                        | 11  | 27.73              |
| Ewing's Sarcoma                 | 4   | 27.50              |
| Osteogenic Sarcoma              | 3   | 18.33              |
| Lymphoma                        | 5   | 13.40              |
| Others                          | 4   | 36.25              |

| 46 (5 patients lost to follow-up) |

There was a significant correlation between survival and the extent of the initial surgical excision (Table 8). Patients treated nonsurgically had a mean survival of seventeen months (survival truncated to sixty months) with only 15 percent of the cases surviving five years. Data for those treated with biopsy only, curettage and incomplete resection are presented in Table 8. The best results were with complete excision of the lesion at initial surgery. These patients had a mean survival of 48.4 months, and a five-year survival rate of 75 percent. This was significantly better than either curettage or incomplete resection (p < .003).

### Table 8

<table>
<thead>
<tr>
<th>Survival in patients with malignancy, by surgical excision. (Survival scores truncated to 60 months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Surgical Treatment</td>
</tr>
<tr>
<td>None</td>
</tr>
<tr>
<td>Curettage</td>
</tr>
<tr>
<td>Incomplete Resection</td>
</tr>
<tr>
<td>Biopsy Only</td>
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<tr>
<td>Complete Excision</td>
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46 (5 patients lost to follow-up)

The group of patients with solitary plasmacytomas had the greatest mean survival, irrespective of surgical treat-
ment. This was thought to be due to their unique radiosensitivity. In order to determine what bias, if any, this patient group might have introduced into our results, mean and five-year survivals were calculated excluding patients with this diagnosis. There was no significant change in the relative outcome among surgical groups, and complete excision demonstrated a significantly improved survival when compared to other treatment groups.

Local recurrence occurred in eleven patients (21 percent) with malignant tumors. Recurrence was clearly associated with specific tumor types: six of eleven chordoma patients, two of four chondrosarcoma patients and the malignant giant cell tumor patient. Seventy percent of all recurrent lesions manifested in the first two years following surgery.

Metastases:

Metastatic disease developed in fourteen patients during follow-up. The most common sites of metastasis were the lungs and other bones of the axial skeleton. The prognosis for patients with metastases from their spinal lesion was poor, with a mean survival of eleven months following discovery of the metastasis. Seventy percent of these patients died within one year of the diagnosis of their metastatic disease, and none survived three years.

Back Pain:

Residual back pain was a significant problem for patients in this review. Pain was reported at follow-up in forty-four of our eighty-two cases, and was significant enough to warrant further surgery in nine cases (11 percent).

DISCUSSION

Primary tumors of the bone or connective tissue of the spine are uncommon and are seen much less frequently than either primary tumors of the extremities or metastatic tumors of the spine. In the past, the treatment of primary spine tumors has been based on small series of tumors or extrapolated from the treatment of tumors in other regions, and has been highly variable. The process of diagnosis and staging has been poorly established for these lesions until recently and the unique anatomy and function of the spine have made application of surgical principles established for tumors of the extremities difficult.

In recent years several authors have directly addressed the problems encountered in the diagnosis and treatment of primary spine tumors. Sachs et al. recently reported twenty cases of primary spinal neoplasm, representing a wide variety of tumor types. They found a very strong correlation between patient age and the likelihood of malignancy, and noted a high incidence of late instability in surgically treated patients who were not stabilized at their initial surgery. Sim et al. likewise noted an association of older age with malignancy in their review of spinal lesions simulating herniated nucleus pulposus. The results of our study confirm these observations: spinal lesions in older patients are most frequently malignant; spinal lesions in children and adolescents are usually benign.

When one considers metastatic disease in the differential diagnosis of an elderly patient, the likelihood of malignancy is increased substantially. Benign neoplasms are a rare finding in elderly patients with spinal lesions.

Malignant lesions also appear to have an affinity for the vertebral body, while benign lesions tend to be more evenly distributed between the anterior and posterior elements, with some lesions (osteoid osteoma, osteoblastoma) showing a strong predilection for the posterior elements, and others (hemangioma, eosinophilic granuloma) predominantly found anteriorly. In our series, the majority of malignancies were found to arise in the vertebral body, and the majority of lesions found in the vertebral body were malignant.

Among the physical findings associated with tumors of the spine was a relatively high incidence of neurologic abnormalities. Shives et al. noted a 70 percent incidence of neurologic signs and symptoms on initial presentation in patients with osteosarcoma. Thommesen and Sim reported a significantly higher rate of neurologic deficits in patients with malignancy than in those with benign lesions. The same finding was present in our series. Nonetheless, the frequency of neurologic signs was greater than 30 percent in the benign lesions. Any patient with a neurologic deficit and back pain warrants a careful radiographic evaluation before the diagnosis of herniated nucleus pulposus is established.

Most authors agree that plain radiographs are indicated in any patient with back pain of unclear etiology, but there is some disagreement as to how sensitive plain films are for spinal tumors. In this series, 99 percent of all tumors could be identified on the initial radiographs. Though a specific diagnosis could not be reached in many cases based on plain films alone, the presence of a spinal lesion was recognized in all but one case. Plain radiographs also provided important information on the benign or malignant nature of the tumor and the presence of soft tissue extension or cortical disruption in individual cases.

Outcome in spinal tumors, as in tumors of the extremities, is distinctly related to the benign or malignant nature of the particular tumor studied. Outcome in benign lesions is typically quite good, with relatively little long-term morbidity and very low mortality rates. Neurologic deficits usually resolve following adequate treatment. Scoliosis and back pain are frequently seen in patients with benign tumors, particularly with osteoid osteoma, and may be present for some time before a neoplasm is suspected. Our results confirm the good prognosis expected of benign lesions.
It is important to emphasize that benign giant cell tumors do not share the same favorable prognosis as other benign lesions. Considered by some to be low-grade malignancies, these lesions behave in a locally aggressive manner which can be particularly menacing in the spinal column. Though some authors have argued that these tumors have a better prognosis than do extremity lesions, their tendency towards aggressive local extension and their high rate of local recurrence make giant cell tumors a more difficult problem to manage than other benign tumors. In our series, these tumors resulted in significant morbidity and mortality, and we would approach them more aggressively than any other benign tumor. Curettage should be avoided in favor of excision to minimize local recurrence and subsequent morbidity and mortality.

The prognosis for patients with malignant lesions of the spine tends to be poor. Surgical resection of the tumor is technically difficult and clear margins may be unattainable. Local recurrence can be a disaster even in slow growing tumors.

Although long-term survival is uniformly poor, short-term survival does tend to vary with tumor type. Slow growing, locally aggressive tumors such as the chordomas and chondrosarcomas are associated with a longer overall survival, but have a high incidence of local recurrence and are highly lethal in the long run. More rapidly growing lesions, with greater metastatic potential, are associated with an early demise in most cases. Long-term survivals have been reported with multi-modality therapy when comparing the malignant tumor groups in our study we were unable to show any statistically significant difference in survival relative to tumor type, though patients with solitary plasmacytomas demonstrated greater survival time approaching statistical significance. These patients deserve special consideration because of the unique radiosensitivity of their primary lesions. Though most patients with solitary plasmacytoma go on to develop multiple myeloma soon after their diagnosis, the patients included in this series were documented as having no dissemination within two years of the onset of their disease. Radiotherapy must be included in the initial care of these lesions, and follow-up must be oriented towards the early detection of disseminated myeloma.

The single most important factor in the prognosis of the patient with a primary spinal malignancy is the ability to obtain a complete excision at the initial surgery, particularly with respect to the chordomas and chondrosarcomas. Although some authors have advised that attempts at surgical extirpation are fruitless and should not be made, it is clear from our experience that the ability to completely remove the primary tumor played a significant role in the overall survival of our patients. This experience confirms the feelings of other authors that surgical treatment of spinal lesions significantly influences the outcome in malignant lesions, both in terms of longevity and quality of life. We believe that the basic tenants of tumor surgery apply — extirpation allows the best prognosis for local control and cure of the disease.

Our current approach to the patient with an undiagnosed spinal lesion incorporates our current understanding of orthopaedic tumor surgery with the results of this review (Figure 1).

Plain radiographs should be obtained routinely in any patient with persistent back pain or with neurologic deficit. Radiographs should be obtained for any child presenting with back pain, particularly in the presence of a painful scoliosis, and in any elderly patient with acute onset of severe back pain suggestive of pathologic fracture. A myelogram and post-myelographic CT scan are usually helpful in cases of neurologic deficit, and are clearly indicated in cases of progressive deficit, or a deficit that is not consistent with the lesion seen on plain studies. CT scanning is usually most useful for planning surgical treatment. Magnetic resonance imaging (MRI) may occasionally be needed to determine the resectability of tumors with extracortical extension and paraspinous soft tissue mass. MRI may also be helpful in identifying skip lesions or drop metastases in patients with spinal cord involvement.

If a lesion is identified that will require biopsy or excision, a routine screening exam consisting of standard blood work, chest x-ray, clinical examination for common sources of metastatic disease, and a bone scan should be performed. A urinalysis and an IVP should be obtained prior to any surgical intervention to rule out hypernephroma. Inadvertent biopsy of this lesion can lead to massive blood loss. Serum immunolectrophoresis should be performed in older patients presenting with lytic lesions or pathologic fractures to screen for multiple myeloma.

The goals of treatment should focus on: 1) obtaining a definitive diagnosis through an appropriate biopsy or with primary excision, 2) institution of appropriate surgical treatment as indicated by tumor type at the time of the initial procedure, 3) preservation or restoration of normal neurologic function, and 4) maintenance of spinal stability. For some benign tumors no surgical treatment is indicated unless there is neurologic compromise.

This review represents a retrospective analysis of eighty-two primary tumors of the spine seen at our facility over a fifty-year period. There are a number of limitations with any study of this type, particularly when the number of subjects included is relatively small. In this case the broad span of time over which patients were seen introduces considerable inconsistency in terms of diagnostic modalities, treatment techniques, and even the goals and expectations of the treating physicians. Also, because of the retrospective nature of this review we were often dependent on operative and pathology reports to establish the
extent of the initial tumor excision, and we frequently had to rely on radiology reports for descriptions of the lesions seen, as many radiographs had been discarded. Finally, the small number of patients in each tumor or treatment subgroup made statistical analysis of outcome difficult.

Despite these shortcomings, we feel that some significant facts have been revealed and that the conclusions drawn from this series are valid and consistent with many smaller series in the literature.\textsuperscript{17,19,20}
CONCLUSIONS

1. Among patients presenting with primary spinal tumors, malignancy tended to be associated with an older age at diagnosis, a higher frequency of neurologic deficits, and a significantly higher incidence of occurrence in the vertebral body.

2. Plain radiographs proved to be a sensitive screening study for neoplasms of the spine and should be obtained in any patient with persistent back pain or neurologic deficit.

3. Among benign tumors, the margin of excision affected outcome only in giant cell tumors. These tumors demonstrated an aggressive tendency towards recurrence and should be excised as widely as possible at the first operation.

4. Survival among malignant lesions was greatly improved when a complete excision of the tumor was obtained at the initial surgery. Curettage proved ineffective in controlling either locally aggressive or malignant lesions.

REFERENCES


ANEURYSMAL BONE CYST

Eugene R. Mindell, M.D.
Professor and Chairman
Department of Orthopaedic Surgery
State University of New York
at Buffalo
School of Medicine
Buffalo, New York

Aneurysmal bone cyst (ABC) is a cystic, vascular, tumor-like process which expands and destroys bone. Its clinical characteristics cover a broad spectrum ranging from lesions that remain quiescent to aggressive ones that mimic sarcoma.

The initial description of ABC as a distinct clinical-pathologic entity was made by Jaffe and Lichtenstein in 1942. They made particular note of two cases in which the radiographs demonstrated an expanded lesion with a coarse, soap-bubble appearance. At operation, unlike the typical unicameral cyst, these lesions contained unclotted blood. Since then many reports have appeared adding data on criteria for diagnosis; natural history, theories of pathogenesis, relationship to other lesions and responses to treatment. However, many questions remain on proper treatment, prognosis, pathogenesis and natural history.

PATHOLOGIC ABNORMALITIES:

Aneurysmal bone cysts are osteolytic, usually expanding the bone. They may markedly distend part of one cortex and appear aneurysmal. The radiographic hallmark is localized expansion of bone with development of a thin peripheral rim of bone which delineates the edge of the lesion and separates it from adjacent normal soft tissue structures. The ABC may not be as clearly delineated within the bone. When located in the spine they may extend into adjacent vertebrae which can be a helpful diagnostic clue.

Bone scans demonstrate increased uptake, particularly in the peripherhal portions, and decreased uptake in its center. This difference is also noted on angiograms where modest vasculature is noted at the rim and relative avascularity in the center.

The peripheral thin rim of bone can be penetrated very easily with an osteotome. The central portion is to be filled with unclotted blood and contains varying amounts of soft tissue. Although initial bleeding may be quite brisk, it can usually be controlled without difficulty by local pressure, indicating the feeding vessels are small ones. Occasionally, however, brisk bleeding with alarming blood loss may occur, particularly in spine and pelvic locations.

Histologic examination reveals the central tissues to contain blood-filled cavernous sinuses, benign spindle cells and new bony trabeculae. Multinucleated giant cells are present which are usually smaller than those found in giant cell tumors. Histiocytes and foam cells are also encountered. The peripheral rim of new bone if often quite cellular with bone formation and resorption often adjacent to large vascular lakes.

CLINICAL FINDINGS:

Symptoms and signs vary widely from none at all to markedly disabling. Presenting symptoms and signs depend on the location, size, and the presence of pathologic fracture or pressure on adjacent vital structures such as the spinal cord.

The most common locations for aneurysmal bone cysts are in the metaphysis of long tubular bones and the vertebral column. However they have been detected in virtually every part of the skeleton. They are slightly more common in females, most frequently found between the ages of ten to twenty, and are rare after age thirty.

The diagnosis is usually suspected from radiographs (Fig. 1). The staging studies often include isotope scans, which demonstrate increased uptake at the reactive rim, and CT scans or tomograms which reveal clearly the thin peripheral rim of bone (Fig. 2). Biopsy is almost always necessary and usually is an open one although fine needle biopsy can sometimes yield adequate tissue. The practical problem is to obtain adequate tissue representative of the lesion.

In children the usual differential diagnosis is from simple bone cyst while in young adults it is from giant cell tumor. However, the possibility of confusing ABC with telangiectatic osteosarcoma must be emphasized.

Tissue grossly and microscopically identical to ABC can be encountered immediately adjacent to other lesions of bone including many benign abnormalities such as fibrous
Figure 1
a) This radiograph of the upper femur in a sixteen-year-old boy with pain and limp for six months demonstrates an aneurysmal bone cyst which has markedly distended the cortex (see arrow).

b) The lesion was successfully removed by marginal excision. This large histosection demonstrates the peripheral rim of new bone (short arrow) and large vascular spaces (long arrow).

c) High power photomicrograph shows a large vascular space. The peripheral bony rim is noted. Septa containing giant cells and benign appearing spindle cells can be seen (Magnification 100x).

Figure 2
CT of an ABC of L4 in a fifteen-year-old girl with mild low back pain for three months. Neurologic exam was normal. The lesion has distended the bone peripherally. Its extension is clearly limited by a thin peripheral rim of bone (see arrow).
dysplasia, giant cell tumor, chondroblastoma, chondromyxoid fibroma, osteoblastoma, and simple cyst, and may even be found in malignant tumors. It has been speculated that the "secondary" ABC develops as a result of bleeding into the primary lesion. These "secondary" ABC's emphasize the great importance of thorough evaluation of the clinical data and radiographs as well as proper examination of an adequate biopsy sample².

PATHOGENESIS:

Although the cause of the ABC remains unknown, Lichtenstein⁷ and others feel the lesion results from a local change in vascular hemodynamics. Several histologically documented cases have developed in children at the site of acute fracture in normal bone suggesting that trauma being the cause or play a role⁴. Its vascular nature has been documented by a few reported pelvic ABC's successfully treated by transcatheter devascularization¹⁰.

TREATMENT:

The results of pelvic ABC's usually reflect their size the of the lesion, symptoms and signs, and threat to normal function. These lesions are not true neoplasms and will often be cured though incompletely removed. Marginal excision is usually the treatment of choice, often consisting of curettage and bone grafting. However, the behavior of the ABC is unpredictable and recurrences are not uncommon. Marginal excision is also the treatment of choice for recurrences unless vital functions are threatened.

Wide excision can be considered in certain locations where such removal is not followed by significant disability. When wide or marginal excision is impractical other methods of treatment should be considered. This includes cryosurgery, cementation and even radiation at a level of 3000-3500 rads. Radiation, however, should only be carried out when the risks of radiation such as sarcoma or myelopathy are less than the risks of surgical removal⁵.

RESULTS OF TREATMENT:

The results depend on the location, type of treatment used and the level of activity of the ABC. Although cure follows wide excision, it may not be indicated if normal function is to be preserved. Marginal excision is followed by a recurrence rate of up to 20 percent¹. Often these recurrences are noted radiographically, do not progress, and may be of little clinical importance. Of great concern, however, is the occasional ABC which, when treated by marginal excision, recurs massively, destroys the bone graft and leads to marked disability. This aggressive, unpredictable behavior unfortunately is quite unusual. Conversely some lesions will subside spontaneously and, although radiographic abnormalities persist, become asymptomatic⁸.

SPINAL ABC:

The spinal column is a common site for aneurysmal bone cyst and presents many unique problems in treatment. We recently studied the 131 cases of ABC in the spine reported in the English literature, plus ten well documented, histologically proven, cases of spinal ABC's of our own which were followed for two to twenty years⁶. Most spinal ABC's were cured by surgical treatment and occasional radiation therapy. Approximately half of the entire group had neurologic deficits varying from mild sensory disturbances to quadriplegia. Two-thirds of the patients with neurologic deficits became normal neurologically after surgical treatment. Most of the surgical procedures were marginal incomplete resections. These results from the literature and from our own ten cases suggest that complete removal is not usually necessary.

The lesions in the spine should be treated by excision of abnormal tissue jeopardizing the neural structures. Spinal fusion is not always necessary although it is occasionally indicated. There is no basis for utilizing radiation therapy routinely. Several sarcomas have developed following irradiation of aneurysmal bone cysts.

Additional long-term studies are needed to document the vagaries of this fascinating entity.

BIBLIOGRAPHY


PERSPECTIVE: ORTHOPAEDIC ONCOLOGY—1986
HUMANISM AND MUSCULOSKELETAL TUMORS

Tribute to Bertil Stener, M.D.
Goteborg University, Goteborg, Sweden
June 7, 1986
by Michael Bonfiglio
Professor, Department of Orthopaedic Surgery
University of Iowa Hospitals and Clinics
Iowa City, Iowa 52242

Many symposia have been devoted to the problem of musculoskeletal tumors2,7,10,12,13. They have dealt extensively with classification and grading of tumors and also with what specific surgery and adjunctive therapy is best for each tumor. While these are clearly important, at no time can the scientific approach to the tumor overshadow the fact that there is a person attached to that tumor requiring an individualized and humanistic approach.

Most orthopaedic oncologists have settled on the World Health Organization (W.H.O.) classification. The Netherlands and Japanese Tumor Registries are relatively minor variations from that adopted by the W.H.O. A controversy has existed over grading tumors and the relative value of grading in determining the prognosis. This is still under consideration in the present discussions on staging of primary malignant tumors of bone. The views of the American Joint Committee1, the Union Internationale Contre le Cancer, and Spanier and Enneking4 as well as those of Suit et al.11 are available.

Although there has been emphasis on limb sparing procedures recently, it must be noted that a few surgeons performed such procedures prior to the last two decades3,9,14. This current emphasis is really a refinement of previous advances. There is considerable use of replacement prostheses with or without methylmethacrylate. The allografts have again had a resurgence of use and of course there are many combinations of these approaches.

The future, in my view, will follow two directions: multicenter studies and laboratory research. Extensive cooperative studies, especially international, evaluating tumor patients in regard to staging systems, treatment, rehabilitation procedures, and biomedical materials would achieve sufficient numbers for statistical purposes.

Such multicenter studies could help answer the following questions. What resection margin is necessary for each particular tumor? Are we overusing radiation and chemotherapy, or doing more surgery than necessary? Is the price of inducing iatrogenic problems worse than the original disease? My patients with radiation-induced pathologic fracture or sarcoma paid a very high price for a relatively short period of primary tumor control. Is the price of prolonged rehabilitation and a variable degree of morbidity after a limb salvage procedure or reconstruction worth the uncertainty of recurrence and the greater risk of metastases?

The second and probably most significant area for the future will be research. One of these will be immunologic studies regarding the use of monoclonal antibodies which are targeted to the tumor to identify micro and macro metastases5,6. The more exciting corollary to that is coupling chemotherapeutic agents to monoclonal antibodies which would then be targeted toward tumor cells. Surgical treatment would still be essential for excision of the bulk of the tumor.

It is not my purpose, however, to explore or suggest any of the myriad of protocols which could be developed for such studies. In my opinion, however, it will be more appropriate to give special emphasis at this symposium to the role of humanism in cancer of the musculoskeletal system so that all we do for and to the patient can be kept in proper perspective.

As orthopaedic surgeons caring for the patient with musculoskeletal tumors, we must assist our patients to understand the stage of the disease at the outset and through its entire course. Our challenge is to balance the scientific aspects of evaluation and treatment with the human concerns about the tumor. How can the patient be best prepared for treatment and still preserve the patient’s psychic if not physical integrity? He needs honesty, understanding and support. We and the patient must learn to live with the uncertainty of the situation and our own finiteness to cope with the situation. These are more than the questions of life and death. They now encompass such questions as can you save the arm or leg? How will I be able to do any number of things?

Once through the evaluation process we must ask ourselves whether the patient or the tumor shall be the focus of our treatment. I think we should be wary of an over concern for the scientific aspects of the tumor and its cure and rigid adherence to a protocol. This could be at the expense of human values relating to the quality of the
patient's life. In my view, these two opposing views are not mutually exclusive.

In sketching the dilemma which we all face, we have only to look at the contributions of Bertil Stener\(^8\) to recognize that he exemplifies the epitomy of a humanistic-scientific approach in the care of patients with musculoskeletal tumors.

An individualized analysis and treatment is the only defensible approach we can take to resolve the problem presented by a patient with an uncommon disease. Such individualized care requires that we must inform the patient, his family, and his community (including religious advisor—priest and/or minister) of all that could happen in a "cold" hospital environment where the radiologist, pathologist, oncologist and radiation therapist will or may be involved in reaching a decision about the patient. The orthopaedic surgeon who does the biopsy is usually considered the person in charge. He therefore serves as the "patient's advocate" even when care is taken over by someone else. The orthopaedist also sees the patient for care after amputation or resection, and is usually the first notified in the event of recurrence. A patient can easily be lost within an institution where no one knows who is in charge.

We must explain the evaluation procedures, the short and long-term effects of surgical treatment, and rehabilitation. An attitude of hope should be conveyed as we present information on the nature of the tumor. At first, the extent of information should be only as much as the patient and his family are capable of understanding. We would be wise to guide but not to dictate a decision toward a particular form of treatment. It is easy to influence a decision toward your wishes and not those of the patient or his family. It makes everyone more comfortable and reassured if you sit down when you talk to the patient and his family rather than standing at the bedside and "talking down" to the patient.

The orthopaedic oncologist gradually develops these communication skills as he involves the patient through each step in a candid, gentle manner, allowing him to accept the reality of the situation and have a part in the decision.

The surgeon must be willing to provide hope and to reassure the patient that he will continue to support him through the entire disease. Such reassurance is essential in order to show you are willing to share failure, although you emphasize success. Some families appreciate knowing the information provided by an autopsy, for example—if only to realize that all that could have been done was.

We all remember the successes but learn more from our failures.

The courage of my patients to endure and accept even small periods of uncertain life has been an inspiration to me and has made an otherwise difficult field bearable. I know of no other area of medicine which calls more on your ability to practice all your skills as a physician, as a surgeon, as a biologist and as a human being than that of orthopaedic oncology. At times musculoskeletal reconstruction after tumor resection requires the conceptual skills of a sculptor. When the result achieves the intended purpose, there is nothing more satisfying to the patient and the surgeon.

REFERENCES

AN ANALYSIS OF CALCIUM PYROPHOSPHATE DIHYDRATE CRYSTAL DEPOSITS IN TRIANGULAR FIBROCARTILAGE COMPLEXES

Richard A. Berger, M.D., Ph.D.
Resident Physician
Department of Orthopaedic Surgery
University of Iowa Hospitals and Clinics
Iowa City, IA 52242

Joseph A. Buckwalter, M.D.
Professor
Department of Orthopaedic Surgery
University of Iowa Hospitals and Clinics
Iowa City, IA 52242

Crystal induced arthritis can be disabling and difficult to treat. Three general types of crystal deposition have been described and related to arthropathic changes: monosodium urate, calcium pyrophosphate dihydrate, and hydroxyapatite. Cholesterol crystals have also been found in joint effusions but have not been shown to be related to articular inflammation in humans. The importance of calcium pyrophosphate dihydrate (CPPD) deposition in articular tissue has only recently been recognized. McCarty and others have defined various classifications of symptomatic CPPD deposition disease or pseudogout. The presence of CPPD crystals in synovial fluid aspirate or synovial biopsy establishes the diagnosis of pseudogout, although clinical and radiographic features are used to support the diagnosis. The knee is the most common joint affected, however CPPD deposition can occur in the hip, shoulder, elbow, ankle, subtalar and wrist joints. CPPD deposition in the wrist is prevalent enough to warrant inclusion of wrist radiographs (along with the symphysis pubis and knee) when screening for CPPD disease.

While investigating the usefulness of arthrotomography of the wrist using fresh cadaver upper extremities, we found several specimens with radiographic signs of CPPD deposition in the triangular fibrocartilage complex (TFCC), (Fig. 1). Encountering a paucity of information regarding crystal deposition specifically in this structure, we decided to study the affected TFCCs using light and scanning electron microscopic techniques.

METHODS AND MATERIALS

In the original arthrotomography investigation, eighteen fresh-frozen cadaveric adult upper extremities were used. The mean age of the specimens was sixty-five years (range, forty-three to eighty-three years). Five wrists showed radiographic evidence of calcification of the TFCC, all of which were found in specimens with arthrotomographic evidence of TFCC defects. After performing the arthrotomographic evaluations in each specimen, the hand was

Figure 1
Relationship of the triangular fibrocartilage complex (TFCC) to the distal radius (R) and Ulna (U). The two most common patterns of TFCC defects are outlined in the upper schematic. Type 1 TFCC defects are narrow linear defects, paralleling the radial insertion of the TFCC, 1 to 2 mm ulnar to the insertion. Type 2 TFCC defects continue in a circular pattern into the central portion of the TFCC.
disarticulated sharply from the forearm at the level of the radiocarpal joint, with care taken to preserve the TFCC. This was initially performed to correlate arthrotomographic images with actual gross observations of the TFCC. In those specimens with TFCC defects noted arthrotomographically and grossly, the TFCC was excised sharply by dividing all fibrous insertions into the radius, ulnar head and styloid, and proximal carpal row. The TFCCs were then fixed in buffered formalin for one week and dehydrated.

The specimens were then transversely mounted in paraffin and cut in 8 micron sections. The superficial-most sections were submitted to deparaffinization using xylene. The deeper sections were stained with either hematoxylin and eosin or Weigert's trichrome stain, then observed and photographed using standard and polarized light microscopy. Those sections deparaffinized were then mounted on a stub, critical point dried, and coated with either carbon or gold. These sections were then examined using a scanning electron microscope and photomicrographs were taken of representative areas. The sections were also submitted to examination by x-ray energy dispersion analysis to determine the elemental composition of different regions.

Additionally, a review of wrist radiographs of all patients diagnosed with pseudogout, CPPD deposition disease, or chondrocalcinosis between 1980 and 1984 at the University of Iowa Hospital and Clinics was made. Of a total of forty-seven patients, ten patients had wrist radiographs taken which showed findings consistent with CPPD deposition disease. These films were observed for patterns of calcification, especially in the region of the TFCC and photographed. None of these patients were noted to have undergone arthographic or arthrotomographic examination of the wrist.

**RESULTS**

1. **Cadaver Study**

In those specimens showing either radiographic evidence of mineralization of the TFCC or arthrotomographic evidence of TFCC defects, no gross evidence of calcification was noted in the substance of the TFCC. Only with microscopy were changes observed consistent with crystal deposition. Even at low power using light microscopy, the appearance of the crystal deposit is striking compared to the homogeneous appearing fibrocartilage (Fig. 2). In sections stained with hematoxylin and eosin, the crystal deposits appeared darkly basophilic and were sharply demarcated from unaffected regions of the TFCC. Numerous fissures were noted within the deposits as well as at the fibrocartilage-crystal interface. These may represent preparation artifacts. There also appeared to be variable densities of deposits, with the less dense crystal deposits having less distinct fibrocartilage-crystal interfaces than the more dense deposits. The polarized light microscopic images confirmed the presence of crystalline structures within the darker staining regions. These areas showed strongly birefringent polarized light transmission in comparison to the typical patterns of polarized light transmitted through collagen in fibrocartilage (Fig. 3). The only locations of crystal deposits in these specimens were in the direct vicinity of the TFCC defects.

Figure 2
Light photomicrograph of CPPD crystal deposits and TFCC. The crystal deposits appear as darkly staining clusters amid normal appearing fibrocartilage. Note the lack of inflammatory cells. The deposits are found near the margins of the TFCC defects (1), however, secondary defects are often noted coursing through the deposits themselves (2), implying mechanical shearing through the crystal-fibrocartilage interface. Hematoxylin and eosin. 63X

Figure 3
Polarized light photomicrograph of CPPD crystal deposits and TFCC. The collagen (col) in the TFCC displays characteristic striations under polarized light, and the crystals in the CPPD deposits (CPPD) show strong birefringence. Hematoxylin and eosin. 63X

The images obtained of crystal-laden fibrocartilage using low power scanning electron microscopy were not dissimilar from light microscopic images. However, the crystalline images appeared white compared to the darker
Electron photomicrograph of TFCC and CPPD crystal deposits. The crystal deposits (C) appear light against the dark background of the fibrocartilage (F). Note the perimeter of crystal deposition forming the margin of a TFCC defect (D). Even at this low power, different densities of crystal packing can be seen, with high density and sharp demarcation found in the central deposit and along the defect, and lower density and less sharp demarcation found in the deposits to the lower left. 160X

Electron photomicrograph of a region of TFCC with sparse CPPD crystal deposition. Note the lack of sharp demarcation between crystal deposits and the underlying TFCC. 440X

Electron photomicrograph of a region of TFCC with low density CPPD crystal deposition. Note the sharp edged crystals appearing to "pierce" through the substance of the TFCC centrally, and the appearance of crystals just beneath the exposed surface of the TFCC (arrows). 4000X

Electron photomicrograph of the interface between CPPD crystal deposits (left) and uninvolved fibrocartilage (right). Note the vertical fissure in the crystal deposits near the far left of the image. 1100X

Electron photomicrograph of a region of ultra-high density CPPD crystal deposition. Note the lack of crystal individuality and apparent blunting of normally sharp-edged crystals. 2400X

fibrocartilage (Fig. 4). Again, crystal deposits were seen with varying degrees of density at both high and low power. Extremely sharp demarcations were seen at the crystal-fibrocartilage interface in regions of dense packing of crystals (Fig. 5), and less well defined demarcation in less densely packed regions (Fig. 6). It was also noted that with more dense packing of crystals, alignment of the crystals seemed to be more parallel (Fig. 5) than in those less dense regions (Fig. 6). Regions of ultra-high density packing were also found, and in general were the largest, most discrete regions of crystal deposition (Fig. 7). In these regions of ultra-high density packing, the crystals were less distinct and appear quite blunted, especially when compared to the long, sharp-edged crystals seen in those areas with sparse crystal packing (Fig. 8).
At higher power, the scanning electron microscope revealed that the crystals were deposited within the substance of the fibrocartilage, and could be seen just underlying the exposed surfaces of the tissues in Figure 8. Crystals could also be seen piercing through the fibrocartilage, disrupting the continuity of the tissue. Although it is difficult to determine if this was present prior to processing, or rather represented an artifact, fissures were seen extending linearly through the crystal deposit superficially and deep into the underlying fibrocartilage. Fissuring was seen primarily in the densely and ultra-densely packed regions (Figs. 5 and 9).

X-ray dispersion analysis of crystal-laden areas revealed elemental calcium and phosphate in proportions consistent with calcium pyrophosphate dihydrate.

![Figure 9](image1)

**Figure 9**
Electron photomicrograph of a region of TFCC with high density CPPD crystal deposition. The crystals in these regions appear to have an overall alignment of long axes and are relatively sharp edged. Note the fissure through crystals and fibrocartilage coursing from the upper left toward the lower right. 2400X

2. **Clinical Study**

The review of wrist radiographs from patients diagnosed with chondrocalcinosis, CPPD deposition disease, and pseudogout revealed several consistent features in the patterns of mineralization of the TFCC (Fig. 10). In each affected TFCC, the most intense mineralization was on the surfaces of the TFCC, i.e., on the surface articulating with the proximal carpal row and the surface articulating with the distal ulna. The deeper aspects of the TFCC appeared to be much less affected, if at all, by calcium deposits. The mineralization radiographically appeared to extend radially to 1 to 2 mm from the insertion of the TFCC into the sigmoid notch of the radius, leaving a crystal-free radial margin of fibrocartilage. If the TFCC is divided into ulnar and radial halves, with the midpoint located at the level of the lunotriquetral joint, the radial half was consistently involved, while the ulnar half variably showed radiographic evidence of mineral deposition. Additionally, the deposits on the proximal and distal surfaces in the radial half of the TFCC appeared to be confluent, a function of the relative thinness of the TFCC in this region.

![Figure 10](image2)

**Figure 10**
Wrist radiograph of a patient with CPPD deposition disease. Note the fine radiodense lines in the TFCC consistent with CPPD crystal deposition. Two distinct lines of radiodensity are seen, one on the carpal surface (C) and the other on the ulnar surface (U). In the radial half of the TFCC, these lines become nearly confluent, compared to divergence of the lines in the ulnar half. A consistent finding is a lack of radiodensity in the region of insertion of the TFCC into the radius (R). Note also the scapholunate diastasis and radiodensity of the scapholunate interosseous ligament (SL).

**DISCUSSION**

The exact mechanism of crystal deposition and the requisite conditions leading to that deposition are not fully understood, although substantial research is being carried out currently to study this phenomenon. The predilection of the wrist, especially the triangular fibrocartilage complex (TFCC) to calcium pyrophosphate dihydrate (CPPD) crystal deposition is well documented. Our study of cadaver and patient radiographs revealed consistent patterns of deposition not previously mentioned in the literature which may lend insight into the mechanism of deposition. It was discovered that the crystals appear to
be deposited on or very near the articular surfaces of the fibrocartilage. In the ulnar half of the TFCC, this results in two distinct layers of mineral deposits, one lining the distal or carpal articular surface, and one lining the proximal or ulnar articular surface. In the radial half, the same phenomenon is observed. However, due to the relative thinness of the radial half of the TFCC compared with the ulnar half, this in effect results in crystal deposition throughout the thickness of the radial half of the TFCC. Additionally, as observed in the patient radiograph series, mineralization consistently occurred in the radial half of the TFCC, and only variably in the ulnar half. Finally, a section of mineral-free TFCC was consistently noted in the insertion zone of the TFCC into the radius averaging an estimated 1 to 2 mm in width.

Although the number of specimens in our cadaveric study was low, the correlation between TFCC defects and the discovery of CPPD crystals was high. Five of the eight specimens with TFCC defects exhibited radiographic and histologic evidence of mineralization of the fibrocartilage. Although a cause and effect relationship cannot be determined, there does seem to be a strong association between traumatic and/or degenerative disruption of the TFCC and CPPD crystal deposition. Mikic found gross evidence of TFCC calcification in only two of twenty-nine individuals studied over the age of sixty. He did not address the frequency of calcification in other age groups, microscopic analysis, or any relationship to defects in the TFCC. Resnick and Utsinger found no clinical cases determined arthrographically in which TFCC defects were associated with chondrocalcinosis of the TFCC. They did not, however, discuss the total number of patients in their series with TFCC involvement with systemic chondrocalcinosis and did not discuss any patients presenting with isolated mineralization of the TFCC. In our series of cadaver specimens the medical records were not available, hence the existence of clinical CPPD deposition disease, symptomatic or otherwise, was not known. However, the high correlation between microscopically evident CPPD crystal deposition and TFCC defects, and the close proximity of the crystals to the margins of the defects, lends itself to the hypothesis of a relationship between the two phenomena. This is furthered by the observation of the location of the defects and the distribution of the deposits within the radial half of the TFCC. It is also interesting to note that no crystal deposition was noted within 1 to 2 mm of the insertion of the TFCC into the radius. It seems possible then that the crystal deposits are secondary to primary disruption of the TFCC, independent of other joint involvement with chondrocalcinosis. Alternatively the crystal deposition, assuming systemic chondrocalcinosis is present, may in part be responsible for initiating degenerative changes in the TFCC. Possibly both mechanisms are involved.

When observing the patterns of distribution of crystal deposits in fibrocartilage, it has been emphasized that the packing of the crystals developed in a way which sharply demarcates the deposits from surrounding uninvolved fibrocartilage. It has also been demonstrated that the crystals pierce through the substance of the fibrocartilage, producing what morphologically appears to be disruption of the continuity of the fibrocartilage. It is not difficult to imagine the sheer stresses that would be generated at the interface between the stiff crystal-laden fibrocartilage and the resilient uninvolved tissue. The combination of the above factors may be responsible for initiation of a tear of the TFCC. It is not known what prevents crystal deposition in the marginal regions of the TFCC and why TFCC defects do not penetrate these same regions. The relatively higher degree of vascularity in these regions as demonstrated by Mikic may be a factor.

Finally, the usefulness of scanning electron microscopy in studying the crystal deposits should be emphasized. The resolution and depth of field afforded as well as an ability to survey the surfaces of structures such as the TFCC in the wrist gave significant insight into patterns of crystal deposition in this study. Only one previous published report using scanning electron microscopy in evaluation of CPPD crystals was found. As in that study, we found the morphology of the crystals to be characteristic of CPPD and found variations in crystal packing which were not appreciated using light microscopy. Additionally the combined use of scanning electron microscopy and x-ray energy dispersion analysis proved to be very helpful in confirming the elemental composition of the crystals.

**SUMMARY**

This investigation studied calcium pyrophosphate dihydrate (CPPD) crystal deposition in the triangular fibrocartilage complexes (TFCC) from the wrist of five cadaver specimens using light and scanning electron microscopy. Additionally wrist radiographs from ten patients with clinical diagnosis of CPPD disease, chondrocalcinosis or pseudogout were analyzed for mineralization patterns in the TFCC. The fundamental findings are summarized below:

1) CPPD crystals tend to be deposited in clusters, the margins of which are generally sharply demarcated from uninvolved fibrocartilage.

2) The density of crystal packing within these clusters is variable and is directly proportional to the sharpness of demarcation of the clusters from surrounding tissue.

3) An association was noted between the location of CPPD crystals in the TFCC and TFCC defects.

4) In radiographs of patients with clinical evidence of CPPD deposition, mineralization was consistently located in the radial half of the TFCC, and only variably found in the ulnar half.
5) Scanning electron microscopy with x-ray energy dispersion analysis capability provides a useful tool in evaluating morphologic and elemental chemical features of crystal deposits and their relationship to surrounding tissues.

REFERENCES

INTRAOSSEOUS CARPAL GANGLIONS

Stephen H. Noel, M.D.
William D. Engber, M.D.
University of Wisconsin
Division of Orthopedic Surgery
600 Highland Avenue
Madison, WI 53792

Ganglion cysts arising from the wrist joint capsule are a common clinical entity. A similar pathologic process occurring intraosseously in the carpal bones has only rarely been reported. We present two cases of intraosseous ganglions of the scaphoid which were successfully treated by curettage and bone grafting. The literature on these rare intraosseous lesions will be reviewed.

CASE REPORTS

Case 1

A twenty-nine-year-old, right-handed seamstress, gave a one-year history of progressive left wrist pain. She noted pain on the dorsal radial aspect of the wrist that was exacerbated by activities such as pinching and grasping. She had occasionally been awakened at night with pain. Conservative management including splinting of the wrist, intra-articular steroid injection, and oral anti-inflammatories failed to relieve her symptoms.

On physical examination, palmar flexion was limited to 50 degrees with pain at the extremes. There was marked tenderness to palpation in the anatomic snuffbox. The remainder of the exam was negative.

Complete blood count with differential, sedimentation rate, chemistry survey, and electrolytes were unremarkable.

Radiographic evaluation over an eleven-month period showed an enlarging lytic lesion in the distal pole of the scaphoid (Fig. 1a). Tomograms identified an eight mm, well-defined, distal pole lesion surrounded by a faint sclerotic border (Fig. 1b).

Due to failure of conservative measures, operative management was undertaken. A volar radial incision was utilized to expose the scaphoid. The distal pole of the scaphoid was expanded and slightly discolored with a reddish-gray hue. Gelatinous material surrounded by a fibrous capsule filled the defect. After complete curettage, the lesion was packed with autogenous cancellous iliac crest bone graft.

The gross specimen consisted of the white fibrous tissue which lined the intraosseous cyst. Microscopic examination showed hyalinized fibrous tissue with crypt-like....

Figure 1a
Plain radiograph demonstrating lytic lesion distal pole of the scaphoid.

Figure 1b
Tomogram of same lesion in Fig. 1a, demonstrating an 8mm, well-defined lesion with faint sclerotic border.
spaces lined with a single flat layer of lining cells. Pathologic diagnosis was ganglion cyst (Fig. 2).

She had an unremarkable postoperative course. At seven months she had no residual pain or tenderness and her radiographs showed complete incorporation of graft.

**Case 2**

A thirty-eight-year-old, right-handed secretary gave a ten-year history of dull pain on the dorsal radial aspect of her right wrist. The pain caused her to limit her recreational activities such as swimming, writing, and drawing. She had undergone a course of conservative therapy including oral anti-inflammatories and splinting which failed to give relief.

Physical examination was significant for tenderness in the anatomic snuffbox and volarly at the proximal pole of the navicular. The remainder of her exam was normal.

Laboratory evaluation was unremarkable.

Plain radiographs revealed an oval lytic lesion in the proximal pole of the scaphoid. Tomograms showed the lesion to be along the proximal volar cortex and surrounded by a sclerotic border.

As in the previous case, conservative measures failed. Therefore, the lesion was explored. The operative findings were consistent with a ganglion which was curetted and grafted as above. The wrist joint was explored and no articular defects were identified.

Microscopic pathologic examination showed fragments of fibrous tissue and bone without evidence of malignancy.

She was placed in a thumb spica cast for seven weeks after which time there was evidence of early incorporation of the graft. At five months postoperatively, the patient had no wrist pain and good range of motion. Her radiographs showed continued graft incorporation.

**DISCUSSION**

Intraosseous ganglions in the carpal bones have been only rarely reported. This lesion has been described in the capitate, lunate, pisiform, scaphoid, and proximal phalanx.

Radiolucent lesions in the carpal bones are not uncommon and they are often seen incidentally in asymptomatic patients. The differential diagnosis of a single lytic lesion in a carpal bone includes enchondroma, giant cell tumor, chondroblastoma, uncameral bone cyst, degenerative cyst, fibrous developmental defect, osteomyelitis, and intraosseous ganglion cyst. Radiographic findings of uniform lytic density, surrounding sclerosis, and eccentric placement are suggestive of, but not diagnostic for, an intraosseous ganglion.

Appropriate clinical management of an isolated symptomatic cystic carpal lesion begins with a trial of conservative therapy. Aspirin, or nonsteroidal anti-inflammatories, and splinting are advised. Repeat plain radiographs are important to monitor for changes. Our operative indications are: 1) failure of conservative modalities to provide adequate relief of symptoms; 2) suspicious radiographic change; and 3) progression of the lesion.

Further studies prior to operative intervention have been described. Bower's report on a technetium pyrophosphate scan of an intraosseous and intracarpal ganglion lesion showed increased early blood pool and delayed uptake images. This was used primarily as a research test and he declined to advocate this as a standard preoperative study. We feel that this test would contribute little to clinical decision making and is only indicated for those very rare instances of suspicious change of the lesion. Tomography, on the other hand, has been used by Mogan et al. for evaluation of an intraosseous ganglion demonstrating a joint communication. They felt that this technique was invaluable in evaluating the small bones of the hand. We believe that the detail obtained from tomography allows more accurate assessment of cyst shape, size, and location for adequate curettage. It may even identify previous unseen extensions of a cyst. Therefore, this preoperative study may be an aid in clinical management and should be considered.
S. H. Noel, W. D. Engber

There have been reports of successful treatment of intraosseous carpal ganglia by means of carpal excision, excision with prosthetic replacement, excision with dorsal flap interpositional arthroplasty, intercarpal or radial carpal fusion, ulnar lengthening, and curettage with bone grafting. We believe that when feasible, curettage and grafting is the treatment of choice as it preserves normal anatomic structures, allows normal joint mechanics and reliably relieves pain.

ACKNOWLEDGMENT
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REFERENCES
Silicone replacement arthroplasty has enjoyed tremendous popularity since the introduction of these implants in the late 1960's. Initial enthusiasm for their widespread use has begun to wane, however, with the increasing documentation of prosthesis fracture, prosthetic deformation and reactive synovitis from particulate silastic. Foreign body giant cell reactions associated with silicone replacement arthroplasty have also been confirmed in regional lymph nodes3,7, as well as in non-contiguous areas of bone2,4,9. Particulate flexor tenosynovitis associated with silastic carpal implant has not been previously reported to our knowledge.

CASE REPORT

Six months after a forty-nine-year-old-right-handed woman fell on her dominant hand, she was referred to us for evaluation of persistent dorsal wrist pain. Radiographs were obtained and revealed stage III Kienbock's disease (Fig. 1). She underwent a wrist arthrotomy and silastic implant arthroplasty of the involved lunate. Six months later, the patient noted increasing numbness in her right hand. Electrodiagnostic studies demonstrated evidence of carpal tunnel syndrome without denervation. She continued to complain of discomfort in the wrist with paresthesias in the digits as well as a "bursting" feeling in the hand exacerbated by wrist flexion. Examination revealed hypesthesia in the long, ring, and little fingers as well as fullness of the wrist and palm volarly.

Figure 1
Posteroanterior (a) and lateral (b) radiographs of the wrist show carpal collapse with flattening and widening of the lunate. There are no radial carpal and intercarpal degenerative changes.

Figure 2
Radiographs show satisfactory implant position without evidence of surrounding osteolysis prior to volar wrist exploration.

Approximately one year after the replacement arthroplasty (Fig. 2), the patient underwent volar wrist exploration with release of the carpal canal and Guyon's canal. A large amount of clear amber fluid associated with a marked flexor tenosynovitis was encountered. A flexor tenosynovectomy was performed. No defects in the volar wrist capsule were identified. The tenosynovium specimen sent for histologic examination revealed a marked foreign body giant cell reaction and large amounts of granular refractile material within the giant cells (Fig. 3).

The patient experienced marked relief of the paresthesias and "bursting" feeling in the palmar aspect of the hand postoperatively; however, she continued to have pain in the wrist. She subsequently underwent silastic lunate implant removal and wrist arthrodesis. Microscopic examination of the synovium obtained at the time of implant removal revealed findings similar to the tissue obtained during flexor tenosynovectomy.
DISCUSSION

Silicone synovitis associated with silicone replacement arthroplasty was first reported by Aptekar et al. in 1974. Additional isolated cases of foreign body giant cell reaction occurring with silicone implants were subsequently reported as well as lymphadenopathy with similar histologic features. Worsing et al. demonstrated a reactive synovitis could be produced experimentally in rabbits using microparticulate silastic. Nalbandian et al. responded by reporting an incidence of silicone synovitis and lymphadenopathy of less than 1% and 0.1% respectively. Several recent reports have indicated the occurrence of significant osteolysis and erosions in the surrounding bone after silastic implant arthroplasty within the hand. These lytic regions have occurred in up to 75% of some carpal implants and were found to be areas of erosive giant cell synovitis with large quantities of intra- and extracellular silicone debris. Many of the cases required implant removal for relief of the associated pain and swelling as well as aggressive synovectomy and curettage of the bony lesions to arrest the destructive process.

The route of migration of silastic particles from an intra-articular to an extra-articular location in our case cannot be definitively stated. Most likely, the particles passed from the wrist joint through small rents in the volar wrist capsule which were produced when the lunate was initially excised.

The true incidence and long-term biological effects of silicone-related synovitis, lymphadenopathy, and osteolysis remain unknown. These complications appear more likely to develop in carpal replacement arthroplasty than in other areas of the hand and may be related to greater compressive loads in this region as well as temporary Kirschner-wire or suture fixation of the implant.

Particulate flexor tenosynovitis represents another potential complication and source of disability following silicone replacement arthroplasty.

REFERENCES

DIAGNOSTIC CAPABILITIES OF SELECTIVE MAGNETIC RESONANCE IMAGING IN DEFINING KNEE INJURIES

From THE ORTHOPAEDIC AND RADIOLOGY SERVICE, WALTER REED ARMY MEDICAL CENTER

Cpt. David W. Polly, Jr., MC, USA2
Maj. John J. Callaghan, MC, USA1,2
Ltc. Randall A. Sikes, MC, USA1,3
Ltc. James A. McCabe, MC, USA1,3
Cpt. Kevin McMahon, MC, USA2
Col. Carlton G. Savory, MC, USA1,2

The opinions and assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army, the Uniformed Health Services University of the Health Sciences, or the Department of Defense.

INTRODUCTION

In addition to a good clinical history and physical examination, accurate diagnosis of knee soft tissue injuries may require other diagnostic studies2,3,9,14,16. Arthrography and arthroscopy significantly improve diagnostic accuracy but both are invasive studies and have the potential for complications13. Arthrography has a 60 to 97 percent range of reported accuracy, and requires a person skilled in performing and interpreting the study4,5,6,7,9,10,12,15,21. Arthrography also exposes the patient to ionizing radiation. Diagnostic arthroscopy is a significant advance but is an operative procedure with the attendant risks13,20. Selective magnetic resonance imaging (MRI) is a non-invasive diagnostic modality with no ionizing radiation. This technique can potentially provide accurate diagnostic information concerning the soft tissue structure of the knee with no apparent risk. Further, in this selective form (sagittal plane and T1-weighting only), the cost of MRI is comparable to arthrography.

METHODS

A prospective study was conducted on fifty-four consecutive patients scheduled to undergo arthroscopy. All patients entered into the study signed an informed consent form that was approved by the Walter Reed Army Medical Center Human Use Committee. All patients had a preoperative selective MRI performed and read in a blinded manner by a radiologist. Arthroscopy was performed and the results recorded. The findings of the arthroscopy and the selective MRI were compared. Two patients were excluded because of technically inadequate selective MRI scans. An additional patient had hardware in place which caused distortion of the scan, and a fourth patient became claustrophobic preventing the completion of the selective magnetic resonance imaging scan.

The selective magnetic resonance image scan was specifically designed to evaluate the menisci and the cruciate ligaments, hence it is a very selective and specific study as outlined below. A 1.5 Tesla magnet was used in the scanner. The patient was positioned with the foot in 20 degrees of external rotation and a surface coil placed under the popliteal fossa. Multiple spin echo T1-weighted sagittal images were obtained at four mm intervals using a single average. The TE was 38 msec and the TR 700 msec. The matrix size was 256 by 256 pixels. The total completion time of the selective MRI for each patient ranged from thirteen to fifteen minutes.

RESULTS

Arthroscopy is considered the standard for the accurate diagnosis of knee cruciate ligament and meniscal disorders. Therefore, the sensitivity, specificity, and accuracy of selective magnetic resonance imaging was based on the arthroscopic finding(s).

The criteria used for determining a tear on MRI was the presence of high signal that extended to one of the borders of the meniscus. Anterior cruciate ligaments were read as well visualized or not well visualized. If read as not well visualized no further statement could be made. In these instances, five represented torn anterior cruciate ligaments and seven represented intact anterior cruciate ligaments.

1. Assistant Professor, Uniformed Services University of the Health Sciences, Bethesda, Maryland
2. Orthopaedic Service, Walter Reed Army Medical Center, Washington, D.C.
3. Radiology Department, Walter Reed Army Medical Center, Washington, D.C.
ligaments. If the anterior cruciate ligament was well visualized it was interpreted as well visualized intact or well visualized not intact. Table 1 demonstrates the results of selective MRI compared to arthroscopy and Table 2 demonstrates the sensitivity, specificity, and accuracy of selective MRI. The posterior cruciate ligament sensitivity was undefined because there were no tears examined prospectively.

Table 1

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<th>True Positives</th>
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*Of the twelve "not well visualized" anterior cruciate ligaments, five had tears and seven were intact.
**The false negative medial meniscal tear was a degenerative tear.
***Two of the three false negative lateral meniscal tears were degenerative.

Table 2

<table>
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<tr>
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<td>98.0%</td>
<td>90.0%</td>
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*Anterior cruciate ligaments were read as positive or negative for pathology or as "not well visualized". Twelve of fifty were "not well visualized" and therefore not interpreted as positive or negative for pathology.
**There were no posterior cruciate ligament tears in the series of 54 patients examined prospectively.

Two of the three false negative lateral meniscal tears were degenerative tears. The single false negative medial meniscus tear was also a degenerative tear. In three other instances degenerative tears were identified by selective MRI. No attempt was made to identify the type of tear based on the selective MRI. Tears were simply identified as horizontal, vertical, or complex. However, in retrospect bucket-handle tears were readily identified. Figures 1 a-f demonstrate selective MRI of normal meniscal and cruciate anatomy. Figures 2 a-f demonstrate meniscal and cruciate pathology. Figure 3a and b demonstrate osteochondritis dissecans of the medial femoral condyle.

Large osseous loose bodies and osteophytes were readily identified on selective magnetic resonance imaging. Small osseous and all cartilaginous loose bodies as well as articular cartilage defects were not identified by selective MRI. Synovial processes in general were not well identified (i.e., pathological plicae and nonspecific synovitis). In one case, an isolated pigmented nodular synovitis in the lateral joint capsule was not visualized because the knee was not scanned at the lateral extreme. This is a limitation of the selective sequence study.
Continuing medially the anterior and posterior horns of the lateral meniscus are identified. The arrow points to synovial fluid between the posterior horn and the popliteus tendon.

DISCUSSION

We designed the present study to evaluate the use of selective magnetic resonance imaging as a practical and effective method of determining meniscal and cruciate pathology. The particular selective MRI sequence was used because previous investigators thought it adequate for determining cruciate and meniscal pathology17. When we started performing MRI of knees, we used T1 and T2, sagittal and coronal images with the length of a single study averaging over one hour. The present study is routinely performed in fifteen minutes.

The selective magnetic resonance imaging scan adequately demonstrated the status of the cruciates and the menisci with some limitations. Degenerative tears were frequently not identified (in three out of seven cases). Placing the knee in 20 degrees of external rotation did not always accomplish its purpose of aligning the anterior cruciate ligament in the sagittal plane as 24 percent could not be visualized. Extreme lateral or extreme medial pathology can be missed due to the sagittal cuts as demonstrated by the case of localized nodular synovitis. Large osseous loose bodies as well as the osseous component of osteo-
D. W. Polly, Jr., J. J. Callaghan, R. A. Sikes, J. A. McCabe, K. McMahon, C. G. Savory

CONCLUSIONS

Selective magnetic resonance imaging yielded excellent visualization of the posterior cruciate ligament, medial meniscus, and lateral meniscus in all cases, but in only 76% of cases was the anterior cruciate ligament well visualized. Based on arthroscopic findings, the sensitivity, specificity, and accuracy of selective MRI respectively was 95.8%, 100%, 98%, for medial meniscal tears; 66.7%, 95.1%, 90%, for lateral meniscal tears; undefined, 100%, 100% for posterior cruciate ligament tears; and 100%, 96.9% and 97.3% for anterior cruciate ligament tears, when the anterior cruciate ligament was well visualized. This selective sequence can be performed in fifteen minutes at a cost comparable to arthrography. It is non-invasive and...
Diagnostic Capabilities of Selective Magnetic Resonance Imaging

Figure 2e
A horizontal flap tear of the medial meniscus.

Figure 2f
A lateral meniscal tear. There is high signal in the posterior horn of the meniscus that is not contained within the meniscus.

Figures 3a and 3b
Osteochondritis dissecans of the medial femoral condyle is well delineated on this selective magnetic resonance image (arrows).

Radiograph of the patient in Fig. 3a.

requires no exposure to ionizing radiation. Selective MRI can be a safe and valuable adjunct to the clinical knee evaluation and an aid to efficient preoperative planning.

REFERENCES

17 Personal communication with the Department of Radiology, University of California at Los Angeles.
SECONDARY RECONSTRUCTION OF THE LATERAL LIGAMENTS OF THE ANKLE

Robert Leach, M.D.
Professor and Chairman
Department of Orthopaedics
Boston University School of Medicine
Boston, MA

A sprained ankle is one of the most common injuries seen in an emergency room or athletic training facility. Athletes and nonathletes alike may injure the lateral ligaments of the ankle. With the foot in plantar flexion, the talus is slightly less stable within the ankle mortise. This mild joint play, combined with an inversion force, may injure the lateral ligamentous complex of the ankle. Injuries of the medial ankle ligaments, while far less common, may be more severe and associated with fibular fractures or tears of the tibiofibular ligaments.

There are two possible major injuries to the lateral ligaments of the ankle. The first involves the talofibular and calcaneofibular ligament complex and the second involves the tibiofibular ligament complex. The "usual" ankle sprain causes disruption of the anterior talofibular ligament with an element of anterior capsular tear. If the injury force is continued, the calcaneofibular ligament tears. In major disruptions, i.e., a subluxation or dislocation of the talus out of the mortise (Figure 1), the strong posterior talofibular ligament will be torn. The inversion injury may cause impaction of the talus against the tibial plafond and produce an osteochondral or chondral fracture of the talus, usually on the medial aspect (Figure 2).

Injury to the tibiofibular ligaments occurs as a result not of plantar flexion and inversion but due to supination of the foot combined with external rotation. This force results in injury to the medial ligament complex with spreading of the mortise and subsequent damage to the inferior tibiofibular ligaments and even tearing of the tibiofibular syndesmosis. Careful examination is necessary to pick up this latter injury because, while the initial soft tissue reaction is less than that of a damaged tibiotalar ligament, the medium-term sequelae seem to be more severe, particularly in the athlete. It is a simple matter to palpate for areas of maximal tenderness. If this area is in the interval between the fibula and talus, as opposed to between the fibula and talus, one assumes there has been damage to the anterior inferior tibiofibular ligament. Tenderness at the deltoid ligament also leads one to suspect an inferior tibiofibular ligament injury. But it is also possible to injure the medial deltoid ligament with a major inversion plantar flexion injury which damages the anterior talofibular and calcaneofibular ligament. A careful physical examination is the key to delineating these two injury types and to proper treatment.
In this paper, I do not intend to review treatment of acute ankle injuries. Immediate surgical repair, functional mobilization, and immediate casting each have advocates in the voluminous literature. of the past several decades. Certainly in a third degree injury involving all three lateral ankle ligaments or with a suspected osteochondral fracture, operative intervention with primary repair of the ligaments seems indicated and has given excellent results. However, for most ligamentous ankle injuries, the prevailing method of treatment is some type of functional mobilization with early protection, rehabilitation, and early return to activity.

Interestingly, despite the very large number of injuries suffered and the protean modes of treatment used, relatively few patients undergo secondary reconstruction of the ankle ligaments. This is in marked contrast to the number of people who undergo secondary reconstruction of the anterior cruciate ligament in the knee. This is more interesting when one considers that secondary reconstruction of the ankle ligaments has a very high success rate, certainly higher than that of secondary reconstruction of the anterior cruciate ligament. This information leads to the inescapable conclusion either that: 1) various modes of treatment are relatively effective in allowing restoration of ankle stability; or 2) some degree of ankle instability is tolerated relatively well even by athletic people.

Some patients with lateral ankle instability, however, are unable to function. This primarily involves athletic individuals, inhibiting their recreational activities, but even activities of daily living can be affected. These patients complain of recurrent episodes of their ankle giving way or turning over with subsequent swelling and pain. Sometimes the swelling may be present constantly, and the person may have pain with even light activity.

Physical examination usually reveals an anterior drawer sign and increased tibiotalar tilt. These findings may be measured on stress roentgenograms (Figures 3, 4, 5). Stress roentgenograms can be valuable when they are done in a standardized manner and the injured and uninjured sides compared. Most authorities would agree that an increase of 10 degrees of tibiotalar tilt on the injured side over the uninjured side indicates major laxity. Seligson states that stress tests done for an anterior drawer sign of the ankle are more valuable than those done for tibiotalar tilt. An anterior drawer of three to four millimeters more than the uninjured side is significant (Figures 5 and 6). We look at the total amount of inversion of the foot and ankle which includes subtalar and tibiotalar motion (Figure 7) and measure the distance between the distal tip of the fibula and the anterior beak of the calcaneus on both sides. Normally we can make the diagnosis with the history and a judicious physical examination. The use of stress roentgenograms is reserved for possible surgical candidates in whom the surgical indications are not certain.

Treatment may require only modification of activity, in some cases combined with other conservative measures. To start conservative treatment, I place the patient on an exercise program stressing dorsiflexion and eversion of
the foot. I hope to not only improve the strength of these muscles but to decrease the reaction time so that in a potentially disabling situation, the peroneal muscles will react quickly bringing the foot and ankle out of the dangerous position. Patients are advised to stretch the posterior structures of the ankle and the Achilles-tendon complex. The ability to dorsiflex normally provides more inherent stability for the ankle. Athletic people who have been previously injured are put on a series of proprioceptive and agility drills. We recommend some type of ankle protection which may range from adhesive strapping, for athletes with access to trainers, to fabricated ankle wraps or air-stirrup braces. High-top shoes in certain sports seem helpful. Regular use of a protective device may allow the athlete to participate in their sport.

For many serious or competitive athletes, an appliance fails to provide adequate stability and/or hinders performance. In these people who have continued pain, swelling, or disability, secondary reconstruction of the ankle ligaments should be discussed. As with conservative treatments of lateral ankle sprains, there are several methods available for secondary reconstruction of the lateral ligaments. Three procedures seem to have stood the test of time and have enough data for evaluation. The most simple operation is that advocated by Broström which is done using locally available tissues; specifically, imbricating the anterior talofibular ligament remnants. Brand and Cox advocate this method. The basic premise for this reconstruction is that the anterior talofibular ligament is the
major stabilizer of the ankle and prevents anterior talar subluxation (drawer sign). Broström states that if one inhibits anterior talar subluxation, the ankle will be stable. Several reports have shown good results with this procedure. A concern with this operation is the lack of reconstruction of the calcaneofibular ligament. Some authorities feel this is very important in limiting excessive inversion of the foot and ankle. As the lateral tibiotalar joint becomes loose, there is often a gradual laxity of the subtalar area thus tending to increase the amount of foot inversion. A calcaneofibular ligament reconstruction corrects this subtalar problem.

The second operative procedure, devised by Evans, addresses the calcaneofibular ligament and is attractive for its simplicity. The distal portion of the peroneus brevis tendon is left attached to the base of the fifth metatarsal and rerouted through the fibula from distal to proximal and attached there. This produces a calcaneofibular ligament substitute and decreases foot inversion and tibiotalar tilt. No attention is paid to the anterior talofibular ligament and, theoretically, a positive anterior drawer sign would not be corrected. This procedure, more popular several decades ago, is still a reasonably effective mode of treatment.

At University Hospital, our method of secondary reconstruction of the lateral ankle ligaments is a modification of the Chrisman-Snook procedure. This operation, first described by Windfeld in 1953, uses half or, occasionally in our modification, all of the peroneus brevis tendon which remains attached to the fifth metatarsal. The proximal tendon is freed from the muscle, detached, and threaded through the base of the anterior talofibular ligament (Figure 8). It is then brought through a drill hole, beginning anteriorly one inch from the distal tip of the fibula and directed towards the calcaneus roughly in the line of the original calcaneofibular ligament. The peroneus brevis tendon is then passed behind the remaining peroneal tendon and brought down to the calcaneus approximately to the attachment of the original calcaneofibular ligament. We use a staple to attach it to the calcaneus after roughening the bone surface. When attaching the tendon to the calcaneus, it should be pulled taught with the foot in neutral position (zero degrees of plantar flexion and zero degrees of inversion and eversion). After attaching it to the calcaneus, it is sutured to the anterior talofibular ligament and to the soft tissues at the entrance to the hole in the fibula. Usually we have enough tendon left to form another leg coming back over the peroneal tendons distal to the fibula (Figure 9). This portion prevents dislocation of the remaining peroneal tendon and reinforces the anterior talofibular ligament. When the peroneus brevis tendon is passed through the distal portion of the anterior talofibular ligament the latter tendon is divided in half and then imbricated. This increases the bulk and strength of the tissue replacing the attenuated anterior talofibular ligament.

Figure 8
Chrisman-Snook repair going through base of anterior talofibular ligament indicated by single arrow. Dual arrows indicate calcaneus attachment.

Figure 9

Those critical of this operation state that it takes longer to perform and that the patient is casted for six weeks. He may return to action less quickly than after other
Secondary Reconstruction of the Lateral Ligaments of the Ankle

procedures. We allow the patient to bear weight in a short leg cast after the second week. At three weeks we change to a hinged cast brace and begin weight bearing and some ankle motion.

Several operative details are important. Care is taken to avoid branches of the sural nerve during skin incision and subcutaneous dissection. If the foot is placed in eversion while the substitute ligament is made tight, it may be difficult to regain good inversion. The foot must be placed in neutral position during the attachment of the peroneus brevis to the calcaneus. We have not had problems with failure to regain sufficient inversion for athletic competition, nor have we had problems with weak eversion following loss of half or all of the peroneus brevis tendon. We do suture the peroneus brevis muscle to the longus tendon.

RESULTS

From 1968 through 1984, we have operated upon thirty-eight patients (one bilateral) for laxity of the lateral ligaments of the ankle. There were thirty males and eight females, who ranged in age from sixteen to fifty-four. All patients had had symptoms for longer than one year and were engaged in active athletics including basketball, wrestling, gymnastics, tennis, football, racquetball and volleyball. All patients were unable to perform near the level they desired. All thirty-nine ankles had excessive inversion and a positive anterior drawer sign. In eighteen ankles there was subluxation of the ankle with plantar flexion and manually applied inversion.

The follow-up period ranged from two to sixteen years. The results were rated as: excellent—able to perform all athletic activities without symptoms; good—able to perform all athletic activities with only occasional aching after exercise but no symptoms of instability; fair—athletically active but at a level less than prior to injury, plus episodes of pain or instability with participation; and poor—unable to participate in athletic activities.

Of the thirty-eight operated patients, we classified thirty-four as excellent and four as good. There were no patients in the poor or fair categories. Following surgery, no patient had residual instability in the anterior/posterior or inversion plane. Dorsiflexion and eversion strength appeared normal by manual testing about one year postoperatively in all patients.

Complications were minimal. Most patients were able to jog at ten to twelve weeks. Their return to athletic competition was quite variable thereafter. There were no infections but one patient had a reaction to deep suture material and over the course of six months extruded five nylon sutures from the site of the repair. One patient had a small area of numbness on the lateral aspect of his foot, apparently due to damage to a small branch of the sural nerve. Early in the series two patients had staples removed because they became slightly loose. We changed to a different type of staple and have had no loosening since that time. Two patients complained of some lack of inversion at six months following surgery. They were doing well at one year and one was performing gymnastics. Inversion following surgery ranged from 9 degrees to 19 degrees.

During the course of doing this procedure, we have changed the incision from running somewhat posterior to the fibular malleolus to going over the malleolus. By plantar flexing the foot and relaxing the tissues, we can dissect below the lateral malleolus down to the calcaneus and insert the staple.

Reported results of the Chrisman-Snook procedure\textsuperscript{6,7,8,14} have been about as good as those detailed in this paper. The question has been raised whether the Chrisman-Snook operation is too much surgery as opposed to the more simple Broström operation. We worry that the old anterior talofibular ligament is so attenuated in some instances, that imbrication (even with additional repair of the calcaneofibular ligament) would not provide enough ligamentous stability. Based on our consistently good results, we feel the Chrisman-Snook procedure continues to offer excellent potential for reconstruction of the lateral ligaments of the ankle in the athletic person.

BIBLIOGRAPHY

PHYSICAL EXAMINATION OF THE KNEE
SOME PHILOSOPHICAL THOUGHTS AND A NEW TEST

John A. Feagin, Jr., M.D., F.A.C.S.
Reprints Requested from John A. Feagin, Jr., M.D., P.O. Box 2770, Jackson, Wyoming 83001

PHYSICAL EXAMINATION OF THE KNEE
SOME PHILOSOPHICAL THOUGHTS AND A NEW TEST

It is an honor to have been invited to the University of Iowa and to contribute to this Journal. Although my orthopaedic career did not overlap with Dr. Steindler, we have all been influenced by that giant of a man. “Post-Graduate Lectures on Orthopedic Diagnosis and Indications” were required reading in my day, and rightfully so—-they still deserve review by the serious student of Orthopaedic Surgery. Volume I of these lectures is entitled, “Propedeutics in Orthopedic Diagnosis — i.e. Preliminary to the Teaching of Orthopedic Surgery”— that is where I believe this essay on the physical examination of the knee should fit — preliminary to the surgery.

PHYSICAL EXAMINATION

Physical examination is an art and a science. Through the physical examination, we seek a ligament-specific diagnosis. This is done by comparing the excursion of the tibia on the femur. Relaxation is essential to these diagnostic efforts and should be sought while the examiner first examines the normal knee.

The initial examination can be particularly revealing when it occurs before the onset of effusion and muscle spasm. A single examination is seldom definitive. Reexamination is appropriate and essential. Sometimes a change in venue will promote relaxation of physician and patient and result in a more productive physical examination. Ice is a useful adjunct to the physical examination as it decreases pain and promotes relaxation.

INSPECTION—LOOK!

The injured knee must be considered in the context of the entire patient. The physiologic age, body fat, and muscle mass reflect the patient’s previous selection of activities. The brachioradialis and gastrocsoleus are excellent muscles to observe, since they are seldom developed in adult activity and thus reflect the activities of youth.

During inspection of the legs, I check to see if the skin is intact. Are there abrasions, old scars, or bruising? The comparative quality of the skin envelope may give information about the direction, force, and mechanism of injury, and the past history. The shape of the joint, the general alignment, atrophy, and swelling (localized or diffuse) should be noted. These observations lead to the laying on of the hands— palpation.

PALPATION—FEEL!

The hands of the skilled examiner are a wonderful arthrometer. The palpatory examination of the knee represents a subtle gradient of force application. The initial laying on of the hand is done on the normal side with only sufficient pressure to gain appreciation of the subtleties of form. This complements the visual inspection. When the form is ascertained, the next level of pressure applied is for induration—the hardness of the various tissue planes. This induration often is the clue to the level as well as the anatomic site of injury. Gentle flexion of the knee, if possible without pain, is helpful during this search for induration because it may separate some of the anatomic structures and help to localize more precisely the sites of injury.

Finally, palpation is conducted with slightly more vigor to elicit tenderness and/or gaps in the underlying soft tissue. This must be done with the patient’s full knowledge and cooperation and the patient must appreciate the precision with which this portion of the examination can be conducted. Gentleness is the key to this precision.

Problems left unattended within the knee do not get easier with the passage of time. Initial subtleties can become blunted by induration, edema, and effusion which develop during the ensuing days. One misses important details by not examining the knee-injured patient shortly after injury.

MOVEMENTS—MOVE!

Should the examiner begin with active or passive movements? I prefer to ask the patient to move the well leg within the range of motion that is comfortable and possible for him. This gives a standard of comparison for the injured leg. Then, I ask the patient to move the injured extremity within the bounds of comfort. This will tell the examiner what range of motion is available to position the leg for the ligamentous examinations.
The collateral ligaments are best examined at hyperextension, neutral, and 30 degrees flexion. If the knee is stable in hyperextension, the medial and lateral capsuloligamentous structures and the posterior cruciate ligament (PCL) are intact. When varus and valgus angulation are applied with the knee at zero degrees, the ACL and PCL are slackened sufficiently that these tests may be diagnostic of medial or lateral capsular injuries. At 30 degrees flexion, the cruciates are in their most relaxed state and the pathologic laxity palpated is primarily capsular laxity.

The appreciation of increased rotary excursion requires careful attention to detail. The pivot shift test, with any of its presently recognized modifications, is sufficiently useful and specific to the examiner that he should master one or more of the named tests. In its various forms, the MacIntosh test², the Losee test³, the Slocum test⁴, the flexion-external rotation-drawer test (Noyes)⁵, and the jerk test (Hughston)⁶, help the examiner to determine the abnormal translation and rotation of the medial and lateral compartments of the knee. Positive results in any of these tests depend, I believe, upon an incompetent ACL. If the MCL is disrupted then there may not be sufficient restraining force medially for the test to be meaningful. The test may be falsely negative because of muscle spasm. A false positive test is quite rare and would lead one to suspect either congenital laxity or congenital absence of the ACL.

EXAMINATION IN THE PRONE POSITION

The supine or sitting position is currently the standard for examination. Too often we forget “the other side of the joint”, which is brought to view when the patient is in the prone position. I have found the prone position to be particularly helpful when performing the Lachman test, and would like to describe this new test in more detail.

The Prone Lachman Test. The prone position is especially useful in evaluation of the ACL-injured knee. The examiner flexes the knee to 30 degrees, leaving the upper leg flat on the table for relaxation. In this position, the hamstrings can be directly visualized for spasm or tightening. The patient’s ankle is secured between the examiner’s arm and body, leaving both hands free to firmly grasp the proximal tibia (Fig. 1). The examiner then applies an antero-posterior translation force—palpating excursion and the quality of the end point. This is done precisely as with the supine examination. The benefits to the prone examination are:

— patient relaxation.
— Improved fixation of the upper leg through extension of the hip and quadriceps contact with the table.
— Both hands are free.

— Anterior displacement is gravity-assisted, thus less manual force is required to reach the limits of excursion.

Figure 1
The Prone Lachman Test.

COMMENTS

The philosophy of the physical examination may not seem important but an inadequate initial physical examination is probably the most common cause of failure in care of the knee. It is a discipline which can be taught at all levels. Since we do not have a universally accepted classification of knee laxities, it is all the more important that our examination be ligament specific. A positive Lachman test is generally thought to be specific for incompetency of the ACL. Thus, I have described the prone Lachman test which I believe enhances patient relaxation and examiner appreciation of pathologic excursion. The significance of the test is the same as the standard Lachman test (ACL incompetency), but with practice a greater appreciation is attained of pathologic excursion of the posteromedial and posterolateral compartments.
In summary, I have found the examination of the injured knee in the prone position to be a useful addition to our standard tests for knee ligament laxity. The prone Lachman test aids in the assessment of the injured knee. The test can be recommended to all who need to examine the knee since the test is simple to perform, gentle, ligament specific, and gives added insight into evaluation of the primary and secondary restraints of the knee.

REFERENCES

LIZARDS

Gregory H. Jacobs, B.S.
State Laboratories
University of Iowa
Iowa City, Iowa

and

Richard L. Jacobs, M.D.
Albany Medical College
Albany, New York

"Like a lizard, smooth, slippery, faithless"

Thomas Mann

This is a cautionary tale for orthopaedic parents. Things can get out of hand. This _could_ happen to you! The purpose of this paper is to _warn_!

OVERTURE

One of us (R.L.J.) is a fond parent, and wishes his offspring to have every educational experience. The son (G.H.J.) has an abiding interest in lizards (teneramente).

One weakness of orthopaedic surgeons is pride in craftsmanship. Thus it came that before one Christmas we built what we call a lizardormitory.

This creation is three feet high, three feet deep, and eight feet long. The entire front is Plexiglas. The top is two overlapping sliding doors. Inside are thermostatically regulated heat lamps, multiple cacti, and everywhere sand and gravel (which later becomes embedded in the floor, bedding and rug; all the usual places).

This endeavor is blessed with issue. Squeaking, croaking, mortally ugly come the geckos (agitato). The anoles come, dainty and diminutive (let us say, leggero), wanting to live and let live. The golden skink (misterioso), think of the oboe. The rainbow lizard, a fluorescent blue confection, is dubbed Vida Blue (a small athletic joke, a small lizard). The basilisk lizard (crescendo) perpetuates Greek mythology and adds to the obvious educational benefit of the whole thing. Who can ever forget John Mortimer’s description of a notorious criminal as “he of the basilisk facies-?”

The king of the enclosure, though, is the tegu lizard. He is easily four feet long, as large in circumference as your arm, and beautifully striped (Figure 1). As lizards will, he speaks (hisses actually) with a forked tongue! He is the hero of the composition (fortissimo).

Talk of heroes, and you must have a villain. The villain is Lisa our cat. Black as midnight, sleek as the wind, she is ideally suited for her part (legato! pun intended . . .).

Figure 1
The Tegu Lizard.

ACT I

In which Lisa develops an appetite for lizards. She learns to come flying down the hall, jump and land on the lid with sufficient force to knock it into the cage. A quick sweep of the cage, a mouthful of lizard, and she is gone!

This happens several times before her grim secret is discovered. On this occasion, the lid falls onto the tegu and fractures his femur. In pain, he thrashes angrily. She flees, (you bet!).

ACT II

R.L.J. comes home. G.H.J., in tears, presents the tegu. Superficial examination establishes the injury (Figure 2).
Facile explanations are given. Like, "God's punishment to serpents is to crawl on their belly; legs are not too important and will heal," this type of thing. Allusions to the good book and Leviathan, that crooked serpent.

No sale. Orthopaedic surgeons fix broken bones. Any kid (G.H.J.) knows that!

The next day, father and son on their way to the University of Illinois hospitals with tegu in a picnic basket with hot water bottle. None of the people on the subway seem to notice.

In the minor operating room, a friend anesthesiologist administers a bolus of Ketamine, and it is over soon; an intramedullary Steinmann pin and nylon sutures to the (lizard) skin. The approach is not found in Henry!

**ACT III**

Lizard on a pillow, with hot-water bottle and heat lamp in the orthopaedic offices of the University. All the elements are there; pathos, redemption. The director of the hospital drops by to pay his respects. Well he might, for we claim priority for the first internal fixation of a fractured lizard femur in a major teaching hospital!

**Finale**

Boy and lizard reunited, femur goes on to heal (Figure 3).

In form and content, a little like Mozart, no? No? Would you settle for Twisted Sister or Black Sabbath? (Fine) Curtain.
A FINITE ELEMENT ANALYSIS OF RECONSTRUCTION OF THE ACETABULUM WITH METASTATIC DISEASE

William M. Pekman, M.D.
Department of Orthopaedic Surgery
University of Pittsburgh
Pittsburgh, PA 15261

Thomas D. Brown, Ph.D.
Biomechanics Laboratory
University of Iowa Hospitals
Iowa City, IA 52242

INTRODUCTION

Surgical treatment of metastatic disease of bone has of late become a matter of great clinical interest. Although the overall percentage of patients with malignancies who sustain bony metastases varies, recent series based upon abnormal bone scans or autopsy findings place the incidence at 70 percent or more.6,7. Surgical intervention is now indicated for many pathological fractures involving bony metastases.9,17,18,20,22. Prophylactic internal fixation of metastatic lesions in long bones has been advocated if the lesion is larger than 3 cm in diameter, if 50 percent or more of the cortex is destroyed, or if there is persistent pain in a lytic lesion.1,24. Following surgery, palliative benefits of excellent pain relief in 80 to 90 percent of patients have been well documented, as have been the facilitation of nursing care and generally shortened hospital stays.15,18,22. Significantly, up to 90 percent of patients with surgically treated metastatic bone disease remain ambulatory until death.

In his recent series of 399 patients suffering from metastatic lesions of bone, Harrington14 found evidence of involvement of the acetabulum in 9 percent. Despite this significant incidence, the principles underlying successful surgical reconstruction of the acetabulum with metastatic disease have been only cursorily explored. In particular, with current interest in the use of total hip arthroplasty in these patients, there is a need for quantitative biomechanical analysis of the complex relationships between bone stock deficits and load transmission anomalies in the reconstructed acetabulum.

From previous clinical experience in protrusio acetabuli and in metastatic diseases in long bones, it is recognized that supplemental support is necessary to avoid material failure in the presence of large acetabular bony defects. In addition to polymethylmethacrylate (PMMA) reinforcement, metallic devices such as wire mesh, Steinmann pins or circumferential support rings have been advocated for this purpose.13,25. However, the potentially unfavorable stress redistributions accompanying such metastatic reconstructive procedures have not been biomechanically studied.

Two of the major methods available for stress analysis of the reconstructed acetabulum are strain gauge testing and finite element analysis. Cadaveric strain gauge testing has the advantage of exact replication of the three-dimensional geometry, and it permits direct measurement of strains at the surface of the pelvis. However, to study the wide variety of bony defects and available reinforcement techniques would require a prohibitively large number of specimens. Moreover, inherent biological variability among cadaver specimens would introduce a source of experimental artifact which would be difficult to quantitate. Even within the context of a specific test, strain gauge data obtained at the external surface are of little value in quantitating the internal stresses predisposing to failure of the system.

Finite element analysis, by contrast, allows one to calculate stress distributions at a large number of points within a material region. External restraint conditions, loading characteristics, and local material properties can be varied. Obviously, certain limitations accompany the necessary simplifying assumptions. For acetabular stress analysis, two-dimensional models have to date been most frequently used. The unusually complicated geometry and larger amount of computer time required for a three-dimensional acetabular stress analysis present formidable obstacles to comprehensive parametric studies.11,19. For the purpose of studying load redistribution phenomena associated with the most commonly encountered metastatic lesions, which almost always feature grossly non-axisymmetric involvement, the geometrical formulation chosen for study was one of two-dimensional plane strain.

The biomechanics of the acetabulum following total hip arthroplasty have been much less extensively studied than those of the femoral side. The early work of Goel et al.11 and of Jacob et al.16 concentrated on load transmission in
the normal acetabulum and pelvis. Jacob et al.'s analysis used gauges to measure surface strains on an epoxy model of the pelvis, under loading intended to simulate the midstance phase of gait. Their major conclusions were that the subchondral bone functioned essentially as membrane, transferring weight-bearing stress effectively to the lateral cortex of the ilium; and that the cancellous bone was essentially shielded from load, such that stresses were seven-fold less in the cancellous bone than in the subchondral bone. These investigations postulated a "sandwich structure" in which cortical bone carries the vast majority of the load, with the cancellous bone serving merely as a spacer to maintain the overall structural form. Goel and his associates, using finite element analysis, reached similar conclusions concerning the stress levels developed in cortical versus cancellous bone. However, their data suggested that the magnitude of the acetabular stresses was substantially higher than that estimated by Jacob et al.

The changes in acetabular stress distribution accompanying prosthetic component implantation have recently been considered by two groups. Vasu et al. used a two-dimensional (plane strain) finite element formulation to investigate the acetabulum, both with and without a prosthetic component. Their computations showed that the addition of a prosthetic component markedly changed the stress distribution from that in a normal hip. Specifically, stresses were redistributed to the central and superior cancellous bone, and away from the lateral pelvic cortex. The medial pelvic cortex was also noted to carry increased stress. Associated with these changes was the formation of "significant" tensile stresses in the cement region. Any or all of these phenomena could have potentially adverse effects on the long-term mechanical integrity of the prosthesis. The addition of a metal backing on the prosthesis, while not entirely eliminating these redistribution effects, markedly reduced their magnitude.

Pederen et al. used a non-axisymmetrically loaded, geometrically axisymmetric model to study several different parameters in the prosthetic acetabular system. They found that the use of thinner prosthetic components and/or the removal of the subchondral bone led to increased principal stresses near the bone/cement interface. Also, their modelling of a metal backing on the prosthesis showed effects similar to those seen by Carter et al. More recently, Crownsinshield, Brand and Pedersen have extended their axisymmetrical model to the case of acetabular protrusio, focusing upon the effects of polyethylene component placement, and upon the effects of peripheral versus complete metal protrusio rings on stress redistribution.

In view of the clear success of these recent finite element studies in documenting acetabular stress redistributions following conventional total hip arthroplasties, it seemed reasonable that a similar approach would be helpful in understanding biomechanical phenomena associated with acetabular reconstruction following metastatic disease. However, unlike the situation prevailing for conventional arthroplasty, metastatic disease inherently involves a broad variety of lesion sizes, shapes and locations. To avoid the potential pitfalls of basing general conclusions upon lesion-specific data, it was necessary to perform a much larger number of geometrically individualized stress analyses than is otherwise customary in a study of this type.

METHODS

The basic geometric model used in all cases studied was prepared from sections of the pelvis of a fifty-six-year-old white male free of skeletal disease. The pelvis was first divided sagittally, and one hemipelvis was rigidly held in a bandsaw. Serial cuts parallel to the coronal plane were then made at 5 mm intervals through the specimen. Roentgenograms of each section were done, and the coronal midsection (Fig. 1A) was chosen for analysis. The detailed geometry was replicated by manual tracing of the enlarged slab roentgenogram. Templates prepared from equal enlargements of midsections of commercial acetabular total hip prosthetic components were used to determine the standard component size most appropriate for this particular acetabulum. A 20 mm thick (48 mm outside diameter) trapezoidal 28mm component was judged to be the best fit for the acetabulum; its positioning was selected to closely simulate the position used in the clinical setting. That is, the cup was placed so as to insure bony coverage laterally, with 45 degrees of abduction, and with a continuous cement layer whose thickness varied with location in the acetabulum. The study section was then zoned into 1031 constant strain triangular elements with 568 nodes (1136 degrees of freedom) (Fig. 1B). The mesh was structured for greatest resolution in the subchondral (cortical) bone, in the polymethylmethacrylate cement, and in the polyethylene prosthetic component — particularly in the regions underlying the acetabular dome.

The acetabulum was divided into several discrete material zones, whose mechanical properties were inferred from the literature (Fig. 2).

The cancellous bone was subdivided into three distinct regions, with assigned moduli based upon the trabecular patterns and density apparent radiographically. All materials were assumed to behave as homogeneous, isotropic, (direction-independent) linearly elastic continua. Since no data were available for the cobalt-chromium reinforcement mesh, a series of three-point-bending tests was performed in the laboratory, from which an apparent Young's modulus of 8.74 × 10^6 psi was inferred. The Poisson's ratio was taken to be identical to that of solid cobalt-chromium alloy, namely 0.33. Two of the reinforcements, the metal backing on the acetabular prosthesis and the Harris-Oh ring were mod-

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eled to be of cobalt-chromium, and hence were assigned an elastic modulus of $32.0 \times 10^6$ psi.

The acetabulum was considered to be loaded by distributed intra-articular contact stress, and by traction forces acting at the approximate location of the gluteal muscles' attachment on the ilium. The joint load employed was a five-fold multiple of the plane-strain equivalent of body weight for a 70 kg person. The resultant load axis was taken to be inclined 12 degrees to the vertical. The joint load was distributed in proportion to the cosine of 1.56 times the local angular displacement, relative to the resultant load axis. The use of a cosine distribution function was based on work by Greenwald and O'Connor. The specific coefficient of 1.56 was introduced so as to ensure that the contact stress decayed to zero at the lateral periphery of the polyethylene cup. The gluteal muscle force was 450 Newtons, corresponding to the plane strain equivalent of Crowninshield et al.'s value for the instant of peak joint loading. Restraining conditions remained unchanged through the study. Full restraint was assumed across the margin of the study region bordering the sacroiliac joint, and full restraint was assumed across the margin of the study region parallel to the symphysis pubis. A direct stiffness finite element program for constant-strain triangular elements was used to obtain internal stress solutions for the various cases considered.

Corticocancellous bony defect regions of various sizes and shapes were postulated at various locations in the acetabulum. The specific defects were chosen, based upon clinical experience, in order to ascertain the effects of location, involvement of cortical bone, etc., as well as size. To explore stress redistributions following reconstruction,
The various material regions modelled in the study. The property values (inset) are compiled from the literature sources indicated in the text.

the region of the defect was assigned the material properties of polymethylmethacrylate cement, reflecting a customary surgical technique for replacing metastatic lesions in bone. After analyzing conventional arthroplasties in a series of twenty-five individual defects, a series of eight representative defects (two from each of the major anatomical regions) was chosen for the study of three alternative reinforcements. The methods of reinforcement studied for each of these eight selected lesions were: a metal backing on the acetabular prosthesis, a malleable cobalt-chromium acetabular mesh, and a Harris-Oh ring. The physical dimensions of each reinforcing device were replicated in the model. The cases of the Harris-Oh ring and malleable cobalt-chromium mesh required special attention. Despite its excellent capacity to support hoop stresses, the Harris-Oh ring is essentially an incomplete hemisphere. Since the corresponding actual cross-sectional geometry is composed of two discontinuous arcuate segments, it was assumed in the present analysis that these segments were linked through an equally thick polar arch segment whose modulus (8 × 10^6 psi) was adjusted to be intermediate between those of cortical bone and of the cobalt-chromium Harris-Oh ring. The malleable cobalt-chromium mesh required local rezoning of the finite element mesh so as to allow exact replication of the thickness of the metallic mesh.

RESULTS

A vectorial representation of the principal stress distribution, and contours of the von Mises equivalent stresses (vMES), are plotted in Figures 3 and 4, respectively, for the case of the acetabulum with otherwise "normal" bony architecture but with an implanted prosthetic component. The von Mises equivalent stress is a single index computed from the various stress components, and reflects the local elastic distortional energy, a widely-employed parameter for assessing material failure. The applied load creates the largest equivalent stresses in the weight-bearing tract. Within the prosthesis itself, compressive principal stresses of about 3000 psi (equal to a 60 percent of the vMES for material failure) are developed in the darkly-shaded region in Figure 4, near the line of action of the resultant load. This stress intensification rapidly diminishes for regions out of the superior weight-bearing tract. Within the PMMA layer, principal stresses (Fig. 3) of orientation similar to those in the cup but of lesser magnitude, are developed. Typical peak compressive principal stresses of 1600 psi (40 percent of failure) are noted in the cement. It is in the superior cortical (subchondral) bone of the acetabulum that the highest principal stresses are developed; these are tensile (hoop) stresses, which act nearly perpendicular to the direction of the resultant applied force. But while these principal tensile stresses are on the order of 5000 psi, the corresponding vMES is only about 30 percent. It can be seen that these subchondral hoop stresses are transferred preferentially to the lateral pelvic cortex and, to a lesser degree, to the medial pelvic cortex. This suggests that the acetabular cortical (subchondral) bone acts somewhat as a shell, transferring load to the pelvic cortices instead of to the overlying cancellous bone. The largest principal stresses occurring in the cancellous bone of the weight-bearing tract are compressive, with a magnitude of about 800 psi and correspond to vMES levels of only 30 to 35 percent.

The resultant joint force used in the present analysis is 71 percent greater than that used by Vasu et al. When the stress levels at various points in this linear problem are normalized to the respective applied joint loads, very reasonable correlation is seen to exist. For example, the calculated normalized stresses in the prosthesis (point A in Figure 3) are only 13 percent greater in the present analysis. Unfortunately, Vasu et al. do not include a subchondral bone layer in their analysis of the prosthetic acetabulum, so direct comparison of subchondral bone stresses in the weight-bearing dome are inappropriate. However, comparing our values for replacement PMMA with their corresponding PMMA layer gives normalized principal compressive stresses within 32 percent (ours being higher). In addition, our normalized maximal tensile stresses in the acetabular cortical (subchondral) bone are about 20 percent less than those calculated by Goel et al. for point B in Figure 3.

Numerous changes in the acetabular stress distributions are introduced under simulation of a large corticocancel-
A vectorial plot of the principal stresses for a "normal" hip. "Normal" here implies that the acetabular section has complete osseous integrity, including the subchondral bone (i.e., no metastatic lesion is present).

lous metastatic bony lesion replacement with PMMA cement (shaded region of Figure 5). Interruption of the intact subchondral ring leads to loss of its membrane or shell effect, causing transmission of "weight-bearing" stresses directly into the replacement PMMA and its surrounding cancellous bone. Within the replacement PMMA itself, the magnitude of both the tensile and compressive principal stresses increase, but proportionally the increase is much greater for the tensile component. That is, the replacement PMMA develops stress trajectories similar to those of the replaced subchondral (cortical) bone (point E of Figure 5), but the stresses in the replacement PMMA are of lesser magnitude.

There is a corresponding increase in the maximum shear stresses developed in the replacement PMMA and, to a lesser degree, in its surrounding cancellous bone. For the replacement PMMA, this shear stress elevation is on the order of 20 to 30 percent in the weight-bearing regions (from about 950 psi to 1200 psi). In large corticocancellous defects, shear stress elevations of 50 percent are sometimes seen in the cancellous bone at the extreme corners or margins of the defect (e.g., point C in Figure 5). While the present finite element mesh is not specifically zoned to examine interfacial phenomena, it nevertheless can be reasonably inferred that the average interfacial shear stress at the bone/cement interface should increase roughly by

\[
\sigma_{\text{mises}} = \sqrt{\frac{1}{2} (\sigma_x - \sigma_y)^2 + \frac{1}{2} (\sigma_y - \sigma_z)^2 + (\tau_{xy})^2}
\]

where \(\sigma_x, \sigma_y, \) and \(\sigma_z\) are the in-plane horizontal and vertical normal stresses, \(\sigma_r\) is the out-of-plane normal stress, \(\tau_{xy}\) is the in-plane shear stress, of \(\sigma_f\) (Fig. 2A, inset) is the material failure stress in uniaxial tension.
the principal stress plot for a large superior defect. The shaded area, D represents the corticocancellous defect.

Figure 5

The vMES plot for a superior defect including the lateral pelvic cortex. The darkly shaded regions represent areas of high equivalent stress levels; vMES values are noted up to 0.9 in the lateral cortex, and up to 0.7 in the prosthesis.

Figure 6

this same factor of 20 to 30 percent, with increases of again roughly 50 to 60 percent at the corners in selected defects.

In medial defects, the presence or absence of cancellous bone adjacent to the medial pelvic cortex had significant effects on stress transmission to the cortex. As long as even a thin layer of cancellous bone remained next to the medial pelvic cortex, principal stresses in the cortex itself remained essentially unchanged. However, if for otherwise equivalent cases the cancellous bone was entirely removed and replacement PMMA was extended all the way to the medial pelvic cortex, principal stress magnitudes in the cortex were reduced on the average 40 to 50 percent. Some of the load originally present in these cortical areas was redistributed to surrounding PMMA and cancellous bone. The rather diffuse nature of this stress redistribution was such that there appeared to be no danger of material failure in the surrounding regions.

By contrast, replacing a lesion area which included part of the lateral pelvic cortex (lightly shaded region, D, in Figure 6) led to some areas of very marked stress concentrations. Indeed, principal compressive stresses on the order of 4000 to 5000 psi (darkly shaded lateral region) were encountered in the PMMA replacing the absent lateral cortex. Von Mises equivalent stresses of up to 90 percent were seen to occur in this region. Of note is that, for all lesions of this type, the point of highest equivalent stress occurred in the replacement PMMA adjacent to the remaining lateral pelvic cortex, rather than within the remaining lateral cortex itself.
The vMES plot for a medial defect. Elevations in the stress contours are limited largely to the defect itself (compare to Fig. 4).

The location and size of the defect were important in other respects. Those defects located medially or centrally, out of the main weight-bearing tract, had effects which were largely limited to the immediate defect region. Local elevations of stress, up to 40 percent of the von Mises failure criterion, were typically encountered within the replacement PMMA itself (shaded region, D, of Figure 7). However, these high equivalent stress levels were confined to small regions, the elevations diminishing rapidly outside the defect. By contrast, a defect in the weight-bearing tract superiorly, especially a large one as in Figure 5, typically led to two-fold increases in the magnitude of the stress carried in the defect replacement area. This is accompanied by appreciable stress changes in material regions relatively far removed from the defect. For example, relative to the "normal" acetabulum (refer to Figure 4), even the prosthetic component in Figure 5 sustains average increases of 5 to 10 percent (i.e. 100 psi) in principal stresses for areas in the weight-bearing tract.

Comparison of the various methods of acetabular reinforcement revealed a number of significant differences. The addition of a metal backing on the prosthesis led to major decreases in the principal stresses computed for several material regions (compare Figures 8 and 4). This effect was most noticeable for the PMMA cement in the superior weight-bearing tract, where the average reduction in the maximum shear stress was about 50 percent. Smaller reductions in the maximum shear stress on the order of 10 to 25 percent were noted in the prosthesis, in
the lateral pelvic cortex and in the weight-bearing cancellous bone. That is, the metal backing behaved as a stiff shell which partially compensated for the loss of subchondral bone.

The use of cobalt-chromium reinforcement mesh revealed substantial reductions in the stress distributions only for those defects which were located medially. For such defects, regions of PMMA with equivalent stress levels of 40 percent were typically lowered to 30 percent. This is comparable to the reductions achieved with the use of metal-backed prostheses. However, for large defects, especially those in the superior weight-bearing regions, the cobalt-chromium reinforcement mesh was ineffective in reducing the elevated stresses.

The degree of stress relief provided by the Harris-Oh ring was intermediate between that achieved with the metal-backed cup and that seen with the cobalt-chromium reinforcement mesh. In contrast to the metal-backing, the Harris-Oh ring did not appreciably reduce the principal stress magnitude in the prosthesis or in the PMMA overlying the cup. However, in the replacement PMMA and in the cancellous bone above the ring, the principal stress magnitudes were typically lowered by 15 to 25 percent. But the lack of significant stress reduction in lateral pelvic cortex is noteworthy. For a defect with an intact lateral pelvic cortex, the Harris-Oh ring acted as a shell, transferring load to the lateral cortex (Fig. 9). However, if the lateral pelvic cortex was partially destroyed, with PMMA cement replacing a bony discontinuity, such as that in Figure 5, the Harris-Oh ring was ineffective in avoiding a buildup of large stresses in the replacement PMMA. In fact, our results showed that the loss of the lateral pelvic cortex led to von Mises equivalent stresses in the range of 80 to 90 percent, regardless of the method of reinforcement employed.

DISCUSSION

The two-dimensional finite element formulation employed in the present study held certain advantages in terms of simplicity and economy, but these assets were achieved at the expense of limitations in the precision of the model. In particular, out-of-plane effects (especially circumferential "hoop" stresses) occurring in the natural acetabulum and/or in the various prosthetic devices could not be completely modelled. Indeed, even the representation of three-dimensional objects in plane section (e.g. the Harris-Oh ring) sometimes required compromise. Further, the finite element zoning involved distinct demarcations between material regions, with result that the effects of subtle gradations in material properties were possibly missed. Interfacial phenomena, often of interest at the bone/cement interface of a prosthetic joint, were not directly addressed because inclusion of the necessary number of suitable (nonlinear) interfacial elements would have been prohibitive for a problem of this size.

Model limitations notwithstanding, the numerical results from this study unequivocally reinforce recent findings concerning the importance of the acetabular cortical (subchondral) bone. In the normal acetabulum, this subchondral layer behaves as a membrane or shell, whose loss results in redistribution of stress to neighboring regions (particularly the overlying cancellous bone) which are not well suited for transmitting elevated stresses.

Two classes of difficult to quantitate parameters have a major effect on the magnitude of the stress computed in finite element models of this type: the applied resultant load (magnitude and direction), and the properties assigned

Figure 9
vMES plot for Harris-Oh ring in a "normal" hip. Compared to the conventional prosthesis (Fig. 4), there is a modest decrease in the stress for the cancellous bone in the weight-bearing tract. There is little or no appreciable difference in the stress levels for the prosthesis and PMMA.
The resultant joint load adopted in the present (linear) analysis was five times body weight, assuming a 70 kg person at midstance. This value, 71 percent larger than that used by Rushfeldt23 or by Vasu et al.27, represents the temporal maximum contact force reported by Crowninshield et al.8 for the case of a natural hip. This particular load level may not necessarily be achieved in many ambulatory cancer patients. Also, the material property values used herein were inferred from the literature, but for cancellous bone they were somewhat lower than those chosen in other studies. These two factors would seem to account for the higher bony von Mises equivalent stresses in our analysis, compared to those computed in previous work.

When replacement PMMA cement is stressed in weight-bearing regions, it develops stress trajectories similar to those in the material which it replaced. For superior bony defects, the replacement PMMA develops large tensile principal stresses, as well as increased shear stress. While shear stress levels within the replacement PMMA are not near failure, projected levels at the bone-PMMA interface are increased substantially. This may prove to be one of the factors contributing to mechanical loosening in clinical situations with deficient bone stock.

One substantially new finding of the present model is the very important role of the lateral pelvic cortex in load transmission. Its function in the otherwise normal acetabulum with a prosthesis is to transmit the large tensile stresses developed in the acetabular cortical bone. With PMMA replacement of a defect in the lateral pelvic cortex, very high von Mises equivalent stresses, typically 90 percent of failure level, are developed within the replacement

Figure 10
A comparison of the maximum vMES levels attained in the various material regions, for a conventional UHMWP prosthesis implanted, respectively, in the "normal hip", and in hips with medial, superomedial, and superior defects of equivalent size. For purposes of comparison, the label "DEFECT" denotes an area in the "intact" hip corresponding to the individual defect considered, i.e. corresponding to the area which has been filled by replacement (R) PMMA. The labels CANC, LPC, and MPC denote, respectively, cancellous bone, and the lateral and medial pelvic cortices.
PMMA. Further, while either a metal-backed acetabular component or a Harris-Oh ring decreases this stress concentration somewhat, von Mises equivalent stresses still remain above 60 percent. It may be that clinically, as the survival of cancer patients improves, those patients with metastatic acetabular lesions in this area will experience a high incidence of material failure and loosening.

Figure 10 further illustrates some effects of the location of a metastatic defect on the von Mises equivalent stresses. Those defects located within the weight-bearing tract experience the most elevated stresses in their replacement PMMA, and hence would appear clinically to be most in need of supplemental reinforcement. Unfortunately, no presently feasible computational model can be directly applied to a clinical situation to determine just which lesions need mechanical reinforcement, and if so, of what type. However, the present results do indicate certain clinically applicable trends. The metal-backed acetabular cup appears to offer excellent reinforcement and stress relief of replacement PMMA and cancellous bone for all situations studied, except those with loss of the lateral cortex. Indeed, this cup has the advantage of not only decreasing stress levels in most bony regions and in the replacement PMMA, but in the normal PMMA layer above the prosthesis as well. Computationally, neither the Harris-Oh ring nor the cobalt-chromium reinforcing mesh proved more effective in lowering these stresses for any case considered. For those defects located near the superolateral acetabular margin, however, the Harris-Oh ring offered stress relief of comparable magnitude to that seen with the metal-backed prosthesis. Finally, the biomechanical role of cobalt-chromium reinforcing mesh would appear to be limited. This is not to imply that clinically it does not function usefully as a molding containment for unsolidified PMMA or bone graft. But for the great majority of superior or superomedial defects studied, little reduction in the predicted stress levels was observed. Indeed, even for medial defects, equal or lower stress levels were achieved simply by the use of a metal-backed cup.

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A RELATIONSHIP OF TOTAL KNEE DESIGN KINEMATICS TO PATIENT FUNCTION

James N. Weinstein, D. O.
Department of Orthopaedics
University of Iowa Hospitals and Clinics
Iowa City, IA 52242

Thomas P. Andriacchi, Ph.D.
Department of Orthopaedics
Rush-Presbyterian-St. Luke's Medical Center
1753 West Congress Parkway
Chicago, IL 60612

Jorge O. Galante, M.D.
Department of Orthopaedics
Rush-Presbyterian-St. Luke's Medical Center
1753 West Congress Parkway
Chicago, IL 60612

At present the relationship between total knee prosthesis design and patient function is not clearly understood. The mechanics of the knee are complex. The knee during some activities will undergo motion with 6 degrees of freedom. Within each plane, there must be stability as well as mobility. Some authors however, have suggested individual planes of motion to be important in the kinematics of various total knee designs. Possibly these authors are correct but to date these studies have been limited to *in vitro* models without analyzing actual patient function.

Quantitative studies of patient function during activities of daily living have been performed. These studies indicate differences in patient function not accounted for on the basis of prosthetic design alone. Asymptomatic patients following total knee replacement, even with an excellent result, may have gait abnormalities. These abnormalities consist of a shorter than normal stride length, reduced midstance knee flexion, and abnormal external knee flexion and extension moments. The explanation of these functional abnormalities was felt to be related to the interaction of the knee joint kinematics and surrounding soft tissues. However, none of the reports have examined quadriceps function and its relationship to knee joint kinematics following total knee replacement surgery.

The purpose of this study was to examine the hypothesis that aspects of functional abnormalities during gait following total knee replacement surgery are a result of a reduction in the mechanical efficiency of the quadriceps mechanism. The hypothesis was tested through combined analysis of patient function and an *in vitro* experimental model.

MATERIALS AND METHODS

*In Vitro* Experimental and Analytical Cadaver Knee Model

The *in vitro* experimental knee model consisted of the distal one-third of the femur and the proximal one-third of the tibia with all soft tissue structures in and about the knee left intact. Four specimens were selected fresh at autopsy (with no evidence of any previous knee surgery or other knee problems), and kept frozen until the time of testing. Throughout testing the specimens were kept moist with the use of an aerosol spray. The quadriceps forces required to balance a constant external flexion moment of 1 Nm was measured at 5 degree increments of knee flexion ranging from 0 to 90 degrees. A pulley system was arranged to apply a constant flexion moment as the knee was flexed by maintaining the line of action of a 1 Nm force always perpendicular to the longitudinal axis of the tibia. The resulting quadriceps force was then measured using a spring balance connected to a cable attached to the quadriceps mechanism (Fig. 1).

The experimental procedure and analysis assume a two dimensional idealization of the knee joint in which the external flexion moment is balanced by the quadriceps mechanism. Therefore, the model assumed that the only forces acting on the tibia were the quadriceps force (Fq) directed through the patellar ligament, the reaction force (R) located at a position of zero net moment in the AP direction (tibial-femoral contact) and the force applied to the tibia to produce the flexion moment. The angles of the patellar ligament as a function of knee flexion angle were
derived from the literature\(^9\). The objective of the model was to calculate changes in the location of the tibial-femoral contact from the measures of quadriceps force, applied moment and knee flexion angle. The movement of the tibial-femoral contact was then calculated for the normal knee and four designs of prosthetic knee replacements.

The normal knee was tested first and then each of the four prosthetic knee designs were sequentially implanted and tested in a uniform manner. The designs tested included the J and J Unicompartmental, Zimmer 1 Unicompartmental, Cloutier and Total Condylar. The J and J Unicompartmental design is a hemi-arthroplasty with a single semicircular runner for the femoral component and an independent tibial component. The operative placement of the femoral and tibial components can be varied from anterior to posterior. This design allows for both cruciate ligaments to be retained and does not include patellar resurfacing or patellar flange (Fig. 2A). The Zimmer I design is also a hemi-arthroplasty. It differs from the J and J prosthesis in that the femoral component has a broader base and a larger radius of curvature. The tibial component is slightly more concave on its articulating surface. This design does not allow for variability of placement in the anterior to posterior plane (Fig. 2B). The Cloutier is a bicondylar prosthesis that allows for retention of both cruciate ligaments; the femoral condyles are asymmetrical, diverge and have varying radii of curvature. The tibial component consists of a flat articular surface supported by a metal retainer. This design has a patellar flange, but patellar resurfacing was not performed (Fig. 2C). The Total Condylar is a bicondylar design that sacrifices both cruciate ligaments with anterior and posterior stability provided by the conformity of the tibial articulating surfaces (Fig. 2D).

As stated above, the J and J Unicompartmental design permits variability of sagittal plane placement of the femoral and tibial components. Therefore, the position of the femoral-tibial balance point and its influence on the efficiency of the quadriceps mechanism and patient function could be experimentally and clinically evaluated by using this prosthetic design. The J and J Unicompartmental knee design was therefore implanted in two fresh cadaver knees. The femoral component was placed anterior in one and posteriorly in the other (Fig. 3). The relative component positions could be distinguished from the lateral roentgenograms. Component placement was determined by identifying the sagittal midline of the tibia and locating the anterior edge of the femoral component relative to the intersection of the tibial mid-line with the tibial plateaus. The component was considered to be posteriorly placed when, in the fully extended position, the anterior edge of the component was posterior to the midline of the tibia.

**In Vivo Gait and Stair climbing Study**

Eight patients were studied in two experimental groups during level walking and stair climbing. Patients were grouped according to which of the two prosthetic designs they received. The two implants selected for this study were the J and J and Zimmer I Unicompartmental designs. Lateral roentgenograms of each of the patients were

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![Experimental Knee Model](image)

**Figure 1**
An illustration of the experimental knee model. The quadriceps forces required to balance a constant external flexion moment were measured at 5 degree increments of knee flexion from 0 to 90 degrees.

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<tr>
<th>J &amp; J UNICOMP.</th>
<th>ZIMMER 1</th>
<th>CLOUTIER T.K.A.</th>
<th>TOTAL CONDYLLAR T.K.A.</th>
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**Figure 2A**
An illustration of the Johnson and Johnson Unicompartmental Arthroplasty and its design characteristics in the sagittal plane.

**Figure 2B**
An illustration of the Zimmer I and its design characteristics in the sagittal plane.

**Figure 2C**
An illustration of the Cloutier total knee arthroplasty and its design characteristics in the sagittal plane.

**Figure 2D**
An illustration of the Total Condylar total knee arthroplasty and its design characteristics in the sagittal plane.
analyzed to determine the relatively anterior-posterior positioning of the femoral component relative to the tibia. The patients selected for this study were matched according to postoperative status in terms of pain, function, passive range of motion and joint stability. The Harris knee rating was used to quantitate postoperative status. All patients were required to be at least one year status post knee joint surgery to qualify for this study, and had to have scored eighty-five or more points based on this point system. Consequently, all patients had an excellent clinical result, were able to walk without aids, had little or no pain, and were able to climb stairs in a reciprocal manner.

The resulting population consisted of twelve knees in eight patients, seven patients with eleven involved knees were diagnosed as having osteoarthritis while the remaining patient with one knee involved had rheumatoid arthritis (Table 1). None of the eight patients had previous joint surgery, none of the patients had any knee joint flexion contracture, and all patients had both the anterior and posterior cruciates retained.

The control group consisted of fourteen healthy adult subjects (seven males and seven females) with an average age of 62.4 years (s.d. = 6.3). Both the control and study groups were tested using the same protocol. The gait of each subject was measured during twelve stride cycles each of which occurred midway during a separate walking trial on a ten-meter walkway. Gait measurements were considered with walking speed as an independent variable in order to separate gait differences that may be due to factors other than changes in speed. Each subject was observed walking up and down a three step staircase. The experimental observations were based on idealization that considered the lower extremities as a three dimensional linkage with moveable joints at the hip, knee and ankle. The joints were assumed to have a fixed axis of motion. Limb motion was monitored by observing the spatial position of six light-emitting diodes (LED) placed on the lower limbs in a fashion previously reported.

The three dimensional position of each LED was sampled seventy-five times per second using an optoelectronic system. Ground reaction force measurements were acquired simultaneously with the limb position measurements using a piezoelectric force platform. The force platform measured the three components of ground reaction force, vertical twisting moments, and location of the resultant forces at the foot. To calculate the moments, each limb segment (thigh, leg, and foot) was idealized as a rigid body with a coordinate system chosen to coincide with the anatomical axis. The moments were compared selecting the measurements closest to 1 meter/second for each subject. In addition, time-distance measurements and limb motion parameters were derived. For the purpose of this study, only data about the knee joint will be described.

RESULTS
In Vitro Experimental and Analytical Cadaver Model

The relationship between the quadriceps forces, lever arms and knee flexion angles was nearly the same for the two normal control knees (Fig. 4). The lever arm was quite short near full extension and showed a rapid increase in length as the knee flexes from 0 to 20 degrees (0.85-4.31 cm) reflecting a posterior movement of the tibial-femoral contact. In the range of 20 to 60 degrees the quadriceps lever arm did not change substantially (4.09-4.11 cm), while between 60 and 90 degrees the quadriceps lever arm increased slightly (3.92-5.09 cm).

When the J and J design was implanted posteriorly, the quadriceps lever arm was relatively normal in the range of 0 to 20 degrees of knee flexion (.08-4.20 cm) and continued in a relatively normal pattern throughout knee flexion (Fig. 5). When implanted anteriorly, the quadriceps lever arm was two to three times shorter than the controls in the range of 0 to 20 degrees (0.11-2.19 cm). However in the range of 60 to 90 degrees, the quadriceps lever arms were relatively normal (3.92-4.06 cm) (Fig. 6). The Zimmer I Unicompartmental design did not allow for significant variability in the anterior-posterior placement. In the first 0 to 20 degrees of knee flexion the quadriceps lever arm was up to three times shorter than the control (0.21-4.54 cm). In the 60 to 90 degree range the quadriceps lever arm remained up to two times shorter than the control normal knee (2.76-2.89 cm). The Cloutier knee design maintained the shortest quadriceps lever arm in the model during the first 0 to 20 degrees (0.23-0.71 cm). However, in the range of 60 to 90 degrees (3.89-4.3 cm) the quadriceps lever arm remained in a relatively normal range (Fig. 7). The Total Condylar design produced a quadriceps lever arm four times shorter than normal in the range of 0 to 20 degrees (0.23-3.98 cm) and one and one-half times shorter than normal in the range of 60 to 90 degrees (3.05-3.11 cm) (Fig. 7).

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<th>J&amp;J UNICOMPART. ANTERIOR POSITION</th>
<th>J&amp;J UNICOMPART. POSTERIOR POSITION</th>
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<td>An illustration of the J and J Unicompartmental placed anteriorly in one knee and posteriorly in another.</td>
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Figure 3
The posteriorly placed J and J Unicompartmental was the only design to produce a relatively normal quadriceps lever arm and quadriceps forces in the range of 0 to 20 degrees of knee flexion. Therefore, altering the position from anterior to posterior increased the length of the quadriceps lever arm and decreased the quadriceps force necessary at varying degrees of knee flexion.

In Vivo Gait and Stair climbing Data

The range of walking speeds of the unicompartmental knee patients was 0.60 to 1.93 meters/second, while the range of walking speeds for the normals was 0.61 to 2.05 meters/second.

As described in other total knee patients\(^1,3\), our patients demonstrated a shorter than normal stride length and had a less than normal change in midstance knee flexion angle. A third characteristic of gait in total knee patients is an abnormal pattern of flexion-extension moments. The normal and abnormal patterns of flexion and extension moments were characterized by analyzing the wave forms for moment patterns for each patient\(^3\). Normal patterns were characterized by a biphasic pattern with two relative maximums trending to extend the joint. The two abnormal patterns were characterized by a tendency to maintain an extrinsic moment in a direction to either flex the knee joint (flexional moment patterns) throughout stance phase or extend the knee joint throughout stance phase (extensional moment patterns)\(^3\). In both abnormal patterns, the abnormality occurred during the middle portion of the stance phase.

Four out of five J and J Unicompartmentals had normal patterns of stance phase flexion-extension moments, while all seven Zimmer I Unicompartmentals had abnormal stance

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*OA = Osteoarthritis, RA = Rheumatoid Arthritis

A description of the patient population, divided into two groups and a comparison of the unicompartmental femoral component position and flexion-extension moment pattern during level walking.

---

### Table 1

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age Years</th>
<th>Time Months</th>
<th>Diagnosis*</th>
<th>Knee Rating</th>
<th>Femoral† Positioning</th>
<th>Flexion-Extension Moment Level Walking</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>F</td>
<td>71</td>
<td>36</td>
<td>OA</td>
<td>99</td>
<td>P</td>
<td>Normal</td>
</tr>
<tr>
<td>B</td>
<td>M</td>
<td>78</td>
<td>29</td>
<td>OA</td>
<td>95</td>
<td>A</td>
<td>Extensional</td>
</tr>
<tr>
<td>C</td>
<td>M</td>
<td>79</td>
<td>60</td>
<td>OA</td>
<td>92</td>
<td>P</td>
<td>Normal</td>
</tr>
<tr>
<td>D</td>
<td>M</td>
<td>79</td>
<td>36</td>
<td>OA</td>
<td>96</td>
<td>P</td>
<td>Normal</td>
</tr>
<tr>
<td>E</td>
<td>F</td>
<td>63</td>
<td>48</td>
<td>OA</td>
<td>91</td>
<td>P</td>
<td>Normal</td>
</tr>
<tr>
<td>A</td>
<td>M</td>
<td>75</td>
<td>28</td>
<td>RA</td>
<td>99</td>
<td>A</td>
<td>Extensional</td>
</tr>
<tr>
<td>B</td>
<td>M</td>
<td>75</td>
<td>34</td>
<td>OA</td>
<td>99</td>
<td>A</td>
<td>Extensional</td>
</tr>
<tr>
<td>C</td>
<td>F</td>
<td>75</td>
<td>36</td>
<td>OA</td>
<td>90</td>
<td>A</td>
<td>Flexional</td>
</tr>
<tr>
<td>D</td>
<td>M</td>
<td>65</td>
<td>36</td>
<td>OA</td>
<td>98</td>
<td>A</td>
<td>Flexional</td>
</tr>
<tr>
<td>E</td>
<td>M</td>
<td>65</td>
<td>52</td>
<td>OA</td>
<td>99</td>
<td>A</td>
<td>Extensional</td>
</tr>
<tr>
<td>F</td>
<td>F</td>
<td>77</td>
<td>83</td>
<td>OA</td>
<td>93</td>
<td>A</td>
<td>Extensional</td>
</tr>
<tr>
<td>G</td>
<td>F</td>
<td>77</td>
<td>77</td>
<td>OA</td>
<td>93</td>
<td>N</td>
<td>Extensional</td>
</tr>
</tbody>
</table>

†P = Posterior, A = Anterior, N = Neutral

*OA = Osteoarthritis, RA = Rheumatoid Arthritis

---

**Figure 4**

An illustration of the change in quadriceps lever arm with knee flexion angle for the normal knee joint. \( F = \) force. \( M = \) moment.
phase flexion-extension moments. Moment patterns in all knee patients in the abduction-adduction and internal-external rotation planes were normal. The relationship between prosthetic positioning and moment patterns is also shown (Table 1). Those patients with J and J Unicompartmentals positioned posteriorly all had "normal" flexion-extension stance phase patterns, while the one patient with an anteriorly placed prosthesis exhibited an "extensional" moment pattern. None of the patients with Zimmer I Unicompartmentals had normal moment patterns.

Stair Climbing

All patients were able to climb up and down stairs in a reciprocal manner. Both groups exhibited relatively normal ranges of motion while ascending (controls 86.4 degrees; patients 86.4 degrees) and descending (controls 92 degrees; patients 86.6 degrees). Flexion-extension moment patterns for ascending stairs were compared with the normal control group. Two distinctive patterns while ascending the stairs were identified. Pattern I was characterized by a wave form which reached a maximum in a flexion direction during mid-support phase while Pattern II was characterized by a sign reversal from flexion to extension at mid-stance phase\(^3\). Those with the J and J design had moment patterns similar to the normals, those with Zimmer I design had moment patterns of the type found in patients with Total Condylar design, as previously reported\(^3\).

DISCUSSION

In interpreting the results of this study, it is important to consider the assumptions used in developing the experimental model and its subsequent analysis. The purpose of the model was to test quantitatively the hypothesis that the lever arm of the quadriceps has a substantial influence on function and that changes in the normal lever arm will cause abnormal function. There are many factors, including magnitude and direction of the applied force as well as anatomical variations which may affect differences in the biomechanical response of the joint. Thus the model should not be considered for its absolute prediction of the location of the tibial-femoral contact point but rather in terms of trends and changes associated with various designs of knee replacement. It was demonstrated by the reproducibility of this method among the controls, that even this simplified model was useful for predicting differences between selected total knee designs.

The results of this study point to a direct relationship between the design of the total knee replacement and patient function. Through cadaver studies it was shown that the anterior-posterior displacement of the femur on the tibia can substantially influence the mechanical efficiency of the quadriceps mechanism.
In the designs tested in our in vitro model, the quadriceps were mechanically compromised at critical degrees of knee flexion. This necessitated abnormally high quadriceps forces in the range of knee flexion necessary for level walking in all designs, and in stair climbing for the Zimmer I and Total Condylar designs. As a result, the functional deficit in level walking and stair climbing observed in those patients may be attributed to the compromised mechanical efficiency of the quadriceps mechanism. The influence of this reduced efficiency can be demonstrated by examining the demand on the quadriceps during stair climbing. From previous studies the maximum moments tending to flex the knee during stair climbing occurs between 60-70 degrees of knee flexion. The average moment in this range is 60 Newton meters. Taking the quadriceps lever arm for the normal (4 cm) and a Total Condylar (2.8 cm) at 65 degrees of knee flexion, an estimate of the difference in quadriceps force can be calculated by taking the ratio of the external moment to the quadriceps lever arm. A Total Condylar patient would have to generate a quadriceps force of 2140 Newtons while a normal subject would have to generate a quadriceps force of only 1500 Newtons to climb the stairs in the same way, approximately one body weight difference. Thus, alterations in the quadriceps lever arm have a substantial influence on the quadriceps loads.

In patients following total knee arthroplasty, the magnitude of the quadriceps forces was directly related to the kinematics of the prosthesis and the length of the quadriceps lever arm at different degrees of knee flexion. Thus, if the results of this study are extrapolated, they would indicate that alterations in knee joint mechanics are at least in part the result of the kinematics of these prosthetic implants, which may significantly affect patient function. On this basis, one can relate the abnormal gait patterns seen following total knee replacement arthroplasty to the mechanically inefficient quadriceps mechanism produced by these prostheses.

REFERENCES

KINEMATICS OF THE CERVICAL SPINE FOLLOWING LAMINECTOMY AND FACET WIRING

Charles R. Clark, M.D.*, Vijay K. Goel, Ph.D.**, and Kurt G. Harris, B.S.*
Departments of Orthopaedic Surgery* and Biomedical Engineering**
The University of Iowa, Iowa City, Iowa 52242

Altered intervertebral motion has been implicated as a possible etiology in various clinical pathologic processes in the cervical spine. Such abnormal motion may be the result of degenerative diseases or trauma, or may be iatrogenically induced by surgery such as interbody fusion or laminectomy. Callahan, Johnson, and others observed that some patients undergoing decompressive cervical laminectomy had a tendency to develop instability or deformity months to years after surgery1,5,12. Three groups of patients were found to have a higher probability of developing progressive deformity: children or young adults under twenty-five years of age, patients requiring laminectomy following trauma, and patients who have undergone laminectomy with foraminotomy or extensive dissection about the facets. More recent clinical studies have also lent support to the hypothesis that laminectomy alone can lead to increased motion, instability, and deformity, particularly in very young patients13,14.

An investigation of the three-dimensional motion of intact and injured cervical spines in vitro would help elucidate the immediate biomechanical effects of laminectomy and serve as a data base for clinical decision-making by helping to identify injury types which may require stabilization. Similar data for spines that have been stabilized in vitro would identify segments which may be subjected to pathologic motion or stresses by the stabilization procedure itself. These data may be related to post-surgical complications, provided the correlation between abnormal motion and subsequent pathology itself is valid. The present study, using multi-level lower cervical spine segments, was initiated to collect this necessary basic data.

Investigators have studied cervical spine motion behavior through in vitro studies using single motion segments comprised of two adjacent vertebrae and their interconnecting soft tissues6,8,11,15. The effects of an induced injury or stabilization which acts across multiple motion segments cannot be studied adequately using such a model.

There have been few published studies of the three-dimensional motion behavior of multi-level lower cervical spinal segments. Panjabi, Goel, Clark and others investigated the relative rotations between various vertebrae of multi-level (C2-T1) cervical ligamentous spine segments3,4,7,8,9,10. The present study is an extension of this earlier work and is part of our ongoing program investigating the biomechanics of cervical spines subjected to quasi-static load types, both when intact and when affected by injuries including various surgical techniques used to stabilize spines. In this study the injury is total laminectomy at two levels performed in a sequential manner, first at C5 and then at C6, followed by stabilization using a modified facet wiring technique with iliac bone grafts. This procedure has been advocated as a means of stabilizing spines after laminectomy (prophylactically) or bilateral facet dislocation1.

MATERIALS AND METHODS

Fresh-frozen cervical spines (C2-T2) were obtained from donated human cadavers. All were screened with anteroposterior and lateral roentgenograms to exclude specimens with significant degenerative changes including disc space narrowing, ankylosis of the disc, facet joints, or lateral joints of Luschka, and gross osteophyte formation, particularly those "bridging" between the vertebral bodies. Six specimens found to be acceptable for motion studies were kept frozen in plastic bags at -20°C until further preparation for testing. Characteristics of their donors are compiled in Table I.

Specimen Preparation: Three days before a specimen was to be tested, it was thawed out at room temperature while still in its plastic bag. All the paravertebral musculature was cleaned off. During cleaning, extreme care was taken to avoid disrupting ligaments, particularly the capsular ligaments which are vulnerable to accidental "nicking". The superior surface of the axis (C2) was cleaned to facilitate mounting on a loading frame. The spine was refrozen while lying on its side to avoid any distortion of the natural lordosis. At a later date the cleaned specimen was prepared further to secure a Plastic Padding® base for its mounting in a testing setup, a loading frame to C2 for applying loads, and a set of three infrared light emitting diodes (LEDs) to each of the five vertebrae (C3-C7) for recording the motion through the Selspot II® system. The techniques used were similar to ones used in our earlier studies and as such only a brief description is included here3,4.
Table I: Physiological data of the specimens.

<table>
<thead>
<tr>
<th>Specimen #</th>
<th>Age (yrs.)</th>
<th>Sex</th>
<th>Height (cm)</th>
<th>Weight (lbs.)</th>
<th>Cause of Death</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(112)</td>
<td>77</td>
<td>M</td>
<td>180</td>
<td>135</td>
<td>Bladder Cancer</td>
<td>Disc narrowing with osteophytes at C3-4 and C4-5</td>
</tr>
<tr>
<td>2(483)</td>
<td>72</td>
<td>F</td>
<td>168</td>
<td>185</td>
<td>Liver Cancer</td>
<td>Small, hyper mobile specimen</td>
</tr>
<tr>
<td>3(482)</td>
<td>58</td>
<td>M</td>
<td>178</td>
<td>170</td>
<td>Glioblastoma</td>
<td>Normal specimen</td>
</tr>
<tr>
<td>4(2)</td>
<td>55</td>
<td>F</td>
<td>173</td>
<td>160</td>
<td>Cerebro-vascular accident (stroke)</td>
<td>Normal specimen</td>
</tr>
<tr>
<td>5(446)</td>
<td>57</td>
<td>M</td>
<td>170</td>
<td>130</td>
<td>Trauma</td>
<td>Minimal osteophytes, otherwise normal specimen</td>
</tr>
<tr>
<td>6(9)</td>
<td>85</td>
<td>F</td>
<td>155</td>
<td>95</td>
<td>Carcinomatosis</td>
<td>Very mobile and osteopenic, presented some problems during stabilization</td>
</tr>
</tbody>
</table>

The frozen specimen was “potted” by casting a Plastic Padding® block around vertebrae T1 and T2. The specimen was oriented in anatomic position, such that the C5-6 disc space was horizontal. A loading frame was secured to C2 parallel to the base via two threaded rods passed through the frame and the holes in the vertebra (Fig. 1A). (Combined mass of the frame and the rods was about 70 gm.)

Knowledge of the location of three non-colinear points on a rigid vertebra was both necessary and sufficient to uniquely specify the position of the vertebra in space. Such a set of points was provided by the three light-emitting diodes (LEDs). In order to attach these rigidly to each of the five vertebral bodies without disrupting the ligamentous structures to any significant degree, a novel technique was developed. One self-tapping 2.8 mm threaded Steinmann pin was placed transversely through the anterior portion of the vertebral body and another perpendicular to it in the AP direction (Fig. 1B). The LEDs were attached to the ends of the pins. These fixtures were so arranged that (a) none of them interfered with their respective adjacent fixtures, and (b) the attached LEDs were within the view of the Selspot cameras throughout the testing. A special set of three LEDs was secured to the base to define an anatomically relevant Cartesian axis system. The X-axis lay in a frontal plane with its positive direction stretched out toward the left of the specimen. The Z-axis lay in the midsagittal plane with its positive direction stretching out anteriorly and the X-Z plane parallel to the base. The Y-axis, obtained as the cross product of these two axes, rose vertically from this plane. The prepared specimen ready for testing in Selspot II® system is shown in Figure 2.

Selspot II® System: The three-dimensional (3-D) motion of the specimen was monitored using the Selspot II® system (Manufactured by Selcom Selective Electronic, Inc., Valdese, North Carolina, U.S.A.). It is an opto-electronic system based on the principles of stereo-photogrammetry. The infrared LEDs, attached rigidly to the five vertebrae,
Kinematics of the Cervical Spine

are used as definable points. The LEDs are fired sequentially. The emitted light is picked up by the two cameras, through infrared light detectors, analog amplifiers and other associated electronics. Thus, through proper calibration, it is possible to locate the spatial position of an LED from the X and Y voltage data.

Testing of Intact (IN) Specimen: The prepared specimen was attached to the base of a testing cage. The specimen, after its complete thawing, was manually put through the extremes of motion in each mode and test firing of the LEDs was performed to assure that both cameras could "see" each LED. The distal ends of the Steinmann pins were adjusted as necessary to achieve this.

Experimental loads were applied in the form of moments exerted at C2 through use of a system of weights, pulleys, and nylon strings attached to the ends of the arms on the loading frame. The loads were meant to approximate pure moments as closely as possible. To achieve this, the pulleys were slid along moveable suspension bars so that the strings would flex the spine in the desired plane for the desired load modality. For example, to effect axial rotation, the strings were arranged parallel to each other in a transverse plane, pulling the loading arms in opposite directions (Fig. 1A). The loads were then applied in a graduated manner by progressive addition of 25 gm weights onto each string, eventuating in a final load step of 1.9 N producing a maximum moment of 0.3 Nm. These loads steps were repeated six times in a prescribed load type sequence; flexion (FLX), extension (EXT), right and left lateral bending (RLB and LLB), and left and right axial rotation (LAR and RAR). The LED locations after each load step and in each load type were recorded by the Selspot II® system.

Laminectomy (LM) and Facet Wiring (FW): Following collection of the data for the intact specimen, the entire testing sequence was repeated for two sequential injuries and the facet wiring stabilization procedure.

The first injury was a total laminectomy performed on C5 (LM5). This was done by first severing the supraspinous, interspinous and flavum ligaments connecting C5 to both C4 and C6, and then removing the entire vertebral arch with a rongeur. Care was taken to avoid damaging the facet joints medially. The second injury was total laminectomy performed on C6 (LM6). The facet wiring procedure was performed as described by Callahan et al.1 with the modification of extending the wiring to include the spinous process of C4. The basic technique involved first drilling holes through the inferior articular processes of both C5 and C6 bilaterally and then passing double-twisted 24 gauge wire down through the holes so that they emerged from the facet joint spaces. (The capsular ligaments were disrupted in order to do this.) The wires were then twisted around biconcave iliac bone grafts, producing an effective fusion between C5 and C6. The construct was further stabilized by drilling holes laterally through the bases of both C4 and C7 spinous processes, and fixing the bone grafts to these vertebrae also (FW47). A C4 to C7 fusion construct was selected because the laminectomies at C5 and C6 destabilized the C4-5 and C6-7 interspaces, respectively. The end result was a spine which had an intact anatomic arrangement between C2-3, C3-4 and C7-T1 (unaffected motion segments), but was fused from C4 through C7, (affected motion segments) as shown in Figure 3. Following the facet wiring stabilization, the specimen was put through the testing sequence a final time.

Figure 3
The sequential laminectomies done on C5 and C6 and the stabilization achieved through the facet wiring. Motion segments, C3-4 and C7-T1 were unaffected during the injuries and stabilization. Motion segments C4-5, C5-6 and C6-7, being injured/stabilized, were affected in this process.

Selspot II® System Accuracy: The overall reliability and accuracy of the system used to monitor the changes in the specimen motion behavior, evaluated through a set of independent experiments, was found to lie within 5 percent of the actual motions. Only the motion data corresponding to the final load step (0.3 Nm) are reported in the results section since the motion magnitude at smaller load steps is relatively smaller.

DATA ANALYSIS AND RESULTS

The spatial locations of the LEDs were all expressed with respect to the anatomically relevant Cartesian axis system located at the base plate fixed to T1. After each load increment of a given load type, the spatial data were reduced further to compute the three Brayant/Euler angles as rotations between any two vertebrae. These angles (hereafter termed rotational angles) represent three sequential vertebral rotations: rotation in a sagittal plane (flexion or extension, ± Rz), followed by a rotation in the transverse plane (axial rotation, ± RY), and lastly, a rotation in the frontal plane (lateral bending, ± Rx). Graphs of the three rotations vs. the load magnitude for intact as well as injured specimens and for all load types were
The load-deformation behavior of various vertebrae during lateral bending for an intact specimen. The major motion is the rotation about Z-axis ($R_Z$). Table II includes the mean (± S.D.) data obtained from all specimens.

obtained. Such graphs for an intact specimen are shown in Figure 4. These graphs, nonlinear in shape, depict major rotation ($R_Z$) for all the five vertebrae (C3 to C7) subjected to lateral bending moment with respect to the fixed vertebra (T1). Table II lists the mean (one standard deviation) relative motions between the motion segments of the six intact specimens subjected to 0.3 Nm load in all the load types. For further details concerning data analyses one may refer to our earlier publications.3,4

The data for the injured and stabilized specimens were normalized with respect to the corresponding motion of the intact specimens using the following relation:

$$NR_j = \frac{(R_j - R_o)}{R_o} \times 100$$

where

$NR_j$ = Normalized relative rotational angle between two vertebrae about the j axis (X, Y or Z) for the injured/stabilized specimen at a specific load step (percentage);

$R_j$ = Relative rotational angle between two vertebrae ($R_X$, $R_Y$, or $R_Z$) for the injured/stabilized specimen at the corresponding load step;

$R_o$ = The corresponding relative rotational angle for the intact specimen.

Normalizations were done to make interspecimen comparisons more meaningful and to highlight the change in the motion behavior after injury, if any.

Two-tailed Student's t-tests were performed to evaluate the significance levels of the changes in the motion after injury and stabilization with respect to the intact state.

Table III shows the mean (± 1 S.D.) increases (or decreases) in the major motion with each particular load type, as indicated by the normalized data of six specimens corresponding to the final load step of 0.3 Nm. The motion behavior of the affected motion segments (C4-5, C5-6 and C6-7) in right axial rotation, for example, showed a slight increase after laminectomies at C5 and C6 (LM5 and LM6) but showed a significant decrease (~80 per cent with $p < 0.01$) post-facet wiring of vertebrae C4 through C7 (FW47). The changes in motion at the unaffected motion segments (C3-4 and C7-T1) were also very small. A visual comparison of the normalized major rotation ($NR_D$) vs. the state of the specimen in right lateral bending for the affected as well as unaffected motion segments can be seen in Figures 5A-E. A significant decrease in motion was observed at the affected motion segments (Figs. 5A-C) after facet wiring ($p < 0.01$). The level of significant changes in motion, (with $p < 0.1$) at various motion segments and load types are illustrated in Table IV.

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DISCUSSION

This kinematic study of the effects of multiple laminectomies and subsequent stabilization by facet wiring on the motion behavior of whole cervical spine segments is the
Table II: Mean normalized and coupled rotations for various load types.

<table>
<thead>
<tr>
<th>Load Type</th>
<th>Motion (Deg.)</th>
<th>C3-4 (Mean(S.D.))</th>
<th>C4-5 (Mean(S.D.))</th>
<th>C5-6 (Mean(S.D.))</th>
<th>C6-7 (Mean(S.D.))</th>
<th>C7-T1 (Mean(S.D.))</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLX</td>
<td>Rx**</td>
<td>3.5(1.7)</td>
<td>3.4(1.1)</td>
<td>2.4(1.2)*</td>
<td>3.0(1.6)</td>
<td>1.4(0.6)</td>
</tr>
<tr>
<td></td>
<td>Ry</td>
<td>0.10(0.7)</td>
<td>0.10(0.5)</td>
<td>0.5(0.1)*</td>
<td>1.4(1.6)</td>
<td>0.10(2.2)</td>
</tr>
<tr>
<td></td>
<td>Rz</td>
<td>0.00(0.7)</td>
<td>-0.90(9.9)</td>
<td>0.00(0.5)*</td>
<td>0.2(1.0)</td>
<td>-0.10(3.2)</td>
</tr>
<tr>
<td>EXT</td>
<td>Rx**</td>
<td>-1.9(1.3)*</td>
<td>-2.7(6.6)*</td>
<td>-2.8(1.0)</td>
<td>-2.7(1.3)</td>
<td>-1.10(8.5)</td>
</tr>
<tr>
<td></td>
<td>Ry</td>
<td>0.40(0.9)*</td>
<td>0.10(0.5)*</td>
<td>-0.10(5.0)</td>
<td>-0.30(0.5)</td>
<td>0.00(2.2)</td>
</tr>
<tr>
<td></td>
<td>Rz</td>
<td>-0.20(1.0)*</td>
<td>0.10(0.8)*</td>
<td>0.2(1.0)</td>
<td>0.8(1.0)</td>
<td>-0.10(3.3)</td>
</tr>
<tr>
<td>RLB</td>
<td>Rx</td>
<td>0.10(1.7)</td>
<td>0.30(1.5)</td>
<td>0.3(1.4)</td>
<td>-0.20(4.0)</td>
<td>0.00(3.3)</td>
</tr>
<tr>
<td></td>
<td>Ry</td>
<td>-1.4(1.1)*</td>
<td>-1.4(1.0)</td>
<td>-1.3(1.1)</td>
<td>-0.7(1.2)</td>
<td>0.50(8.3)</td>
</tr>
<tr>
<td></td>
<td>Rz**</td>
<td>3.30(2.0)</td>
<td>3.82(2.5)</td>
<td>2.7(2.5)</td>
<td>1.8(1.2)</td>
<td>1.50(9.9)</td>
</tr>
<tr>
<td>LLB</td>
<td>Rx</td>
<td>-0.50(1.4)</td>
<td>-0.40(0.7)</td>
<td>-0.8(1.0)</td>
<td>-0.10(5.0)</td>
<td>-0.10(2.0)</td>
</tr>
<tr>
<td></td>
<td>Ry</td>
<td>1.41(1.1)</td>
<td>1.6(1.6)</td>
<td>1.00(0.6)</td>
<td>0.8(1.4)</td>
<td>0.30(7.7)</td>
</tr>
<tr>
<td></td>
<td>Rz**</td>
<td>-3.72(2.1)</td>
<td>-3.72(2.8)</td>
<td>-2.50(9.0)</td>
<td>-2.0(1.2)</td>
<td>-1.6(1.1)</td>
</tr>
<tr>
<td>RAR</td>
<td>Rx</td>
<td>-0.30(0.9)</td>
<td>-0.20(0.8)</td>
<td>-0.30(5.0)</td>
<td>0.00(6.9)</td>
<td>-0.30(4.0)</td>
</tr>
<tr>
<td></td>
<td>Ry**</td>
<td>-2.31(1.9)</td>
<td>-2.21(3.1)</td>
<td>-2.41(0.1)</td>
<td>-1.9(1.4)</td>
<td>-1.30(8.0)</td>
</tr>
<tr>
<td></td>
<td>Rz</td>
<td>2.21(1.1)</td>
<td>2.61(1.5)</td>
<td>1.30(9.0)</td>
<td>0.60(9.9)</td>
<td>-0.40(6.6)</td>
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<td>LAR</td>
<td>Rx</td>
<td>0.71(1.2)</td>
<td>0.51(1.0)</td>
<td>0.20(8.0)</td>
<td>0.00(0.3)</td>
<td>0.00(3.3)</td>
</tr>
<tr>
<td></td>
<td>Ry**</td>
<td>1.51(1.3)</td>
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<td>1.7(1.1)</td>
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<td></td>
<td>Rz</td>
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<td>-1.20(9.0)</td>
<td>-0.61(4.0)</td>
<td>0.40(8.8)</td>
</tr>
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</table>

*Based on five specimens.
**Signifies major rotations. The remaining two are coupled rotations for that load type.

Table II: The relative motion between two vertebrae segments (intact) at a load step of 0.3 Nm. The load types are flexion — FLEX; extension — EXT; and right and left lateral bending — RLB, LLB; and right and left axial rotation — RAR, LAR.

Table III: Mean normalized major relative rotation between two vertebrae segments for various load types. Motion segments C4-5, C5-6, and C6-7 were involved during laminectomy and facet wiring. LMS and LM6 — laminectomy at C5 and C6 respectively; FW47 — facet wiring spanning vertebrae 4 through 7. The major motion for a particular load type is shown within brackets.
second in our series of biomechanical studies of clinically important injuries and surgical stabilizations\(^3,4\). The present study, like all in vitro biomechanical studies, has some limitations. First it does not account for stability provided by muscles. Second, the loading rods and strings, used for administering loads to the specimen, sometimes obscured the LEDs from the camera's view during testing in a particular load type. This necessarily led to an incorrect prediction of the LED's spatial location. The data sets from such LEDs were thus excluded. Consequently, the data in Tables II and III include, at places shown with an asterisk, values based on fewer than the total number of specimens included in the study.

The data of Table III (normalized relative motions) and Table IV (significant changes with \(p < 0.1\)) combined together can help put the effects of laminectomies and stabilization on the motion behavior in a clinically relevant perspective. For example, the increases in motion at various motion segments after two sequential laminectomies are not significant on a statistical basis except in extension (Table IV). However, the normalized relative motion data of Table III reveal that this is due to very large variation in the data (as indicated by a large standard deviation, e.g., 124.1 at C5-6 in flexion mode post LM6 injury). Thus, the normalized motion data do suggest that there is a tendency for the motion to increase at the injured levels after laminectomy in some specimens. This tendency towards an immediate increase in motion after laminectomy may relate to the subsequent development of clinical instability in some patients, a phenomenon which has been observed by Callahan et al. and others. It may thus be prudent for surgeons to fuse cervical spines following multilevel laminectomy via a facet wiring or similar posterior stabilization procedure. Fusion may be most important in younger age patients to prevent further deformity due to the absence of stabilizing effects of degenerated tissues (disc, bony spurs, etc.) usually present in older age patients.

The results of the present study clearly indicate that facet wiring is an effective technique to stabilize cervical spines injured in this manner (i.e. multi-level laminectomy). Its use results in a significant decrease (~80 per cent) in motion at the injured levels (at \(p < 0.05\)) compared to the corresponding motion of the intact specimen without altering the motion behavior at the unaffected motion segments to any significant degree. These findings are in agreement with the clinical observations of Capen et al.\(^2\), Shields and Stauffer\(^12\), and others that posterior spinal fusion is a safe procedure capable of providing immediate stability to the injured spine.

### ACKNOWLEDGMENT

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REFERENCES


HAEMOPHILUS INFLUENZA CAUSING SEPTIC ARTHRITIS OF THE HIP IN A CHILD—A CASE REPORT

“Children, you are very little and your bones are very brittle. If you would grow great and stately, you must try to walk sedately.”

Robert Louis Stevenson

David J. Stapor, M.D.
Jeffrey Lozman, M.D.
Richard L. Jacobs, M.D.
Albany Medical Center Hospital, Division of Orthopaedic Surgery
Albany, New York 12208

Acute infectious arthritis of the hip is a relatively uncommon though serious disease in children. Early detection combined with surgical drainage and antibiotic therapy are essential to prevent irreparable damage to the hip joint. The purpose of this paper is to present a case of septic arthritis of the hip joint caused by *Haemophilus influenza* in a child recently inoculated with the capsular polysaccharide Haemophilus vaccine.

CASE PRESENTATION

A thirty-month-old white male child was seen at the County Health Department where Haemophilus b polysaccharide (b-Caps™ I) vaccine was administered subcutaneously in the left shoulder region. The child was in apparent good health at the time and had no recent history of any infections or illnesses. That evening, the parents observed the child favoring his right leg when walking. This was associated with a low grade fever. Later that evening, he developed chills and fever. The following morning, twenty-four hours post vaccination, the child refused to stand or walk on his right leg.

In the emergency room the oral temperature was 103 degrees but the child did not appear to be acutely ill. External ear canals were both erythematous with good light reflexes and tympanic membranes were not bulging. General physical examination was unremarkable and there was no palpable adenopathy. Pedal pulses were present and there was no peripheral or localized edema.

The child held the right hip in approximately 45 degrees flexion. There was resistance and pain with passive hip extension and rotation. There was also tenderness on palpation in the right groin. Examination of all other joints was unremarkable. Neurologic exam was within normal limits.

Serum white count on admission was 22,700 with a differential of sixty-three polymorphonuclear leukocytes and five bands. Erythrocyte sedimentation rate was fifty mm per hour. Roentgenograms showed distention of the right hip capsule. Aspiration of the right hip, performed in the emergency room under local anesthesia, yielded five ml. of grossly purulent fluid.

Incision and drainage of the septic right hip was performed using a posterior (Ober) approach. An additional five ml. of purulent fluid was obtained from the joint. The femoral head was intact. The joint was washed thoroughly with saline solution, the hip capsule left open, and the wound closed over a Penrose drain. Postoperatively, skin traction was applied bilaterally with the legs abducted 20 degrees and ampicillin and oxacillin were started intravenously.

Subsequently, the child’s temperature dropped and remained between 99-100 degrees during the remainder of his hospitalization. The Penrose drain was removed on the fifth postoperative day. The surgical wound healed without consequence. Serum white count decreased to 7,500 one week postoperatively. Gram negative *Haemophilus influenza*, sensitive to ampicillin, grew from intraoperative cultures. Oxacillin was discontinued and intravenous ampicillin continued for a total of three weeks from time of surgery. The child was then placed in a spica cast and discharged on oral ampicillin and oral rifampin (20 mg daily for four days). Sedimentation rate at discharge was thirty-four mm per hour. The cast was removed three weeks later. Ten months postoperatively the child showed no sequelae of infection and had performed normal activities appropriate for his age.

DISCUSSION

Septic arthritis of the hip in children is primarily a disorder of hematogenous origin and occurs most commonly during the first year of life. During the period of epiphyseal growth, the arterial circulation in the proximal femoral metaphysis is more active and intracapsular spread of a blood-born infection to the femoral neck and head via the
negative bacteria are capsular and all bacterial diseases in young children in the United States.

The incidence of certain systemic Haemophilus influenza type b (Hib) disease is increased in Eskimo and American Indian children, as well as in patients with asplenia, sickle cell disease and antibody deficiency syndromes. Hib can also cause outbreaks of systemic disease among previously healthy children attending nursery schools or day care facilities. Several studies conducted within the last ten years indicate that a child's cumulative risk of developing systemic Hib disease at some time during the first five years of life is about 1 in 200, with "high risk" children having a greater chance of acquiring the disease.

Hib diseases can usually be treated successfully with antibiotics, although about 20 percent of Haemophilus influenza, type b, isolated in the United States from patients with systemic disease are resistant to ampicillin. In addition, resistance to chloramphenicol and multiple antibiotics has emerged.

The capsular polysaccharide of Haemophilus influenza type b is its principal virulence factor. This has been purified for use as a vaccine to prevent Hib diseases. The process involves inactivation and separation of culture grown bacteria, followed by isolation of the polysaccharide. Anti-haemophilus polysaccharide antibody mediates complement-dependent bacteriolysis and opsonization in vitro and has been shown to protect experimentally infected animals.

Induced antibody response in humans is directly related to the age of the recipient. Infants respond infrequently, with the response rate improving by eighteen months of age, and reaching adult levels by the age of six years. In addition, children eighteen to twenty-four months old do not respond as well as those two years of age or older. The vaccine has been demonstrated to be 90 percent effective in preventing all forms of Hib disease among children between eighteen months and five years of age.

The Immunization Practices Advisory Committee recommends administration of the Hib vaccine to all children at twenty-four months of age and immunization of those children in known high risk groups at eighteen months of age. The immunizing dose is a single injection of 0.5 ml (25 mcg) of reconstituted vaccine given subcutaneously. Recent data have shown no adverse short-term or long-term effects from the vaccine, though local reactions (erythema and induration at the injection site) and fever (>101 degrees) have been observed in a small percentage of vaccinated children (1.5 percent and 0.75 percent respectively).

CONCLUSIONS

This case illustrates a classic presentation of septic arthritis of the hip in a child. Fortunately, the presence of clinical symptoms in this instance facilitated early diagnosis and prompt surgical drainage.

Typically, septic arthritis of the hip is most common during the first year of life; it is far less common in a child of this age (thirty months).

The origin of the haemophilus bacteremia that probably caused the infection remains obscure. The most reasonable explanation seems to be hematologic spread of a haemophilus otitis media. This was suspected based on erythema of the child's ear canals, but never proved during his hospitalization. There were no other obvious signs of infection in this child and no recent history of illness.

Haemophilus bacteremia and subsequent development of septic arthritis in this patient is probably not related to his recent vaccination even though four bacteremias within one day of Haemophilus bacteremia vaccination have been recently reported to the Center for Disease Control. The polysaccharide vaccine itself is only a portion of the inactivated bacterial capsule and could not produce an infection. However, the vaccine can generate an immune response in the immediate time period following its administration, binding anti-haemophilus antibodies (already present in the child's system). A subclinical haemophilus infection (e.g. otitis media) could then escalate resulting in a bacteremia significant enough to produce a septic joint.

REFERENCES


6. Verbal communication CDC, Atlanta, GA.