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LETTER FROM THE CHAIRMAN

Scott D. Boden, MD

We have a long tradition of outstanding leaders of our profession who have taken time from their personal and professional schedules to serve as the Kelly Visiting Professor. Dr. Anderson clearly ranks as a leader in Orthopaedics today, and I am particularly grateful to him for being with us and enriching our educational program.

I next want to acknowledge all of our faculty, residents, students, researchers, and staff. Each of you help contribute to giving patients back their lives, a privilege that not every medical specialty can claim with the same vigor. We can all be proud of how the Department has continued to grow and excel in both patient care and quality of patient and family experience. We look forward to the expansion this fall to six fellowship trained trauma surgeons at Grady, and a number of other key faculty additions at a variety of our locations. The MSK service line remains a critically important component of Emory Healthcare, with approximately out of every . new patients to Emory entering through Orthopaedics, and planning for new facilities for the clinical and research enterprise continues.

The blend of clinical efficiency, academic opportunities, and diverse patient care environments have resulted in the Emory Orthopaedic Residency and Fellowship training programs becoming increasingly among the most sought after in the country. In the coming years, we will expand our fellowship offerings to include Upper Extremity, Trauma, and Pediatrics.

We continue to undergo a major expansion of our basic/translational and clinical research team. Our Vice-Chair for Research, Hicham Drissi, PhD, and our Director of Clinical Research, Michael Gottschalk, MD, are leading those efforts with outstanding early successes.

Support and contributions from the alumni are increasingly needed to enhance the support for resident education and research, which are an integral component of these Department achievements. Thank you for your continued support.

With sincere appreciation for each of your efforts that contribute to Team MSK,

Scott

Scott D. Boden, M.D.
For over 40 years, Kelly Day has represented the culmination of the academic year for the Orthopaedic Surgery Residency Program at Emory. Not only does the event allow time to recognize the research efforts of our residents, but as importantly, it serves as a venue by which we can discuss innovative approaches to patient care, quality improvement and knowledge gaps within our field.

It is truly an honor to host Dr. Bob Anderson as the 2 Kelly Visiting Professor. Dr. Anderson’s numerous accomplishments in sports medicine and foot and ankle surgery are a testament to his character. We are fortunate to briefly pause from the daily grind to spend time with him discussing our research initiatives and ways to improve the care we provide. Dr. Anderson, thank you.

As importantly, Kelly Day 2 gives us the opportunity to recognize the accomplishments of six very special individuals. Although Sandi, Rishin, Tim, Ian, Briggs and Jeff are very unique as individuals, they share several common threads: they are dedicated, they are empathetic, and they have each learned the importance of self-evaluation as a means to optimize their own performance as surgeons. Over the past years, they have dedicated almost every waking hour to the pursuit of knowledge, skill and the care of their patients. They have defined what it means to be a team. In my mind, they embody our Residency Program’s ultimate objective to produce the kind of doctor you would want to care for your own family. Please join me this weekend in celebrating the achievements of this outstanding group.

Tom

[Signature]

Thomas L. Bradbury, M.D.
Dr. Anderson is the founding orthopaedic surgeon of the O.L. Miller Foot and Ankle Institute of OrthoCarolina in Charlotte, North Carolina, practicing there since 2008. He recently joined the Titletown Sports Medicine and Orthopaedic Clinic in Green Bay, WI. He is fellowship-trained in foot and ankle disorders (Dr. John Gould, Milwaukee WI) and has vast experience treating sports-related injuries.

Dr. Anderson was as a team orthopaedist to the Carolina Panthers (2012-2016) and is now an associate team physician to the Green Bay Packers. He is also chairman of the Foot and Ankle Subcommittee for the NFL, since 2016, and was recently named the co-chair of the NFL’s Musculoskeletal Committee, overseeing all orthopaedic injuries and research in professional football. Dr. Anderson remains an active consultant to a number of NFL, NBA, NHL, and MLB teams and colleges.

Additional leadership roles include Chief of the Foot and Ankle Service at Carolinas Medical Center (2008-2012) and former president of the American Orthopaedic Foot and Ankle Society. With his clinical research expertise, he currently serves as Co-editor of the 6th edition of Mann's: Surgery of the Foot and Ankle, and is an associate editor/reviewer for JBJS, JAAOS, FAI, AJSM and numerous other peer-review publications and author/editor of numerous chapters and manuscripts. He was also a former Editor-in-Chief of the Techniques in Foot and Ankle Surgery Journal.

Dr. Anderson was born in Milwaukee, Wisconsin and attended the University of Mississippi where he was inducted into their Hall of Fame.
2019 KELLY DAY AGENDA

Friday, June 7, 2019

: AM  Registration & Breakfast

: AM  Welcoming Remarks
Scott Boden, MD  
Professor and Chairman  
Department of Orthopaedics  
Emory University School of Medicine

Resident Research Presentation: Session I

: AM  Development of a Small Animal Ankle Arthrodesis Model  
Rishin J. Kadakia, MD, PGY

: AM  Distressed Community Index as a Composite Score for Social Determinants of Health Predicts Loss to Follow Up and Readmission in Orthopaedic Trauma Patients  
Andrew Schwart, MD, PGY

: AM  A Biomechanical Evaluation of Multiple Fixation Methods for the Treatment of Low Transverse Distal Fibula Fractures seen with Supination Adduction Ankle Injuries Using an Osteoporotic Sawbones Model  
Ian Gao, MD, PGY

:2 AM  Modified Frailty Index is an Effective Risk Stratification Tool for Patients Undergoing Total Shoulder Arthroplasty  
Russell Hol grefe, MD, PGY

: AM  Discussion:
Dr. Robert Anderson and Emory Faculty

Sports Elite Athlete Case Presentation

: AM  David Shau, MD, PGY

: AM  Jeremy Pflederer, MD, PGY2
Coffee Break

Translational Research Update

- AM  Regenerative Rehabilitation for Musculoskeletal Injury and Disease
  Nick Willett, PhD
- AM  Developmental Links Between Synovium and Articular Cartilage
  Pavalli Bhattaram, PhD

Resident Research Presentation: Session II

- AM  The Role of Intraosseous or Intraarticular BMAC versus Saline Injections in the Treatment of Cartilage Defects in a Rat Knee Model: A Prospective Randomized Trial
  Briggs Ahearn, MD, PGY
- AM  Hypoalbuminemia is an Independent Risk Factor for 30-Day Mortality, Postoperative Complications, Readmission, and Reoperation in the Operative Lower Extremity Orthopedic Trauma Patient
  Jake Wilson, MD, PGY
- 2 AM  Obesity is Associated with Worse Perioperative Outcomes and Increased Costs in Lumbar Fusion Surgery: Analysis of 1,196 Cases at a Single Institution
  Sandra Hobson, MD, PGY
- 2 AM  Provider Variability in Emergency Department Opioid Administration to Patients with Two Common Orthopaedic Injuries
  Robert Wham, MD, PGY
- AM  Discussion:
  Dr. Robert Anderson and Emory Faculty

Complex Foot and Ankle Case Presentation

- AM  David Shau, MD, PGY
- AM  Dale Segal, MD, PGY
**2019 Kelly Day Lecture**

: AM  
Introduction of 2  Kelly Society Visiting Professor  
Thomas Bradbury, MD

**2019 Kelly Visiting Professor**  
Robert Anderson, MD  
Bellin Health Titletown Sports Medicine and Orthopaedic Clinic  
Green Bay, WI  
Chairman, Foot and Ankle Subcommittee for the NFL  
Co-Chair, NFL Musculoskeletal Committee  
Team Physician, Green Bay Packers  
Co-Founder, OrthoCarolina Foot and Ankle Fellowship

**Lunch Presentation:**

: PM  
Nicki Colleen  
Head Coach, Atlanta Dream

**Resident Research Presentation: Session III**

2: PM  
Intraoperative Neuromonitoring Use Patterns in Degenerative, Non-deformity Cervical Spine Surgery: A Survey of the Cervical Spine Research Society  
Jeff Konopka, MD, PGY

2: PM  
Reducing the Reductions: An analysis of Distal Radius Fractures in a Pediatric Emergency Department  
Keith Orland, MD, PGY

2: PM  
Posterior Labral Repairs in Baseball Players: Results and Outcomes with Minimum 2-Year Follow-Up  
Timothy McCarthy, MD, PGY

2:2 PM  
Laminoplasty does not lead to Worsening Axial Neck Pain in the Properly Selected Patient with Cervical Myelopathy: A Comparison with Laminectomy and Fusion  
Thomas Neustein, MD, PGY

2: PM  
Discussion: Dr. Anderson and Emory faculty

**Research Year In Summary**

: PM  
Research Update  
Hicham Drissi, PhD
Rapid Fire

: PM  Geriatric Mobility: A new PRO in Older Orthopedic Patients
      Jason Bariteau, MD

: PM  Hand Research Update: From Policy to Benchtop
      Charles Daly, MD

: PM  High-Need, High Cost Trauma Care
      Mara Schenker, MD

:2 PM  MILES Project Update
       Michael Gottschalk, MD

: PM  Closing Remarks
      Scott Boden, MD and Thomas Bradbury, MD

CME credits will be issued in January 2020.
Please remember to provide your email address to receive your statement.
2018 – 2019 PGY-5 Orthopaedic Surgery Residents

Briggs Ahearn, MD
Post Residency Plans:
Sports Medicine & Shoulder Reconstruction Fellowship
Steadman Hawkins Clinic of the Carolinas
Greenville, SC

Ian Gao, MD
Post Residency Plans:
Sports Medicine Fellowship
Stanford University
Stanford, CA

Sandra Hobson, MD
Post Residency Plans:
Sports Fellowship
Mayo Clinic
Rochester, MN

Rishin Kadakia, MD
Post Residency Plans:
Foot & Ankle Fellowship
Duke University
Durham, NC

Jeff Konopka, MD
Post Residency Plans:
Spine Fellowship
Harvard University
Boston, MA

Tim McCarthy, MD
Post Residency Plans:
General Orthopaedics
United States Air Force
Landstuhl Regional Medical Center/Ramstein Air Force Base
Landstuhl, Germany
The Role of Intraosseous or Intraarticular BMAC versus Saline Injections in the Treatment of Cartilage Defects in a Rat Knee Model: A Prospective Randomized Trial

Briggs Ahearn, MD; Emily Whicker, MD; Jay McKinney, BS; Nick Willett, PhD; Sam Labib, MD

INTRODUCTION

Focal articular cartilage in uries commonly occur due to athletic injury, trauma, or other activities of daily living and the incidence is on the rise in part due to increasing athletic participation in today’s society. Successful treatment of cartilage in uries is important for the young and active patient’s ability to return to sport, for the longevity of athletic participation, and to minimize the risk of further oint destruction and osteoarthritis. Unfortunately, most articular cartilage in uries do not heal spontaneously therefore, eventually surgical intervention is usually required in this patient population.

Successful surgical repair or replacement of cartilage for these types of in uries has proven to be limited in utility and in the longevity of the repaired cartilage. Current therapies include marrow stimulation, osteochondral transplantation, and cell-based repair methods. In a long-term outcome study of knee cartilage in uries, it was demonstrated that of patients undergoing chondrocyte implantation and of patients treated with marrow stimulation techniques had evidence of early osteoarthritis at follow up. Thus, in an effort to improve the repair of both chondral and osteochondral defects, there have been increasing efforts in tissue engineering, regenerative medicine, and other biologic approaches both as an ad, to surgical treatment and also as a potential primary treatment modality.

Bone marrow aspirate concentrate (BMAC) has emerged as a major biological tool for orthopaedic surgeons in the United States because it is one of the few forms of delivering mesenchymal stem cells (MSCs) and growth factors that is currently allowed by the United States Food and Drug Administration (FDA). BMAC is obtained after a sample of autogenous bone marrow is harvested then concentrated using a centrifuge and, as such, it is no ad or culturing and is considered minimally manipulative. Previous studies have demonstrated the ability of MSCs to differentiate into chondrocytes and improve cartilage healing via in and surgery on both culture and BMAC. In humans, BMAC is often used as an ad vant treatment for cartilage repair and, at present, there is a paucity of literature that utilizes BMAC alone as a monotherapy in a cartilage defect model. Additionally, human studies that have employed BMAC in their protocols have in ected it directly into the oint space, which could potentially lead to a short residence time due to the body’s natural washout of the oint space. Prior studies have also shown that intra-lesion incisions of BMAC in anascular necrosis of the hip, chronic tendinopathy, and long bone nonunion display enhanced healing effects. The efficacy of inc 1 in stion of BMAC into the subchondral bone plate of an osteochondral defect has been generally understudied.

Previous BMAC animal studies have used rabbit and goat cartilage to model osteochondral defect repairs. However, these large animal models are more expensive and resource heavy than rat models. The rat femoral cartilage defect model is a well established model with translational relevance into modern human clinical practice. While bone marrow derived MSC isolation procedures have been well-established in the rat model, a comparable protocol for the harvest and isolation of BMAC has not been established.

The objective of this study was three-fold. First, we sought to develop a protocol for BMAC harvest, isolation, and characteri ation in the rat model. Second, we aimed to develop and standardize a well-tolerated rat knee cartilage defect model. Lastly, we then examined the efficacy of BMAC delivery via intraosseous (IO) and intraarticular (IA) injections as compared to saline controls. We hypothesized that intraosseous in ection of BMAC would lead to improved unicornality and uality of regenerated cartilage.

METHODS

All animal procedures were performed at the Atlanta Veterans Affairs (VA) Medical Center with approval from the Institutional Animal Care and Use Committee (IACUC). Rats were housed at the VA and had continuous access to food and clean water. The cages were regularly maintained by the VA veterinary staff.

BMAC Isolation

On the day of surgery, a single - 2-week-old male Lewis rat (Charles River Laboratories, Wilmington, MA) was euthanized via CO2 inhalation. The hind limbs were disarticulated at the hip oint and the bilateral femur and tibia were stripped of soft tissue and separated through the knee and ankle oint. The femur and tibia were washed with alcohol. A rongeur was used to cut through the proximal and distal metaphysis in order to allow access to the medullary canal. Each canal was then flushed with ml of Anticoagulant Citrate Dextrose Solution A (ACDA) into a single petri dish. ACDA was chosen as the medium as this mimics current commercially available BMAC systems and is acceptable under minimally manipulated cell guidelines. The bone marrow was then evenly suspended by pipette aspiration. The pooled bone marrow was
flushed through a m cell strainer into a ml conical tube and centrifuged at rpm x min. The supernatant was aspirated and the pellet was re-suspended in ml phosphate buffered saline (PBS). Representative images of the procedure can be seen in Figure.  

**BMAC Characterization**

The MSCs population contained within the BMAC sample was determined by flow cytometry. First, samples were passed through a m cell strainer (Corning) to avoid flow cytometer clogging. Next, samples were stained with MSC markers, including PE-con ugated anti-CD2 (BioLegend), APC-con ugated anti-CD (BioLegend), and BV 2 - con ugated anti-CD (BioLegend). Samples were stained for 
mms and fixed in PFA for 2 mins, then analy ed using a FACS-AriaIIIu flow cytometer (BD Biosciences).

**Surgical Procedure**

- 2-week-old male Lewis rats (Charles River Laboratories, Wilmington, MA) were randomly assigned to the IO group (n = 2) or the IA group (n = 2). For each group, the experimental knee was alternated with the contralateral knee serving as an internal control. After induction of anesthesia, a standard lateral para-patellar arthroscopy was performed bilaterally. A 2mm punch biopsy tool was used to create a mm deep osteochondral defect in the mid trochlea. In the IO group, prior to closing the arthroscopy, the incision was performed by inserting a 2-gauage needle until the entire bevel was buried within the bone plate (approximately mm depth) and inecting 
l of BMAC or saline. In the IA group, the ioint capsule was closed with a water tight running suture and the incision was performed prior to skin closure. The skin was closed with wound clips and routine post-operative care was conducted.

Representative images of the procedure can be seen in Figure 2.

**Femur Isolation**

At weeks post op, the 2 experimental rats plus 2 additional control rats were euthanized. The hind limbs of the 2 rats (2 limbs) were skinned and disarticulated at the hip. The limbs were fixed in formalin for at least hours. All soft tissue was removed from the femur and the limb was disarticulated at the knee oint.

**Histological Evaluation**

Rat femora were decalcified with Immunocal (SKU - 2 StatLab, McKinny, T ) for - days. Dehydrated samples were processed into paraffin embedded blocks, m-thick sectioned and stained with hematoxilin and eosin (H&E Fisherbrand -2, Waltham, MA) or safranin O and fast green (Saf-O Electron Microscopy Sciences 2, Hatfield, PA), following manufacturer protocols. H&E and Saf-O stained sections for each sample were analy ed to evaluate the untiy and uality of regenerated tissue. Sagittal histological sections of the defect region were used to quantify both regions of regenerated tissue in the defect as well as the region of cartilage loss using OsteoMeasure (OsteoMetrics, Atlanta, GA). For each sample, a single section, the best representative for all sections obtained, was selected for analysis. Regenerated tissue was considered to be all tissue in the defect region and regions of cartilage loss were constructed by manually linking the superior and inferior boundaries of normal cartilage on medial and lateral sides of the defect. Tissue percent fill was calculated as regenerated tissue divided by the total volume of the cartilage defect.

Roberts et al. devised a semi uantitative scoring system, the OsScore, to evaluate the histologic features of articular cartilage. In this original paper, the histologic features measured were: tissue morphology, matrix staining, uantity and uality of regenerated tissue, cartilage, and chondrocyte clustering, minerali ation, blood vessels, and basal integration. This was scored from - with representing hyaline cartilage. In our present study, we modified this OsScore, eliminating chondrocyte clustering and minerali ation. We were unable to assess with accuracy the morphology of the chondrocytes and as our samples were deminerai ed prior to staining, we were unable to utilize the necessary von Kossa stain. Thus, our Modified OsScore (Table ) was scored from - with representing hyaline cartilage. All samples were blinded and independently scored by one of the authors (BMA) and a pathologist. These scores were averaged and assessed for statistical differences.

**Statistical Analysis**

Defect fill percentages and histology scoring of articular cartilage are presented as mean standard deviation (SD). Both of these studies were evaluated by repeated measures using two-way analysis of variance (ANOVA) (factors: delivery method and therapeutic delivered) with post-hoc Tukey honestly significant different (HSD) analysis. Statistical significance was set at p . All data were analy ed using GraphPad Prism software version . (GraphPad Software Inc., La Jolla, CA, USA).

**RESULTS**

**BMAC characterization**

Following BMAC isolation, the percentage of MSCs contained within the sample was determined using flow cytometry. First, samples were gated to separate single cells from debris and multiplets. Next, MSCs within the BMAC sample were identified as triple-positive for MSC markers CD2 , CD and CD. It was determined from the BMAC sample that approximately of all cells were positive for the MSC surface markers. Thus, following manual count of all cells contained within the BMAC sample, roughly x cells/ml of the x cells/ml expressed the MSC surface markers. Furthermore, within the 1 in ectio neach rat, a total of 2. x MSC surface marker expressing cells were in ected into each experimental rat knee. The results of flow cytometry and characteri ation can be seen in Figure.

**ulitative analysis of the therapeutic efficacy of BMAC**

Representative histological images of coronal femoral sections showed cartilage loss and regenerated tissue in the defect region for all treatment groups (Figure ). To further analy e the efficacy of each of the therapeutics (saline and BMAC) and delivery methods (IO and IA), all samples in the current study were quantified via cartilage tissue percent fill calculation and histomorphological ualitative scoring.

**Histomorphometric uantitative analysis of cartilage defect fill**

Tissue percent fill, for the cartilage defects, was examined to quantitatively analy e the therapeutic efficacy of BMAC for focal defects in the articular cartilage of the femur.
Histological sections, the same as those prepared for OsScore assessment, were contoured to determine the percent ratio of tissue fill to the cartilage loss yielded by the focal lesion administered in the cartilage defect surgery. Average percent fill for IO and IA BMAC was ( / - ) and ( / - ) while IO saline and IA saline averaged ( / - ) and ( / - ), respectively (Figure ). Comparison of saline and BMAC groups, via a two-way ANOVA, demonstrated increased tissue fill in the BMAC group relative to the saline group (p . 2 ). Furthermore, comparison of IO and IA delivery methods yielded no detectable differences (p . ). Additional details on results and statistical analyses performed are displayed in Table 2 and with graphical representation in Figure .

**Histomorphometric qualitative scoring of cartilage defect region**

Modified OsScore was used to analyze the efficacy of BMAC treatment delivered via IO or IA in ection for focal cartilage defects. Samples were assessed for tissue morphology, matrix staining, surface architecture, blood vessels, and basal integration. Scores ranged from - , with demonstrating characteristics of normal hyaline cartilage. Modified OsScores for IO and IA BMAC were ( / - 2 ) and ( / - ) while IO saline and IA saline were ( / - ) and ( / - ), respectively (Figure ). Scores for all samples did not show any detectable significant differences. More specifically, in comparing saline and BMAC treatment conditions directly, no differences were detected (p . ). Furthermore, comparison of IO and IA delivery methods yielded no significant differences (p . 2 ). Additional details on results and statistical analyses performed are displayed in Table 2 and with graphical representation in Figure .

**DISCUSSION**

The main goal of this study was to evaluate the effects of Bone Marrow Aspirate Concentration (BMAC) monotherapy on the regeneration of cartilage in a rat knee osteochondral defect model. In order to do so, a method for isolating BMAC from rat femora and tibiae was developed and standardized. Additionally, a rat knee model for the creation of an osteochondral defect was successfully created. The efficacy of a monotherapy in ection of BMAC on cartilage regeneration was then studied via intraosseous (IO) and intraarticular (IA) in ections as compared saline controls. This study determined that both the IO and IA in ection of BMAC regenerated more tissue volume within the defect than the contralateral saline controls. The different delivery methods, however, had no effect on cartilage volume. When evaluating the utility of the regenerated cartilage using the modified OsScore, both the saline controls and the therapeutic BMAC in ection produced the same fibrocartilage.

By adapting a preexisting MSC isolation protocol, a known method of bone marrow extraction and centrifugation was used to produce viable stem cells. After analysis with flow cytometry for MSC-specific markers, of viable cells were determined to be MSCs. Previous studies have cited that MSCs make up only . to of all mononuclear cells contained within the bone marrow. By concentrating the bone marrow from two femora and two tibiae, we were able to achieve a reproducible MSC percentage of - .

We also aimed to develop a rat model for the osteochondral defect of the knee. We determined that the troclear region would provide the largest defect area within the knee. A 2mm punch delivered to the trochea gave the most consistent osteochondral defect that we were able to observe intra-operatively. Postoperatively, the rats were closely monitored throughout recovery. It was determined that the rats tolerated the surgery well and were able to return to normal activities roughly - week post op. Thus, we developed a reproducible and well-tolerated rat model for an osteochondral defect of the knee.

The development of this rat model allowed comparison of the effects of an intraosseous (IO) in ection of BMAC to an intra-articular (IA) in ection of BMAC. A control surgery, injecting saline into the contralateral knee of the rat, allowed assessment of healing that may occur without the addition of BMAC. Histologic analysis of the samples allowed comparison of not only the volume of cartilage regenerated, but also the overall utility of the cartilage.

A novel finding of this study is that a significantly higher volume of regenerated cartilage was appreciated with the BMAC therapeutic groups compared with saline controls regardless of delivery method. The modified OsScore, however, did not reveal a statistically significant difference in the utility of regenerated cartilage between both the IA and IO BMAC groups as well as between their respective controls. Thus, while BMAC monotherapy may not help to produce better utility cartilage, it does appear to help increase the overall amount of cartilage healing that occurs within the defect. Similarly, Fortier et al. found that an effective osteochondral defect treated with BMAC led to increased cartilage fill within the defect when compared to microfracture treatment. Additionally, Kyrch et al. found that human patients treated with BMAC also had superior cartilage fill when compared to platelet-rich plasma (PRP) treatment. Given this, it is the opinion of the authors that, while BMAC does appear to improve the regenerative healing process, it may prove inadequate as a monotherapy and be best suited as an ad uct to surgical repair in order to improve both the volume and utility of regenerated cartilage. This conclusion is further corroborated by a systematic review highlighting BMAC’s favorable outcomes when combined with a surgical procedure, such as microfracture.

A ma or limitation of this study is that the defect size was unable to be precisely reported and standardized. Even though a 2mm punch was used with the same technique to create each defect, the defects did not have a consistent depth or size when evaluated under microscopy. While a rat model for an osteochondral defect would be ideal due to the relatively low cost and limited resources needed to care for the animals, the small size of the trochea may inhibit the ability to truly standardize a defect. Additionally, a modified OsScore was required due to our lab’s limitations in staining protocols. Ideally, we would have been able to calculate the OsScore based on the original parameters. It is possible that a difference in
histological quality could have been determined had the original, validated OsScore been used. Lastly, while more differences did not present in the current study, expanding the current sample size may yield further significance as trends began to emerge between saline and BMAC groups for IO and IA delivery conditions. When considering the IO and IA delivery methods separately, the BMAC group did demonstrate increases in cartilage fill, albeit insignificant.

CONCLUSION
This study provides a reproducible method for the harvesting of BMAC and creation of a cartilage defect in the rat knee model. The results of this study suggest BMAC yields a more robust regenerated cartilage volume as compared to a saline control regardless of delivery method. There was no statistical difference in the quality of healed cartilage as assessed using the modified OsScore between treatment groups. All scores were consistent with fibrocartilage-like cartilage.
Figure 1: A) Flushing of rat femur with Anticoagulant Citrate Dextrose-A (ACDA). B) Petri dish demonstrating bone marrow elements following flushing of 2 femora and 2 tibiae. C) Resulting concentrated bone marrow pellet following centrifugation.

Figure 2: A) Surgical draping of rat’s bilateral lower extremities. B) Midline knee skin incision. C) Following lateral parapatellar arthroteny, 2mm punch biopsy tool being used to create a trochlear defect. D) Intraosseous (IO) inection. E) Intraarticular inection following closure of arthroteny. F) Demonstration following closure of bilateral arthrotenies.
**Figure 3:** Flow cytometry results of bone marrow aspirate concentrate (BMAC) sample for mesenchymal stem cell (MSC) surface markers CD44, CD29, and CD105, respectively.

**Figure 4:** Representative histologic imaging based on treatment group. IA intraarticular. IO intraosseous. BMAC Bone Marrow Aspirate Concentrate. H&E Hematoxylin and Eosin stain. Saf-O Safranin O stain.
**Figure 5:** Graphic representation of tissue fill presented as percent volume fill based on treatment method. IA intraarticular. IO intraosseous. Cells Bone Marrow Aspirate Concentrate.

![Cartilage Defect Fill](image)

**Figure 6:** Graphic representation of Modified OsScore results based on treatment method. IA intraarticular. IO intraosseous. Cells Bone Marrow Aspirate Concentrate.

![Cartilage Defect Histology Scoring](image)
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Table 2: Perfect Fill and Modified OsScore Based on Treatment Group

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<th>Group</th>
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IA intraarticular. IO intraosseous. Cells Bone Marrow Aspirate Concentrate.

Table 3: Two-Way ANOVA Statistical Analysis

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<td>Therapeutic (Saline v. BMAC)</td>
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<td>Interaction</td>
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IA intraarticular. IO intraosseous. Cells Bone Marrow Aspirate Concentrate.
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A Biomechanical Evaluation of Multiple Fixation Methods for the Treatment of Low Transverse Distal Fibula Fractures Seen with Supination Adduction Ankle Injuries Using an Osteoporotic Sawbones Model

Ian Gao, MD; Briggs Ahearn, MD; Amanda Fantry, MD; Shary Tennenbaum, MD; Jason Bariteau, MD

Abstract: This study sought to determine the best biomechanical fixation of low transverse distal fibula fractures as seen in supination-adduction-type ankle fractures. Four different fixation methods were compared to determine stiffness of the constructs as well as load to failure (survival).

Introduction: Ankle fractures are one of the most common in uries treated by orthopaedic surgeons, and the incidence, especially in the geriatric population older than 65, is rising. Epidemiologic studies have determined that hospital admissions for ankle fractures between age 2 and 82 have increased by 72.2 annually, mainly accounted for by fractures in elderly women. These fractures pose unique challenges to the orthopaedic surgeon in that geriatric patients are more likely to have numerous medical comorbidities such as osteoporosis and diabetes that can make bony fixation more difficult. One accepted method used to describe ankle fractures is the Lauge-Hansen classification system, which utilizes a mechanistic description of the position of the foot in relation to the force applied to the lower extremity as the injury occurs. Supination adduction (SAD) type fractures make up approximately 10% of all ankle fractures. This pattern entails a vertical shear fracture of the medial malleolus and a low transverse fracture of the distal fibula. The literature describes the optimal method of fixation of the medial malleolus in SAD type fractures; however, the best biomechanical fixation of the lateral malleolus in this fracture type has yet to be determined. The low transverse nature of the fracture presents fixation issues due to its orientation and distal nature. This may be exacerbated in elderly, osteoporotic patients in whom obtaining optimal distal fixation is difficult.

Modern fixation methods for this distal fibular fracture include a one-third tubular plate with one or 2 cancellous screws distally, a 2. mm mini fragment T-plate, and a 2. mm specific locking plate. Previous studies have evaluated different constructs for the distal fibula of supination external rotation (SER) type fractures in osteoporotic models demonstrating either equivocal or superior biomechanical stability using locked plates as opposed to one-third tubular plates. In this study, we compared the aforementioned fixation methods for the low transverse distal fibula fracture of SAD type fractures using an osteoporotic Sawbones model to determine a biomechanically superior construct. We hypothesized that similar to SER fibula fractures, the fibula specific locking plate would demonstrate a more biomechanically stable construct compared to the other methods.

Materials and Methods: Using osteoporotic Sawbones models obtained from Pacific Research Laboratory (Vashon, WA), simulated supination adduction ankle fractures were created. These models consisted of reduced cortical thickness and open cell, cancellous foam inside. An alignment jig was used to produce standardized transverse osteotomy in each fibula at the level of the distal tibial plafond, consistent with the low transverse distal fibula fractures seen in SAD ankle fractures.

Following creation of the fracture, each was fixed with one of four methods: a one-third tubular plate with one unicortical 2. mm cancellous screw in the distal fragment and three bicortical 2. mm cortex screws proximal to the fracture site ( samples), a one-third tubular plate with two unicortical 2. mm cancellous screws in the distal fragment and three bicortical 2. mm cortex screws proximal to the fracture site ( samples), a mini-fragment 2. mm T-plate with three unicortical 2. mm cortex screws in the distal fragment and three bicortical 2. mm cortex screws proximal to the fracture site ( samples), or a specific locking plate with three unicortical 2. mm locking screws in the distal fragment and three bicortical 2. mm cortex screws proximal to the fracture site ( samples). All plates were placed on the direct lateral aspect of the distal fibula. The four different fixation constructs can be seen in Figure.
Once these constructs were created, each sample was then dynamically stressed in axial torsional external rotation at a constant displacement rate of 0.01 mm per minute at a frequency of 2 Hz using a servohydraulic test frame (MTS Corp., Eden Prairie, MN), as seen in Figure 2. Monotonic axial external rotation to failure testing performed previously using this same biomechanical testing protocol adapted from the standard test method for static torsional testing of fixation devices (ASTM F 22) determined a mean static yield load of 75 N-mm in this biomechanical testing model. Under load control, each specimen was torsionally loaded for cycles or until functional failure. The maximum external rotation torsion limit started at 20% of the mean static yield load of N-mm, and testing was repeated for each specimen in a ramping manner with the maximum external rotation torsion limit increasing by increments of 20% of the mean static yield load. Rotational stiffness (measured in N-mm/°) at each increment of testing was also recorded at 2 Hz for each specimen at every ramp step until failure or completion of the test. Survival of the constructs was reported as the percentage (in increments) of the mean static yield load at which the construct failed, and mean survival was calculated for each fixation method group.

A Chi square test (Mantel-Cox) was used to indicate differences with regard to survival between groups. Analysis of variance tests were performed to detect significant differences between treatment groups for rotational stiffness at each increment of testing. In all instances, statistical significance was set to p < 0.05 a priori.

Results:

Mean Survival
Survival of the constructs was reported as the percentage of the mean static yield load (N-mm) at which the construct failed. The mean survival for each fixation construct was as follows: .62 (mean standard deviation) for the one-third tubular plate with one distal screw, .22 for the one-third tubular plate with 2 distal screws, .22 for the 2.2 mm mini frag plate, and .22 for the fibular specific locking plate. A Chi square test (Mantel-Cox) found no statistically significant difference between the fixation method and mean survival (P > .2). These results are summarized in Figure .

Dynamic Stiffness
Dynamic stiffness measured during rotational testing at each increment of mean static yield load for each of the different fixation constructs can be seen in Figure . At 20% of the mean static yield load, the one-third tubular plate with 2 screws distally had statistically significantly higher stiffness than the 2.2 mm mini frag plate (P < .05). At and of the mean static yield load, the one-third tubular plate with 2 screws distally, the one-third tubular plate with one screw distally, and the locked plate all had higher stiffness than the 2.2 mm mini frag plate (P < .05).

Discussion:
SAD type ankle fractures comprise approximately of all ankle fractures, and while many studies exist comparing the optimal fixation construct of the medial malleolus fracture in SAD type fractures, fixation methods of the low transverse distal fibula fracture in SAD injuries have not been thoroughly studied.

In contrast, the oblique distal fibula fracture of the SER type injury has been well studied. For example, although locking plates have not been shown to provide a biomechanical advantage in simple oblique fibula fractures with normal bone density that are amenable to a lag screw, they have been shown to provide a biomechanical advantage (greater stiffness and higher load to failure) over conventional one-third tubular plating in osteoporotic or comminuted distal fibula fractures. Another study in an osteoporotic bone model of distal oblique fibula fractures showed that a postero-lateral anteglide plate with lag screw through the plate had improved biomechanical stability compared to a lateral locking plate with an independent lag screw. Others have suggested the use of mini-frag plate/screw constructs over traditional one-third tubular plate constructs, as they have demonstrated similar mean load of failure. Lag screw only constructs have also been proven to be effective in simple oblique distal fibula fractures.

In SAD type injuries, the low transverse distal fibula fracture poses a unique challenge, as this fracture pattern is not amenable to a lag screw fixation. This study compared different fixation methods for the low transverse distal fibula fracture of SAD type injuries using an osteoporotic Sawbones model to determine a biomechanically superior construct. Results showed that a one-third tubular plate with either one or 2 screws distally as well as a fibula specific locking plate was biomechanically stiffer than a 2.2 mm mini frag T-plate. Survival rates between groups were not significantly different. This data suggests the use of either a one-third tubular plate or a fibula specific locking plate in these low transverse distal fibula fractures, especially in osteoporotic bone. In regards to one versus 2 screws distally for the one-third tubular plate, one screw fixation demonstrated equal mean survival and stiffness as those fixed with 2 screws distally. This result is clinically relevant as it is often difficult to place 2 screws below the low transverse distal fibula fracture seen in SAD type fractures.

Potential limitations within this study are the overall small sample size, as models for each construct (for the locking plate group) were utilized. It is possible this number may be inadequate to detect subtle differences between groups. Additionally, this study is inherently limited by its simulated nature and use of Sawbones models compared to cadaveric specimens.
Conclusion:
This study suggests the use of either a one-third tubular plate or a fibula specific locking plate in the low transverse distal fibula fractures that are seen in SAD type ankle injuries, especially in osteoporotic bone. In regards to one versus 2 screws distally in the one-third tubular plate, one screw fixation demonstrated equivalent biomechanical stability as those fixed with 2 screws distally. This is clinically relevant as it is often difficult to place 2 screws below the low transverse distal fibula fracture seen in SAD type fractures. We feel that this study can provide some guidance to orthopaedic surgeons when the low transverse distal fibula fracture is encountered.
Figure 1: Four different fixation constructs that were tested. (a) One-third tubular plate with one unicortical 2.0 mm cancellous screw in the distal fragment and three bicortical 2.0 mm cortex screws proximal to the fracture site. (b) One-third tubular plate with two unicortical 2.0 mm cancellous screws in the distal fragment and three bicortical 2.0 mm cortex screws proximal to the fracture site. (c) 2.0 mm fibular specific locking plate with three unicortical 2.0 mm locking screws in the distal piece and three bicortical 2.0 mm cortex screws proximal to the fracture site. (d) Mini-fragment 2.0 mm T-plate with three unicortical 2.0 mm cortex screws in the distal piece and three bicortical 2.0 mm cortex screws proximal to the fracture site.
**Figure 2:** Servo-hydraulic test frame setup utilized to stress the different fixation constructs.

**Figure 3:** Mean survival as measured by percentage of the mean static yield load (N-mm) for the different fixation methods.
Figure 4: Dynamic rotational stiffness (measured in N-mm/) at incrementally increasing percentages of the mean static yield load for the different fixation methods.
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Obesity is Associated with Worse Perioperative Outcomes and Increased Costs in Lumbar Fusion Surgery: Analysis of 1,196 Cases at a Single Institution

Sandra Hobson, MD; Amit Jain, MD; Eric Yoon, BS; Scott Boden, MD; John Heller, MD; John Rhie, MD; Tim Yoon, MD, PhD

Abstract
Study Design: Retrospective, single institution

Objective: The aim of our study was to investigate the association of obesity with operating room time, length of stay, perioperative hospital charges, and incidence of wound complications resulting in postoperative irrigation and debridement surgeries in patients who undergo lumbar fusion surgery for degenerative pathology.

Summary of Background Data: Obesity has been shown to be associated with perioperative complications.

Methods: A retrospective review was conducted of consecutive cases of lumbar fusion surgery for degenerative conditions performed at a single orthopaedic hospital during a year period from 2 through 2. Multivariate regression analyses adjusting for patient age, comorbidities, levels fused, revision surgery status, and use of interbody device were performed.

Results: Number of major or medical comorbidities increased significantly with BMI category (p < .05). Compared to normal BMI patients, the adjusted mean operating room time was 2 mins longer in the overweight group, 7 mins longer in the obese group, and 14 mins longer in the morbidly obese group (p < .05 each). Morbidly obese patients had a significantly longer length of hospital stay compared to normal BMI patients (. vs. . days, p < .05). Mean adjusted hospital charges for the index surgery were significantly greater in each of the higher BMI categories compared to the normal BMI group, the total charges in the obese and morbidly obese groups were higher by 2, 2 (p < .05) and 2, 2, respectively. The incidence of postoperative surgical irrigation and debridement increased significantly with BMI category (p < .05). Obese patients had -fold odds (p < .05), and morbidly obese patients had -fold odds (p < .05) of undergoing postoperative surgical irrigation and debridement compared to normal BMI patients.

Conclusions: Higher BMI was associated with increased total hospital charges, operating room time, length of stay, and incidence of postoperative surgical irrigation and debridement procedures in patients treated with lumbar spinal fusion surgery.

Key Words: obesity, body mass index, spinal fusion surgery, health economics, complications, operative time, cost, length of stay, hospital charges, debridement

INTRODUCTION

Obesity is rampant in the United States with approximately adults classified as obese based on the data from National Health and Nutrition Examination Survey from 2. Compared to normal weight patients, overweight and obese patients are at increased risk for a variety of serious health conditions, including all-cause mortality, type 2 diabetes, coronary heart disease, and some cancers.

The impact of obesity on perioperative complications has been described in a variety of orthopaedic surgical settings. In spine surgery, obesity has been linked to worse perioperative medical complications, prolonged length of hospitalization, and higher incidence of wound complications. There have also been some studies in the spine literature which reported the association of obesity with increased perioperative costs. Most of the studies in the spine literature on obesity have utilized large administrative databases such as the National Inpatient Sample (NIS), National Surgical Quality Improvement Program (NSQIP) databases, and the Medicare database, and only a handful have reported single institutional experiences. Large single institutional experiences lend an important view, as they can include all payers and allow for more granular study.

Understanding the impact of obesity on outcomes and costs is essential for appropriate perioperative risk stratification and resource allocation. The aim of our study was to investigate the association of obesity with operating room time, length of stay, perioperative hospital charges, and the incidence of wound complications resulting in subsequent postoperative irrigation and debridement surgeries in patients who underwent lumbar fusion surgery for degenerative pathology at our institution.

METHODS

An institutional review board approval was obtained prior to commencement of the study.

Patient Selection

Patient data from a stand-alone orthopaedic hospital associated with a university healthcare system was queried over a year period from September 2 through August 2 to identify 2 consecutive cases of lumbar spinal surgery in patients...
years age. Patients who underwent the following surgical procedures were excluded from further analysis: microdiscectomy, lumbar decompression alone without fusion, uninstrumented lumbar fusion, surgery for infection, trauma and tumor, staged surgeries, and surgeries involving levels fused. Patients who underwent anterior or lateral lumbar interbody fusion followed by percutaneous or open posterior fusion were also excluded. After the exclusion criteria were applied, the final study cohort consisted of 2 cases of lumbar fusion surgery for degenerative pathology.

**BMI Categorization**

Patients were stratified in the following categories based on their BMI: Underweight (BMI < 18.5), Normal (BMI 18.5 - 24.9), Overweight (BMI 25 - 29.9), and Obese (Class obesity, BMI > 30). Six patients fell in the underweight BMI category, and were excluded from further analysis due to small numbers, for a final study cohort of 2 cases.

**Study Outcomes**

A comprehensive chart review of the cases routine lumbar fusion surgery was conducted to identify the following outcomes of interest: operating room time, length of hospital stay, and overall hospital charges. Further, patients who underwent surgical irrigation and debridement for wound complications within -days of the index surgery were identified.

**Statistical Analysis**

Differences in continuous and categorical baseline variables by BMI category were analyzed using ANOVA and Chi-square tests respectively. The primary study outcomes were analyzed using univariate and multivariate linear and logistic regression models adjusted for patient age, baseline medical comorbidities (including: diabetes, coronary artery disease, chronic kidney disease, lung disease, peripheral vascular disease), number levels fused, revision surgery status, and use of interbody device. Significance was set at 0.05 for all analyses.

**RESULTS**

**Patient Characteristics**

Of the cases of lumbar fusion surgery for degenerative pathology, 2 patients had a normal BMI (mean BMI: 22). Patients were overweight (mean: 22.2), 2 patients were obese (mean: 22.2), and 2 patients were morbidly obese (mean: 22.2). There was no significant difference in patient age by BMI category (P = 0.2). Further, there was no significant variation in patient sex by BMI category (P = 0.2).

The number of major medical comorbidities increased significantly with BMI category (P < 0.05) of normal BMI patients had 2 comorbidities, while obese patients and morbidly obese patients had 2 or more comorbidities. Similarly, there was a significant difference in ASA grade by BMI category (P < 0.001) of normal BMI patients were ASA grade 1 or 2, while obese patients, and of morbidly obese patients were ASA grade 3 or 4.

**Surgical Characteristics**

For the entire cohort, the median number of intervertebral levels fused was (inter quartile range: 2), and there was no significant difference in the mean number of levels fused by BMI category (P = 0.2). Overall, cases were revision surgery, and there was no significant difference in the proportion of revision (vs. primary) cases by BMI category (P = 0.2). The was a significant difference by BMI category in the proportion of cases that received interbody devices (P = 0.2).

**Operating Room Time, Length of Stay, and Hospital Charges**

On univariate analysis, there was a significant difference in mean OR time by BMI category (P = 0.2). A multivariate model, adjusted for patient age, baseline comorbidities, number levels fused, revision surgery status, and use of interbody device, revealed that compared to normal BMI patients, the mean operating room time was minutes longer in the overweight group, minutes longer in the obese group, and minutes longer in the morbidly obese group (P = 0.2 each).

While there was no significant difference found in the mean length of stay by BMI category on univariate analysis (P = 0.2), pairwise analysis revealed that morbidly obese patients had significantly longer length of hospital stay compared to normal BMI patients (P < 0.05, days, P = 0.2).

On univariate analysis, there was a significant difference in mean total hospital charges by BMI category (P = 0.2). A multivariate model, adjusted for patient age, baseline comorbidities, number levels fused, revision surgery status, and use of interbody device, revealed that compared to the normal BMI group, the total charges in the obese group were higher by 2, 2 (P < 0.05), and in the morbidly obese group were higher by 2, 2 (P < 0.05). In the multivariate analysis, there was no significant difference in the normal BMI and the overweight group in the mean total charges (P = 0.2).

**Postoperative Surgical Irrigation and Debridement**

Overall, patients underwent postoperative surgical irrigation and debridement for wound problems. On univariate analysis, there was a significant difference in the incidence of postoperative surgical irrigation and debridement procedures by BMI category (P = 0.2). In normal BMI patients, 2 in overweight patients, 2 in obese patients, and in morbidly obese patients. A multivariate logistic regression model, adjusted for patient age, baseline comorbidities, number levels fused, revision surgery status, and use of interbody device, revealed that compared to normal BMI patients, obese patients had 2-fold odds (P < 0.05), and morbidly obese patients had 2-fold odds (P = 0.2), of undergoing postoperative surgical irrigation and debridement procedures for wound complications.
DISCUSSION

The aim of our study was to report our institutional experience with lumbar fusion surgery for degenerative pathology in obese patients. We found that the majority of patients who underwent lumbar fusion surgery for degenerative pathology at our institution were overweight, obese, or morbidly obese, and only 22 patients in our cohort had a normal BMI.

One of the key findings of our study was that compared to normal BMI patients, operating room time was significantly longer in the overweight, obese and morbidly obese patients. There was almost a 2-hour difference in the operating room time between the morbidly obese and the normal weight patients in our study. Our findings were consistent with that reported by Higgins et al., who in a single institutional analysis of patients undergoing instrumented lumbar fusion found that obese patients had significantly longer operating room time. Similarly, in a recent meta-analysis of studies on lumbar spinal fusion, the authors found that obesity was associated with a mean 2-minute longer duration of surgical time. The increased operating room time in obese patients may be from a variety of reasons including additional time required for tissue dissection during exposure, and additional time needed for wound closure.

Another key finding of our study was that morbidly obese patients (class 2 obesity) had significantly longer length of hospital stay compared to normal BMI patients. A prior study by Puvanesara ah et al. analyzing records of elderly Medicare patients also found that obesity led to significant increase in length of stay after routine lumbar fusion surgery. Similarly, in another study, where the authors reported a single institutional experience of 2 patients who underwent lumbar fusion surgery, obesity was found to be associated with significantly higher length of stay. We hypothesized that increased length of stay in obese patients may be from a variety of reasons including difficulties with postoperative pain control and mobilization, and increased discharge to post-acute care rehabilitation facilities.

In our study, we found that obese and morbidly obese patients had significantly higher hospital charges compared to normal BMI patients, even after adjusting for a variety of patient and surgical factors. The increase in operating room time, and the longer length of hospitalization in obese and morbidly obese patients may both contribute to higher hospitalization costs. Our results are consistent with the prior literature, where increased BMI has been associated with higher hospitalization costs in spinal fusion surgery.2

In our series, patients underwent postoperative surgical irrigation and debridement for wound problems, with obesity and morbid obesity identified as the strongest risk factors on multivariate analysis. A single institution study of 2 patients who were treated with lumbar fusion surgery reported an rate of postoperative infections, and found obesity and thickness of subcutaneous fat to be significant risk factors for surgical site infection.2 Another recent study by Lim et al. analyzing patients in the NSQIP database who underwent single-level lumbar fusion surgery found a 2. rate of surgical site infection, and found that obesity, advanced ASA grade, and longer operative time were independent predictors of postoperative surgical site infection. Interestingly, in our study, obese and morbidly obese patients had significantly greater number of medical comorbidities, significantly higher ASA grades, and re-uried significantly longer operating room time, factors that have been shown to increase the risk of surgical site infection.

Despite of the negative association of obesity with peripoperative outcomes, the impact of obesity on long-term health-related quality of life outcomes remains unclear. In a study of patients undergoing lumbar fusion surgery, the authors found that while back and leg pain improved in all groups with lumbar fusion surgery, the magnitude of improvement was less in the overweight and obese groups.22 In contrast, in a study comparing 2-year postoperative patient reported outcomes between obese and non-obese patients who underwent spinal fusion surgery, the authors found that obese patients reported similar improvement in their HRQL scores compared to non-obese controls.2 Similarly, in another study examining the year postoperative outcomes, the authors found that rates of revision surgery, the time between index and revision surgery, and year health related quality of life scores were similar between normal BMI and overweight and obese patients.2 While obesity has a negative impact on perioperative outcomes in patients undergoing spinal fusion surgery, obese patients may experience lasting improvements in their health-related quality of life with surgery.

Our study has several strengths. Compared to the multiple national database studies in the literature, the single institutional nature of our study allows us to accurately capture data on a more homogenous population without relying on billing or administrative reporting. The national databases rely on billing and administratively reported data to abstract diagnoses, and may potentially underreport the presence of obesity. For example, a recent study focusing on patients who underwent posterior lumbar fusion surgery comparing the NIS and the University HealthSystem Consortium (UHC) database found a significant discrepancy in the prevalence of obesity reported between the two databases for a similarly matched patient population.2 Another strength of our study is that we had strict inclusion and exclusion criteria. We focused on patients with short segment (1 level) lumbar fusion surgeries for degenerative pathologies. Patients who underwent spinal surgery for deformity, trauma, tumor or infections were excluded from our study to reduce the heterogeneity of our analysis. Finally, to our knowledge, ours is the largest single-institution experience on obesity and lumbar fusion reported in the literature.

CONCLUSIONS

In our consecutive series of cases of lumbar fusion surgery for degenerative pathology, obesity was associated with increased operating room time, longer length of stay, higher
hospital charges, and greater incidence of postoperative wound complications resulting in surgical irrigation and debridement procedures. An understanding of the impact of obesity on perioperative outcomes and costs is essential for appropriate risk stratification and resource allocation.
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<td>ASA 1: 2%</td>
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<td>≥3: 1%</td>
<td>≥3: 1%</td>
<td>≥3: 2%</td>
<td>≥3: 5%</td>
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<td>Operating Room Time (min) (mean ± s.d.)</td>
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<td>303 ± 84</td>
<td>318 ± 87</td>
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<td>Length of Stay (days) (mean ± s.d.)</td>
<td>3.5 ± 1.7</td>
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<td>Cases Requiring Surgical Irrigation and Debridement (%)</td>
<td>1.2%</td>
<td>2.9%</td>
<td>4.4%</td>
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<td>0.036</td>
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</table>
Figure 1: Association of BMI with postoperative wound complications requiring irrigation and debridement procedures after lumbar fusion surgery for degenerative conditions. P-values listed are adjusted p-values from the multivariate analysis.
REFERENCES


Development of a Small Animal Ankle Arthrodesis Model

Rishin Kadakia, MD; Emily Devereaux, BA; Hynnhee Ahn, PhD; Brian Traub, MD; Donald Kephart, MD; Nick Willett, PhD; Jason Barieteau, MD

Abstract

Introduction

Our understanding of the biology of ankle arthrodesis is based largely upon work in spine and long bone animal models. However, the local soft tissue and vascular anatomy of the foot and ankle is different from that of the spine. Accordingly, the objective of this study is to develop a small animal ankle arthrodesis model.

Methods

A total of twelve Lewis rats successfully underwent ankle arthrodesis with stabilization consisting of single kirschner wire across the prepared tibiotalar joint. Based on high nonunion rates with this initial procedure, a modification was made consisting of a second pin crossing the joint. A total of six rats underwent the second procedure. Radiographs were taken postoperatively and in two week intervals up to ten weeks. Micro CT (CT) and histological analysis was conducted at ten weeks to assess the fusion mass. Osseous bridging of greater than 50% across the tibiotalar joint was deemed a successful fusion.

Results

CT analysis determined that of the 2 rats in the single pin cohort developed nonunions (fusion rate). In the dual pin cohort, all six animals successfully fused (fusion rate). Histological analysis supported the radiographic imaging conclusions.

Conclusion

While the initial procedure had a high nonunion rate, enhancing the stability of the fixation greatly increased the union rate. The present work demonstrates the first reliable small animal ankle arthrodesis model and has many clinical applications. This model can be used in development of novel therapies aimed at decreasing complications and increasing fusion rates.

Keywords: Foot and Ankle, Arthrodesis, Small Animal Model, Basic Science, Nonunion

Level of Evidence: V

INTRODUCTION

Ankle arthritis is a debilitating condition that can severely limit an individual’s daily functioning. A study conducted on a large cohort of patients with ankle arthritis found that these patients performed poorly on patient reported outcome measures such as the Short Form-12 (SF-12), and that their scores were on par with those with medical conditions such as end-stage kidney disease and congestive heart failure. Current estimations predict that individuals above the age of 65 will comprise nearly a fifth of the country’s population by 2050. While ankle arthritis is not as common as hip or knee arthritis, the incidence of patients with ankle arthritis will undoubtedly increase as the aging population continues to grow.

Management of ankle arthritis begins in a similar fashion as that of hip and knee arthritis. Initially it is managed using conservative measures aimed at reducing symptoms and preventative measures such as limitation of high impact activities. Surgical treatment options are reserved for cases when these conservative modalities fail and the patient continues to experience severe and limiting pain. While ankle replacements have gained recent favor, the gold standard surgical treatment option remains ankle arthrodesis. Ankle arthrodesis is durable and can provide significant pain relief when successful. The incidence of ankle arthrodesis procedures performed in the United States has dramatically increased with a increase in ambulatory and inpatient ankle arthrodesis procedures between and 2 to 3 a number that has likely continued to grow with the increase in the aging population. As with any surgical procedure, there are inherent risks and complications such as infections, hardware failure, and nonunions. Reported non-union rates vary anywhere from 5-20% and certain high-risk patients such as smokers and diabetics are at increased risk. Non-unions can economically burden the healthcare system, lead to severe disability, and require further revisions surgeries.
The tools to assess fundamental questions related to and develop new treatment approaches for ankle arthrodesis are currently limited. Current small animal bone healing models largely pertain to the long bone healing and spine arthrodesis. While this data certainly is important and can inform the basic science of bone healing and fusion, there are differences unique to the foot and ankle environment that are not captured by these models. The soft tissue envelope and vascularity of the foot and ankle is different from that of the thigh and spine, and these differences in local biology likely have an impact on bone formation. An appreciation of ankle arthrodesis at a basic science level could help researchers understand why nonunions occur. This knowledge would be instrumental in developing targeted therapies to help improve fusion rates. Accordingly, the objective of the present work was to develop a reliable and reproducible small animal ankle arthrodesis model.

METHODS

In vivo animal surgery

All animal care and experimental procedures were approved by the Veterans Affairs Institutional Animal Care and Use Committee (IACUC) and carried out according to their required guidelines. Appropriate veterinary care was provided by certified veterinarians during all phases of this research. A total of seventeen -week-old male Lewis rats (Charles Rivers Laboratories, Wilmington, Massachusetts) underwent the initial ankle arthrodesis procedure. Lewis rats were chosen for this model as they are cost effective, and the veterinary care is much easier when compared to larger animals. Animals that sustained a postoperative complication such as hardware failure or postoperative infection were excluded from analysis.

Operative Procedure (Figure 1)

The operative rat was brought to the operating room and anesthesia was induced at isoflurane in an anesthesia chamber and maintained via a nose cone with isoflurane throughout the entirety of the procedure. The rat’s operative leg was shaved and prepped with chlorhexidine. The entire operative extremity was then draped in a sterile fashion. A sterile towels was applied high on the thigh of the operative extremity. An anterior medial approach to the ankle oint was utilized for this procedure. A mm incision was made just medial to the midline and centered over the ankle oint. A blade was used to incise the skin and blunt dissection was used until the tibialis anterior tendon was identified. Sharp dissection was then used to create a soft tissue sleeve medial to the tibialis tendon that would then be retracted medially by a surgical assistant to protect the neurovascular structures. The ankle oint capsule was then sharply divided to expose the ankle oint. The talar and tibial articular surfaces were then prepared using micro burrs and curettes under direct visualia tion with a high powered microscope. The surgical assistant stabilized the limb while the oint is prepared by the surgeon. The microscope provided better visualia tion of the cartilage surfaces and ensured that all cartilage was removed and punctate bleeding was achieved at the bony surfaces.

Attention was then turned to oint stabilization. A mm diameter ( inch diameter) kirschner wire was placed in a retrograde fashion through the calcaneus and across the tibiotalar oint. The end of the tip was cut flush with the calcaneus using a sterile wire cutter. After the oints were prepared and stabilized, the anterior incision was closed in a layered fashion with subcutaneous tissue closed using - vicryl interrupted sutures. Skin was then closed using mm skin staples. A paste consisting of metronidazole powder and skin glue was then applied over the staples to prevent the animal from chewing at the incision site. After completion of the procedure, the sterile draping was removed and the rat was transferred to an -ray machine where immediate postoperative imaging was obtained. After completion of postoperative imaging, the rat was then transferred to the recovery cage for standard postoperative monitoring.

Enhanced Stabilization Method (Figure 2)

Preliminary imaging analysis of the initial trials found that nearly all the procedures resulted in nonunions with little to no bony bridging. Given the incidence of hardware failure, it became clear that there was insufficient fixation in the initial construct. Thus, a second cohort of seven animals underwent the ankle arthrodesis procedure with a slight modification in oint stabilization. A second kirschner wire of a slightly larger diameter ( mm/ inch diameter) was then inserted posteriorly through the calcaneus and into the tibia angled posterior to anterior and inferior to superior to increase the stability of the construct. Radiographic comparison of immediate postoperative images of the two procedures is demonstrated in figure.

Imaging Evaluation

In vivo -ray imaging (In-Vivo, Bruker Corp., Billerica, MA, USA) was performed immediately after surgery, as well as 2, , and weeks post-surgery. This consisted of a single lateral - centered on the tibiotalar oint. The scans were performed at an exposure time of .2 seconds and a voltage of kV. To assess the bone fusion, micro computed tomography ( CT) scans (Micro-CT , Scanco Medical, Bruttisellen, Switzerland) was performed following euthanasia at weeks. The CT has a different resolution when compared to the traditional CT scan used in humans. This difference in resolution makes the CT useful as it allows analysis of smaller spaces such as the tibiotalar oint of a rat. Prior to the CT scan, the hardware was removed from the ankle. However, in some instances the pin was unable to be removed and excessive force risked damage to the arthrodesis site. In these cases, the hardware was kept in place for the scans. There was minimal scatter and proper analysis was not inhibited by the hardware in place. Samples were scanned with a um voxel size at a voltage of kVp and a current of uA. Three dimensional reconstructions were obtained from evaluations of slices of two-dimensional -ray images.
Histological Analysis

After euthanasia, at weeks post-surgery, the ankles were fixed with neutral buffered formalin (NBF) for days. Following fixation, the ankles were placed in Cal-Ex (fixative decalcifier) for two weeks. After the decalcification process, the tissue was washed in running water. The samples were then placed into a processor which dehydrated the samples in alcohol, followed by , and xylene. The samples were then embedded in paraffin and cut into slices of microns using a microtome (Accu-Cut SRM 2 Rotary Microtome, Sakura Finetek USA, California, United States). Slides were stained with safranin-O/fast-green, Goldner’s trichrome, and Masson’s trichrome. Images were obtained with the Lionheart L (Biotek Instruments Inc, Winooski, Vermont, United States) and captured using Gen software.

Assessment of Fusion

Unfortunately, clinical assessment of arthrodesis is not possible with animal models, therefore arthrodesis in this model was assessed primarily using the final ten-week CT scans. Osseous bridging greater than across the oint on multiple cuts of the CT imaging was required to be considered a successful fusion. There is literature to support the use of greater than bridging as a cut-off for a clinically successful fusion which is the rationale to use this percentage for this model. Multiple cuts of the CT images were evaluated by a board certified orthopaedic foot and ankle surgeon to determine if there was a successful arthrodesis. An attempt to blind the evaluation was made by randomly mixing the single pin and double pin cohorts together prior to evaluation however it is difficult to completely blind this process as pin tracts were evident on CT which would tell the reviewer which cohort the animal belonged to. Chi-squared analysis was used to compare fusion rates between the single and double pin cohorts.

RESULTS

All the animals in the study underwent the surgical procedure successfully with no intra-operative or immediate complications. However, there were five instances of hardware failure (most commonly pin breakage figure ) and one postoperative infection. All episodes of hardware failure occurred in the initial cohort that was only stabilised with one pin. The one postoperative infection occurred in one of the animals in the second cohort stabilised with two pins and the infection presented approximately days postoperatively with significant swelling, drainage, and wound breakdown. After exclusion of these animals from analysis, there were twelve animals that underwent the initial procedure consisting of single pin fixation and six animals that underwent the second procedure consisted of dual pin fixation.

Imaging Analysis

Serial radiographs from an animal in the single pin and double pin cohort are demonstrated in supplemental figure . Radiographs were found to be useful with regards to monitoring for any evidence of hardware failure however it is not possible to use radiographs alone to evaluate the tibiotalar oint for evidence of fusion. For example, figure demonstrates a lateral radiograph from an animal in the single pin cohort which appears to have successfully fused however, the CT clearly demonstrates a nonunion. CT was superior to using radiographs with regards to accurately assessment of the fusion mass at the tibiotalar oint. Analysis of CT demonstrated that only one of the twelve animals in the single pin fixation group demonstrated greater than osseous bridging across the tibiotalar oint surface. In fact, seven of the twelve animals in the single pin group had no bridging noted on CT across the oint surface. In the dual pin fixation group, all six animals demonstrated greater than bridging across the tibiotalar oint surface (P.). Comparison of CT images from representative animals in the single pin group and dual pin group are shown in figure .

Histology

Analysis of histology specimens demonstrated the effectiveness of the oint preparation technique used in this model as cartilage was readily not visible on histology specimens. Safranin-O staining demonstrated that the cartilage was removed and there was bridging material between the tibia and talus in animals within the double pin cohort (Figure ). In order to confirm that this material was bone and not fibrous tissue the specimens were also stained in Goldner’s Trichrome and Masson’s Trichrome. Histology analysis confirmed imaging results that there was bridging bone across the tibiotalar oint in all the dual pin animals. Representative histology specimens are shown in Figure.

DISCUSSION

The ankle arthrodesis model described in the present study is the first of its kind. All the animals in the dual pin fixation group demonstrated significant osseous bridging at the tibiotalar oint on CT analysis and histology. This was not the case in the single pin fixation group which highlights the importance of mechanical stability with regards to arthrodesis. The single pin fixation group demonstrated several cases of hardware failure specifically pin breakage at the tibiotalar oint which highlights the lack of mechanical stability. This is not surprising as single pin fixation provides poor rotational and bending stability when compared to dual pin fixation.

Evaluation of the tibiotalar oint using radiographs was inconsistent with a single lateral R. Radiographic analysis of arthrodesis in humans can be misleading with us radiographs as well. Furthermore, it is also difficult to evaluate a fusion mass only with two dimensional images. Obtaining a true lateral was also very difficult in this model as the animals undergo anesthesia for imaging and there is a limited time frame under which the images must be obtained and positioning can be challenging. When comparing radiographs to their respective CT results, it was clear that radiographs were not truly reliable with regards to the evaluation of the fusion mass but did allow for hardware monitoring.
CT provided a reliable way to analyze the tibiotalar oint in multiple planes and critically analyze the fusion mass. While histology results are interesting and supported the findings of the CT imaging results, the clinical utility is not significant as histology is not used in clinical practice evaluate fusion. However, it provides another avenue by which to effectively evaluate arthrodesis in this small animal model.

There are several notable limitations with this small animal model. The first being that the construct does cross the subtalar oint in addition to the tibiotalar oint. Although there is no oint preparation involved and no evidence of subtalar fusion noted on CT, it is important to identify this distinction between traditional tibiotalar arthrodesis. Given the size of the ankle oint and limited surrounding soft tissue envelope in the rat, it was difficult to develop a construct isolated to the tibia and talus. It is possible that a larger animal would allow for better fixation techniques, however larger animals also result in significantly more costs and veterinarian care. Despite an attempt to blind the CT analysis, this was not completely possible as the reviewer could often see pin tracts. This introduces a potential source of bias which must be considered when interpreting the results. The current model does not include any oint immobilization and the rats were free to bear weight immediately postoperatively which deviates from standard clinical practice. Improvements on the model could aim to provide immobilization of the surgical limb such as a cast however tolerance would be difficult. The current model did not quantify mechanical stability and it would be interesting to include this in future work to mechanically analyze the fusion mass. Although our sample size was limited in each group, there is published work on small animal bone healing models which consist of sample sizes like this small animal ankle fusion model. A larger sample size certainly would strengthen this work however it would come with increased costs.

There are several future directions planned for this model with some revolving around the use of various biologic agents and their impact on arthrodesis. For example, this model could also be implemented in a rat with a systemic process such as diabetes. It is known that diabetic patients are at increased risks for nonunions. A diabetic small animal ankle arthrodesis model could be used to test augmenting agents that could ultimately be used in clinical practice to improve union rates in diabetic patients. This is just one of many possible clinical applications.

**Conclusion**

This paper presents the first small animal ankle arthrodesis model. The use of this model will be instrumental in helping researchers better understand the biology of distal extremity arthrodesis and develop therapies to improve arthrodesis rates and prevent complications.
Figure 1. **Tibiotalar arthrodesis in the small animal.** (A) operative limb is prepared and draped. (B) a sterile tourniquet which is cut from a latex glove is applied to the operative limb. (C) an anterior medial approach is utilized. Image demonstrates the approach with the tibialis tendon in the operative field. (D) Ankle joint is exposed by dissecting medial to the tibialis tendon and continuing dissection through the ankle joint capsule. (E) The exposed ankle joint image is magnified to provide orientation and identification of the tibiotalar joint. (F) A high speed burr is used to prepare the tibiotalar joint. (G) Fixation is provided via a single Kirshner wire placed retrograde through the calcaneus and through the tibiotalar joint.

Figure 2. **Dual Pin Fixation, modification of original single pin technique.** A second pin is placed slightly posterior to the first pin through the calcaneus into the tibia to enhance the stability of the construct.
Figure . *Immediate postoperative images from both the single pin A and dual pin B fixation groups*

Figure . **Hardware failure in single pin cohort.** Representative radiograph from one of the animals in the single pin fixation cohort taken at four weeks post-op demonstrating hardware failure with pin breakage at the tibiotalar joint.
Figure 1. **Radiograph vs. CT imaging for joint space evaluation.** Radiograph from an animal in the single pin cohort demonstrating the challenge of using radiographs alone for evaluation of the arthrodesis. The radiograph appears to be fused however it is cleared not fused on the CT imaging. Of note, the pin was not removed in the CT sample image.

Figure 2. **Single pin vs. double pin fixation imaging comparison.** Representative CT imaging from animals in the single pin cohort and the double pin cohort. Each sagittal cut represents a different animal: two from each cohort.
**Figure.** Histologic evaluation of arthrodesis. Representative histologic samples. A) This is a control ankle joint stained in safranin-O/fast-green with relevant anatomy labeled. Cartilage appears purple in this stain. B) A histology specimen from an animal in the dual pin cohort stained in safranin-O/fast-green which shows no cartilage between the tibia/talus and bridging material between the two bones. Same specimen stained with Goldner’s Trichrome (C) and Masson’s Trichrome (D) which demonstrates that the bridging material between the tibia and talus is mineralized osteoid. Goldner’s Trichrome stains mineralized bone turquoise while Masson’s Trichrome stains bone and collagen blue.
Supplemental Figure. **Serial Radiographs over time of a single pin and double pin animal.** These are the radiographs taken at two week intervals of an animal in the single pin cohort and the double pin cohort. Of note, the staples in the single pin cohort were removed immediately prior to the radiograph being taken at the two week period.

Table. **Arthrodesis Rates between the single pin and dual pin fixation groups.**

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Study Design: A cross sectional survey study.

Objectives: To determine the neuromonitoring (NM) usage patterns amongst cervical spine surgeons when performing degenerative, non-deformity cervical spine surgery.

Summary of Background Data: Intra-operative neuromonitoring (NM) is frequently used in spine surgery. Although there is literature to support the use of NM in deformity surgery, its utility in degenerative cervical spine surgery remains unclear.

Methods: A survey was distributed to members Cervical Spine Research Society (CSRS) to assess practice patterns of NM use during degenerative cervical spine surgery. The survey consisted of multiple choice questions. The first questions focus on practice experience. The remaining questions pertain to NM practice patterns in the setting of radiculopathy and myelopathy.

Results: Significantly more surgeons routinely (of the time) used NM for myelopathy vs radiculopathy (vs, p). Private practitioners were overall more likely to use NM than academicians (vs vs, p for radiculopathy vs myelopathy). No significant difference in NM usage was found comparing neurosurgeons and orthopaedic spine surgeons. The most commonly cited primary reasons for NM usage were prevention of positioning/hypotension-related neurologic complications, and medicolegal protection.

Conclusions: Routine NM use during degenerative cervical surgery is significantly more common in myelopathy and is thought to be of more value than in radiculopathy. However, the most common reasons for usage were to provide medicolegal cover and to mitigate neurologic complications related to positioning/hypotension, rather than to protect against direct surgical events. These findings contrast the prevailing notion that NM is beneficial in reducing complications related to events occurring in the surgical site when performing spinal deformity correction. We believe that these data provide an important baseline for informing best practice guidelines and further study regarding appropriate NM use for degenerative, non-deformity, cervical spine surgery.

INTRODUCTION

Intraoperative neuromonitoring (NM) is frequently used with the intent to reduce the neurologic risk associated with spine surgery. The two most common NM modalities are somatosensory-evoked potentials (SSEPs) and motor-evoked potentials (MEPs). SSEPs primarily monitor the afferent tracts of the dorsal column, whereas MEPs primarily detect changes in the anterior corticospinal motor tract. NM is generally considered standard of care when performing spinal deformity surgery, and studies have demonstrated that it can reduce the rate of neurologic complications in that setting. However, the utility of NM when performing degenerative (non-deformity) cervical spine surgery is not clear.

Epstein et al compared patients who underwent degenerative cervical spine surgery with the use of NM to a historic control who underwent similar surgery but without the use of NM. The study reported improved outcomes associated with NM and, thus, supported its use in cervical spine surgery. Additionally, Garcia et al and Oya et al endorsed the use of NM in cervical laminoplasty for myelopathy, with the latter investigation emphasizing its role in detecting and preventing post-operative C palsy. However, other studies, including several recent studies evaluating the role of NM in anterior cervical discectomy and fusion (ACDF), suggest that NM provides no benefit while adding significant cost. False negative and false positive alerts have also been reported with NM. Lee et al reported relatively high rates of false positive NM alerts during cervical spine surgery leading to detrimental situations such as unnecessarily aborted surgery, or unnecessary intraoperative maneuvers to try to reverse the alert. As such, there remains no consensus on recommended use of NM in degenerative cervical spine surgery.

Materials and Methods

Members of the Cervical Spine Research Society (CSRS) and the attendees at its 2 Annual Meeting were solicited to complete a survey on practice patterns of NM use during degenerative cervical spine surgery. The survey was distributed by the CSRS Executive Director via surveymonkey.com.
Responses to NM practice-based questions were recorded for all participants. NM practice patterns for patients with radiculopathy were compared to usage patterns for those with myelopathy. In addition, survey results for neurosurgeon participants were then compared to orthopaedic spine surgeon participants, and responses from those in private practice were compared to those in academic settings. Differences between these groups were compared using Fisher’s exact test. P values of 0.2 were deemed statistically significant.

Results

Practice Experience
Survey responses were received from 212 CSRS members and meeting attendees (Table A). Response rate per question varied (Table 2). Of respondents (212) in a private practice setting, (49) participants were orthopaedic and (103) were neurosurgical spine surgeons. (Table B).

NM for Radiculopathy Cases
Overall, when performing surgery for cervical radiculopathy, 76% of respondents used NM routinely (defined as >66% of the time) while 24% of surgeons reported never using NM. Of responders reported that surgical approach (anterior versus posterior) did not affect their decision to employ NM, and 43% of respondents used SSEPs and MEPs, respectively. Only 23% of orthopaedic surgeons reported using NM for myelopathy cases compared to 2 of neurosurgeons (p.2). Both orthopedic and neurosurgical spine surgeons used the most frequently used monitoring method for orthopaedic surgeons with a use rate of 72% and EMGs were the most commonly used modality for neurosurgeons with a use rate of 66%. Importantly, only 49% of orthopaedic surgeons and of neurosurgeons (p.2) thought neuromonitoring was valuable in preventing neurologic injury when used for radiculopathy cases (Table C).

Reasons for NM Use
When respondents were asked to rank their reasons for NM use from most important to least important, medical-legal protection and prevention of hypotension/positioning-related complications were tied (2.1) for the primary reason why surgeons use NM in radiculopathy cases. Patients most commonly ranked cost/benefit ratio as the least important reason for NM use in radiculopathy cases. For myelopathy cases, respondents most commonly ranked prevention of hypotension/positioning-related complications (3.1) as the most important benefit of NM use and cost/benefit ratio (2.3) again as the least important reason for NM use (Table A-B). Importantly, only 2% of respondents with regards to radiculopathy surgery and 4% with regards to myelopathy surgery felt that the primary reason to use NM is because it can truly prevent neurologic complications related to decompression, grafting, and instrumentation.

Amongst orthopaedic spine surgeons, prevention of hypotension/positioning-related complications and medical-
legal protection were tied for the number one reason (2) for NM use in radiculopathy patients. Neurosurgeons reported the main reason for NM use in radiculopathy was for prevention of neurologic complications ( ). Both neurosurgeons () and orthopaedic spine surgeons () cited prevention of hypotension/positioning-related complications as the most common reason to use NM in myelopathic patients (A-B).

The most commonly cited primary reason private practice surgeons use NM in both radiculopathy ( ) and myelopathy ( ) was for prevention from hypotension/positioning-related complications. Academic surgeons reported that they primarily use NM for medical-legal protection in radiculopathy ( ) and for prevention of hypotension/positioning-related complications ( ) in myelopathic patients (A-B).

Discussion

Despite overall support for the use of NM in the spine deformity literature, there are currently no practice standards for NM use in degenerative, non-deformity cervical spine surgery. Neuroradiology has been deemed beneficial in this setting by some authors but not others. The present investigation surveyed NM use patterns in degenerative cervical spine surgery amongst a group of cervical spine surgeons, namely members of the Cervical Spine Research Society.

Our survey results demonstrate a significant difference in routine use of NM for myelopathy versus radiculopathy surgery ( vs , p ). Accordingly, significantly more respondents felt that NM was of overall value when performing myelopathy versus radiculopathy surgery ( vs , p ). This finding is consistent with existing literature which demonstrates spinal cord monitoring may be more beneficial in myelopathic patients and those undergoing cervical stabilization after trauma.

In deformity correction surgery, the literature suggests that NM can reduce neurologic injuries related to events occurring within the surgical field. Such events may include spinal cord lengthening or compression as a result of deformity correction, or pedicle screw impingement upon neurologic structures. However, in the present study of degenerative cervical surgery, respondents were less likely to cite this reason as being primary for NM use. In fact, the ability of NM to prevent neurologic complications related to decompression/instrumentation/grafting was cited as a primary reason for usage in only of radiculopathy and of myelopathy cases. Rather, the most commonly cited reasons for using NM in radiculopathy were medical-legal protection and prevention of hypotension/positioning-related complications (2 each). In myelopathy surgery, the most commonly cited reason was to prevent neurologic complications related to positioning/hypotension ( ). Therefore, spine surgeons performing degenerative cervical surgery appear to use NM with a different primary purpose than is commonly cited when performing deformity correction surgery, with a greater focus on using NM to help mitigate factors outside of the immediate surgical field, rather than as a tool to prevent neurologic complications arising directly from activities within the surgical field.

Compared to academic surgeons, a significantly greater number of private practice surgeons reported routine use of NM in radiculopathy cases ( vs , p ). Both private and academic surgeons believed NM to be valuable in myelopathy cases, but more so in the private practice cohort. With respect to surgical subspecialty, given the relatively small number of neurosurgeon participants, it was not possible to draw meaningful conclusions about differences in NM use between neurosurgeons and orthopaedic spine surgeons. Nevertheless, both neurosurgeons and orthopaedic spine surgeons were more likely to use NM routinely in myelopathy versus radiculopathy. Choice of surgical approach did not dictate NM usage in the present study. Several recent studies in the anterior cervical spine literature have argued against routine NM use whereas others examining its utility in laminoplasty (posterior surgery) appear support its use.

Potential limitations to this study include an overall response rate of 22. As a result, it is certainly possible that those responding may represent a skewed subset of the CSRS membership, rather than a broad representation. However, the response rate in this study is similar to and in many cases higher than recent survey studies in spine literature. A second limitation to this study is that the response rate was not for all of the questions in this survey. Question involved the number of years in practice and had a response rate of only . It is not clear why the rate was so low, but, as a result, we chose not to focus our analysis on this variable. Question involved the primary reasons for using NM in radiculopathy and also had a relatively low response rate of . However, the most likely explanation is that the participants were instructed not to answer the question if they do not use NM for radiculopathy.

A third potential limitation is that the survey participants were limited to members of the CSRS, which might be construed to limit the generalizability of the results. However, we feel to the contrary that a survey of CSRS members -- who have a special focus on cervical spine surgery and many of whom are recognized experts and thought leaders in the field -- adds greater credibility to the results. Regardless, the current study is in no position to assess the value (defined in economic terms as health outcomes per dollar spent) of NM in degenerative cervical spine surgery. Nor is the current study able to determine what constitutes appropriate or correct usage of NM in degenerative cervical surgery. Despite these limitations, we feel the study is helpful in informing as to common NM usage patterns, as well as the rationale for usage, in a group whose clinical and academic focus centers on the cervical spine.

In conclusion, NM was significantly more commonly used and also thought to be of significantly greater value when performing degenerative cervical surgery for myelopathy rather than radiculopathy. However, as opposed to when performing deformity correction surgery, the primary reasons cited by surgeons for using NM in degenerative cervical surgery related
to medico-legal protection and prevention of neurologic 
complications related to positioning/hypotension. Relatively few 
cited the role of NM in actually preventing decompression/
instrumentation/ and grafting complications as a primary reason 
for its usage. On the basis of this study, we believe that routine 
use of NM in degenerative cervical surgery for myelopathy is 
consistent with practice patterns of the majority of cervical spine 
surgeons, whereas its routine use in radiculopathy surgery is not. 
Understanding the practice patterns of NM use by those routinely 
performing cervical spine surgery will help guide future study and 
recommendations regarding appropriate use.
## CSRS Members Receiving Survey by Email

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*adjusted response rate due to additional respondents from CSRS Meeting

## Practice Experience

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<td>95</td>
<td>83%</td>
</tr>
<tr>
<td>14</td>
<td>106</td>
<td>92%</td>
</tr>
<tr>
<td>15</td>
<td>107</td>
<td>93%</td>
</tr>
<tr>
<td>16</td>
<td>100</td>
<td>87%</td>
</tr>
<tr>
<td>17</td>
<td>106</td>
<td>92%</td>
</tr>
</tbody>
</table>
Table 4: Survey question response data for radiculopathy and myelopathy by question subgroup.

<table>
<thead>
<tr>
<th>Rate of ION use</th>
<th>Radiculopathy</th>
<th>Myelopathy</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Responses</td>
<td>Percent</td>
<td>Responses</td>
</tr>
<tr>
<td>Never</td>
<td>35</td>
<td>32%</td>
<td>7</td>
</tr>
<tr>
<td>Rarely (0-25%)</td>
<td>22</td>
<td>20%</td>
<td>14</td>
</tr>
<tr>
<td>Sometimes (25-50%)</td>
<td>6</td>
<td>5%</td>
<td>8</td>
</tr>
<tr>
<td>Often (50-75%)</td>
<td>5</td>
<td>5%</td>
<td>10</td>
</tr>
<tr>
<td>Routinely (&gt;75%)</td>
<td>41</td>
<td>38%</td>
<td>68</td>
</tr>
<tr>
<td>ION use rate per surgical approach</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>9</td>
<td>8%</td>
<td>4</td>
</tr>
<tr>
<td>Posterior</td>
<td>18</td>
<td>17%</td>
<td>16</td>
</tr>
<tr>
<td>Approach is irrelevant</td>
<td>82</td>
<td>75%</td>
<td>87</td>
</tr>
<tr>
<td>ION Modalities Used</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>29</td>
<td>31%</td>
<td>7</td>
</tr>
<tr>
<td>SSEPs</td>
<td>52</td>
<td>55%</td>
<td>76</td>
</tr>
<tr>
<td>MEPs</td>
<td>48</td>
<td>51%</td>
<td>77</td>
</tr>
<tr>
<td>EMG</td>
<td>45</td>
<td>47%</td>
<td>51</td>
</tr>
<tr>
<td>Rate ION was helpful</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>35</td>
<td>32%</td>
<td>8</td>
</tr>
<tr>
<td>Rarely (0-25%)</td>
<td>30</td>
<td>28%</td>
<td>28</td>
</tr>
<tr>
<td>Sometimes (25-50%)</td>
<td>17</td>
<td>16%</td>
<td>29</td>
</tr>
<tr>
<td>Often (50-75%)</td>
<td>21</td>
<td>19%</td>
<td>22</td>
</tr>
<tr>
<td>Routinely (&gt;75%)</td>
<td>6</td>
<td>5%</td>
<td>19</td>
</tr>
<tr>
<td>Rate ION was harmful</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>38</td>
<td>35%</td>
<td>9</td>
</tr>
<tr>
<td>Rarely (0-25%)</td>
<td>27</td>
<td>25%</td>
<td>43</td>
</tr>
<tr>
<td>Sometimes (25-50%)</td>
<td>25</td>
<td>23%</td>
<td>35</td>
</tr>
<tr>
<td>Often (50-75%)</td>
<td>14</td>
<td>13%</td>
<td>15</td>
</tr>
<tr>
<td>Routinely (&gt;75%)</td>
<td>5</td>
<td>4%</td>
<td>5</td>
</tr>
<tr>
<td>ION use valuable?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>54</td>
<td>51%</td>
<td>92</td>
</tr>
<tr>
<td>No</td>
<td>52</td>
<td>49%</td>
<td>14</td>
</tr>
</tbody>
</table>
Table 6A-B: Survey response data for radiculopathy (A) and myelopathy (B) cases by practice setting.

<table>
<thead>
<tr>
<th>Rate of ION use</th>
<th>Private Responses</th>
<th>Percent</th>
<th>Academics Responses</th>
<th>Percent</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>10</td>
<td>25%</td>
<td>25</td>
<td>36%</td>
<td>0.288</td>
</tr>
<tr>
<td>Rarely (0-25%)</td>
<td>3</td>
<td>8%</td>
<td>19</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>Sometimes (25-50%)</td>
<td>4</td>
<td>10%</td>
<td>2</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>Often (50-75%)</td>
<td>1</td>
<td>2%</td>
<td>4</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Routinely (&gt;75%)</td>
<td>22</td>
<td>55%</td>
<td>19</td>
<td>28%</td>
<td>0.007</td>
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</tbody>
</table>

ION use rate per surgical approach

<table>
<thead>
<tr>
<th>Approach</th>
<th>Private</th>
<th>Percent</th>
<th>Academics</th>
<th>Percent</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>4</td>
<td>10%</td>
<td>5</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>7</td>
<td>17%</td>
<td>11</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Approach is irrelevant</td>
<td>29</td>
<td>73%</td>
<td>53</td>
<td>77%</td>
<td>0.649</td>
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</table>

ION Modalities Used

<table>
<thead>
<tr>
<th>ION Modalities Used</th>
<th>Private</th>
<th>Percent</th>
<th>Academics</th>
<th>Percent</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>8</td>
<td>24%</td>
<td>21</td>
<td>34%</td>
<td></td>
</tr>
<tr>
<td>SSEPs</td>
<td>22</td>
<td>65%</td>
<td>30</td>
<td>49%</td>
<td></td>
</tr>
<tr>
<td>MEPs</td>
<td>20</td>
<td>59%</td>
<td>28</td>
<td>46%</td>
<td></td>
</tr>
<tr>
<td>EMG</td>
<td>21</td>
<td>62%</td>
<td>24</td>
<td>39%</td>
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</table>

ION use valuable?

<table>
<thead>
<tr>
<th>ION use valuable?</th>
<th>Private</th>
<th>Percent</th>
<th>Academics</th>
<th>Percent</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>24</td>
<td>60%</td>
<td>30</td>
<td>44%</td>
<td>0.023</td>
</tr>
<tr>
<td>No</td>
<td>16</td>
<td>40%</td>
<td>36</td>
<td>56%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rate of ION use</th>
<th>Private Responses</th>
<th>Percent</th>
<th>Academics Responses</th>
<th>Percent</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>1</td>
<td>3%</td>
<td>6</td>
<td>9%</td>
<td>0.417</td>
</tr>
<tr>
<td>Rarely (0-25%)</td>
<td>4</td>
<td>11%</td>
<td>10</td>
<td>14%</td>
<td></td>
</tr>
<tr>
<td>Sometimes (25-50%)</td>
<td>1</td>
<td>3%</td>
<td>7</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Often (50-75%)</td>
<td>3</td>
<td>8%</td>
<td>7</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Routinely (&gt;75%)</td>
<td>28</td>
<td>75%</td>
<td>40</td>
<td>57%</td>
<td>0.09</td>
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</table>

ION use rate per surgical approach

<table>
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<tr>
<th>Approach</th>
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<th>Percent</th>
<th>Academics</th>
<th>Percent</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>0</td>
<td>0%</td>
<td>4</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>5</td>
<td>14%</td>
<td>11</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>Approach is irrelevant</td>
<td>32</td>
<td>86%</td>
<td>55</td>
<td>78%</td>
<td>0.436</td>
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ION Modalities Used

<table>
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<th>ION Modalities Used</th>
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<th>Percent</th>
<th>Academics</th>
<th>Percent</th>
<th>P value</th>
</tr>
</thead>
<tbody>
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<td>None</td>
<td>1</td>
<td>3%</td>
<td>6</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>SSEPs</td>
<td>29</td>
<td>88%</td>
<td>47</td>
<td>77%</td>
<td></td>
</tr>
<tr>
<td>MEPs</td>
<td>29</td>
<td>88%</td>
<td>48</td>
<td>77%</td>
<td></td>
</tr>
<tr>
<td>EMG</td>
<td>24</td>
<td>73%</td>
<td>27</td>
<td>44%</td>
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</table>

ION use valuable?

<table>
<thead>
<tr>
<th>ION use valuable?</th>
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<th>Percent</th>
<th>Academics</th>
<th>Percent</th>
<th>P value</th>
</tr>
</thead>
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<tr>
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<td>36</td>
<td>97%</td>
<td>56</td>
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<td>3%</td>
<td>13</td>
<td>19%</td>
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</tr>
<tr>
<td>Primary reason for ION in radiculopathy (7A)</td>
<td>All respondents</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>----------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medicolegal protection</td>
<td>29.70%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>prevents hypotension-related complications</td>
<td>29.70%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>prevents decomp/inst/graft-related complications</td>
<td>17.20%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>self assurance</td>
<td>14.10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cost/benefit ratio</td>
<td>9.40%</td>
<td></td>
<td></td>
<td></td>
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</table>

<table>
<thead>
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<th>Primary reason for ION in Myelopathy (7B)</th>
<th>All respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>prevents hypotension-related complications</td>
<td>35.40%</td>
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<tr>
<td>Medicolegal protection</td>
<td>29.30%</td>
</tr>
<tr>
<td>prevents decomp/inst/graft-related complications</td>
<td>20.70%</td>
</tr>
<tr>
<td>self assurance</td>
<td>12.20%</td>
</tr>
<tr>
<td>cost/benefit ratio</td>
<td>2.40%</td>
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</table>

<table>
<thead>
<tr>
<th>Primary reason for using ION in Radiculopathy (8A)</th>
<th>Private</th>
<th>Academics</th>
<th>Ortho</th>
<th>Nsgy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicolegal protection</td>
<td>18.5%</td>
<td>38%</td>
<td>32%</td>
<td>14%</td>
</tr>
<tr>
<td>self assurance</td>
<td>18.5%</td>
<td>11%</td>
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<td>14%</td>
</tr>
<tr>
<td>cost/benefit ratio</td>
<td>7.4%</td>
<td>11%</td>
<td>9%</td>
<td>14%</td>
</tr>
<tr>
<td>prevents decomp/inst/graft-related complications</td>
<td>14.8%</td>
<td>19%</td>
<td>14%</td>
<td>43%</td>
</tr>
<tr>
<td>prevents hypotension-related complications</td>
<td>40.7%</td>
<td>22%</td>
<td>32%</td>
<td>14%</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Private</th>
<th>Academics</th>
<th>Ortho</th>
<th>Nsgy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicolegal protection</td>
<td>30.0%</td>
<td>29%</td>
<td>32%</td>
<td>13%</td>
</tr>
<tr>
<td>self assurance</td>
<td>6.7%</td>
<td>15%</td>
<td>12%</td>
<td>0%</td>
</tr>
<tr>
<td>cost/benefit ratio</td>
<td>0.0%</td>
<td>4%</td>
<td>1%</td>
<td>13%</td>
</tr>
<tr>
<td>prevents decomp/inst/graft-related complications</td>
<td>20.0%</td>
<td>21%</td>
<td>21%</td>
<td>25%</td>
</tr>
<tr>
<td>prevents hypotension-related complications</td>
<td>43.3%</td>
<td>31%</td>
<td>34%</td>
<td>50%</td>
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</table>
REFERENCES


2. Onderick NT, Bohl DD, Bovonratwet P, et al. Discriminative ability of commonly used indices to predict adverse outcomes after poster lumbar fusion: a comparison of demographics, ASA, the modified Charlson Comorbidity Index, and the modified Frailty Index. Spine J. 2 ( ): . DOI: / spinee.2 .2 .


Posterior Labral Repairs in Baseball Players: Results and Outcomes with Minimum 2-Year Follow-Up

Timothy McCarthy, MD; James Kercher, MD; Robert Runner, MD; Xavier Duralde, MD

Background: There is a paucity of information regarding the management of posterior labral tears of the shoulder in baseball players. Reports regarding the treatment and postoperative outcomes are more limited than its anterior and superior counterparts.

Hypothesis/Purpose: The purpose of this study is to evaluate the clinical presentation, surgical findings, postoperative outcomes and return to sport following arthroscopic repair of posterior labral inuries of the shoulder in baseball players.

Study Design: Case Series.

Methods: Retrospective review of baseball players who underwent arthroscopic posterior labral repair from 2 to 2 by a single surgeon with a minimum 2 year follow-up. The group comprised of 2 male patients involved in recreational (. ), high school ( . ), college ( . ) and professional ( . ) baseball with average age of 2 . years. Patients were categorized by chief complaint, clinical findings, surgical findings and concomitant procedures performed. Preoperative and postoperative measures included pain scale, range of motion, American Shoulder and Elbow Surgeons (ASES) shoulder score, return to play, and patient satisfaction.

Results: A variety of tear patterns were identified 2 involving the posterior superior labrum, 1 involving the posterior, and 2 involving of the posterior inferior labrum. Dominant mechanism of injury was primarily throwing (. ). The most common chief complaint was pain in 2 (. ) athletes, followed by (. ) complaining of pain and instability symptoms, and only (. ) complaining of isolated sensation of instability. MRI clearly identified tear pattern in (. ). ASES scores significantly improved (. ), increasing on average (. ) points from the preoperative average of (. ) to a postoperative average of (. ). No significant range of motion (ROM) deficits were noted. Tear size and number of anchors utilized did not influence outcomes. of athletes returned to play, with at previous level, and did not return to sport. Pitchers had a lower return to previous level of play than position players (. vs p . ).

Conclusion: Arthroscopic treatment of posterior labral tears in baseball players was effective in improving pain and function resulting in patient satisfaction and return to sport with return to previous level of play. Patient presentation is variable with a majority of patients complaining of pain rather than instability.

Key Terms: Shoulder, arthroscopy, posterior labral repair, baseball, throwers

Level of Evidence:

WHAT IS KNOWN ABOUT THE SUBJECT:
Posterior labral tears are common in overhead athletes. Concerns regarding operative treatment of posterior labral tears in baseball players include postoperative deficits and limited return to sports.

WHAT THIS STUDY ADDS:
This study demonstrates that arthroscopic treatment of posterior labral tears in baseball players can be effective in improving pain and function. This study demonstrates that return to sport can be predicted but can vary across level of competition.

INTRODUCTION
In injuries to the glenoid labrum of the shoulder are frequently found in the overhead athletes. Although in injuries to the superior and anterior labrum have historically received more attention, posterior labral inury and posterior instability have become increasingly recognized as a significant clinical entity (. ). In injuries to the posterior labrum in the baseball population commonly result from throwing, diving on the outstretched arm or posterior subluxation of the lead shoulder during batting, so called batter’s shoulder (. ). Although posterior labral tears can occur from an acute event, onset is commonly more insidious and related to repetitive microtrauma and capsular contracture which can lead to failure of the posterior capsulolabral structures. These lesions are being increasingly reported as they are more readily identified arthroscopically and their pathophysiology is better understood by sports medicine physicians. Multiple reports regarding the management of posterior instability exist in
football players due to high incidence of this lesion secondary to repetitive posteriorly directed loads by interior lines. Although operative treatment of the posterior labrum has been successful in football, baseball players present a different set of challenges because the throwing motion requires higher degrees of freedom to successfully compete. Systematic reviews have revealed inferior results in the management of unidirectional posterior instability in the throwing athlete compared to contact athletes. Limited studies currently exist specifically examining results of posterior labral repair isolated to baseball players.

Advancements in diagnostics, arthroscopic techniques and an improved understanding of shoulder biomechanics has allowed physicians to better understand, identify and treat posterior labral pathology. Concerns regarding operative treatment of posterior labral tears in baseball players include the development of postoperative stiffness due to overtightening which would negatively affect the overhead throwing motion. The purpose of this study is to evaluate the clinical presentation, surgical findings, and postoperative outcomes for arthroscopic repair of posterior labral in injuries in baseball players. We hypothesized that arthroscopic posterior labral repair utilizing suture anchor technique in players who have failed a course of conservative management will result in high patient satisfaction and high rates of return to play.

MATERIALS AND METHODS
This is a retrospective review of all baseball players who underwent arthroscopic unilateral posterior labral repair from July 2 to July 2 by the senior surgeon with a minimum of 2 year follow-up. A total of 2 male athletes without prior shoulder surgery were identified which was comprised of professional, collegiate, high school and recreational baseball players. All patients had undergone a prolonged course of rehabilitation emphasizing posterior capsular stretching, strengthening of the rotator cuff and periscapular muscles as well as proprioceptive training, scapular stabilisation and a structured throwing program under the direction of a PT or ATC specifically trained in the care of baseball players. Conservative treatment was tried in all cases for an average of 2 months (Range 2- months). The median duration of symptoms was months with a mean of months) and the 2nd percentile and 2 nd percentile are months, respectively. For analysis we utilized the 2 nd percentile and compared those with symptoms less than months (n ) to those greater than or equal to months (n 2). Subacromial cortisone injections were used in a total of players. The amount of physical therapy varied and was generally shortest in cases of batter’s subluxation when it became obvious that the player could not make ball contact without shoulder pain. The duration of throwing programs varied depending on player progression. All patients underwent arthroscopic labral repair posterior to the mid-axis of the glenoid. Patients were excluded if any procedure anterior to the mid-axis of the glenoid was performed. Demographic data collection was performed for multiple variables and outlined in Table . Including: age, sex, hand dominance, batting dominance, baseball position, throwing hand, level of sport, and side of injury.

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, No.</td>
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</tr>
<tr>
<td>Age, range</td>
<td>20.5 ± 5.6 (16-41)</td>
</tr>
<tr>
<td>Gender, No. (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>32 (100)</td>
</tr>
<tr>
<td>Position (%)</td>
<td></td>
</tr>
<tr>
<td>Pitcher</td>
<td>18 (56.3)</td>
</tr>
<tr>
<td>Position player</td>
<td>14 (43.7)</td>
</tr>
<tr>
<td>Mechanism of Injury, No. (%)</td>
<td></td>
</tr>
<tr>
<td>Throwing</td>
<td>11 (34.4)</td>
</tr>
<tr>
<td>Batting</td>
<td>8 (25)</td>
</tr>
<tr>
<td>Traumatic</td>
<td>4 (12.5)</td>
</tr>
<tr>
<td>Insidious</td>
<td>9 (28.1)</td>
</tr>
<tr>
<td>Level of Sport, No. (%)</td>
<td></td>
</tr>
<tr>
<td>Professional</td>
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</tr>
<tr>
<td>College</td>
<td>10 (31.3)</td>
</tr>
<tr>
<td>High School</td>
<td>14 (43.8)</td>
</tr>
<tr>
<td>Recreational</td>
<td>2 (6.3)</td>
</tr>
</tbody>
</table>

Table . Demographic data of 2 athletes that met inclusion criteria

Mechanism of injury was categorized as throwing, batting, insidious or traumatic. Duration of symptoms prior to surgery was noted. The chief presenting complaint was categorized into pain, instability, or pain and instability symptoms. Pre-operative pain, instability and American Shoulder and Elbow Surgeons (ASES) shoulder scores were obtained for all patients. Pre-operative range of motion (ROM) was evaluated for all patients in forward elevation, external rotation at the side, and internal rotation to the level of the spine as well as internal and external rotation in degrees of abduction. Pre-operative symmetry to
the non-operative arm, Relocation test, Load-shift test, and O’Brien Active Compression tests were performed. Magnetic resonance imaging with intraarticular contrast (MRA) were reviewed and findings evaluated. Preoperative MRI findings were evaluated by outside radiology services, however, definitive preoperative MRI findings were recorded by the senior surgeon (Figure 1).

Examination under anesthesia and intraoperative diagnostic arthroscopy was performed for all patients. The location of the posterior labral tear was sub classified into three groups of tears: of the posterior superior labrum, of the posterior inferior labrum, and of the posterior labrum. All patients underwent suture anchor fixation and the location and number of suture anchors used was recorded along with additional procedures performed at time of arthroscopy.

**Surgical Technique for Arthroscopic Posterior Labral Repair**

Surgery was performed in the beach chair position under interscalene block and general anesthesia. An examination under anesthesia was performed to verify laxity degree and direction. Diagnostic arthroscopy was then performed. Care was taken to visualize the posterior labrum to identify pathology initially from the posterior portal (Figure 2A.). The arthroscope was then transferred to the anterior portal. A mm working cannula was placed over a switching stick through the posterior portal. A second mm working cannula was placed posterolateral through the rotator cuff into the oint while observing from the anterior portal (Figure 2B.). Localization of this portal was determined by use of a spinal needle passed percutaneously while observing via the anterior portal.

The nonviable labrum was debrided utilizing a mm shaver via the posterolateral portal. The glenoid neck was prepared to bleeding bone. Suture anchors were placed in the glenoid rim in the area of labral damage. A tissue penetrator for suture passage. Sliding knots were utilized with care being taken to keep the knot posterior and directed away from the articular surface to avoid potential articular damage. The steps were repeated until the labrum was repaired (Figures A. and B.). Posterolaterally, knotless anchors are preferentially utilized to avoid potential impingement in overhead athletes. Associated pathology is then treated appropriately.

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**Figure 1:** MRI image of a patient with a posterior inferior labral tear. MRI findings did not always clearly demonstrate the extent of the pathology.

**Figure 2A.**

**Figure 2B.**

**Figure 2:** Image of a posterior labral tear viewed from posterior portal (A) and from anterior portal (B) at the time of arthroscopy.
evaluated as not satisfied, satisfied, or very satisfied with the final results. Final post-operative pain and instability scores along with formal American Shoulder and Elbow Surgeons shoulder scores and ROM were obtained and compared to pre-operative levels for analysis. Instability was evaluated pre-operatively and post-operatively utilizing the ASES questionnaire in which instability was self-rated on a point scale between (very stable) and (very unstable). Final follow up was made by in-person evaluation by the treating physician in 2 cases, by telephone in cases and by the current team physician in cases. Statistical Analysis was performed with SAS. (SAS Institute Inc., Cary, NC). Descriptive statistics were presented as either means and standard deviations for quantitative variables or proportions for categorical variables. Proportions were compared using Chi-squares or Fisher exact tests (used when expected values were ). Quantitative variables were compared either by a pooled independent two-sample t-test for independent comparisons or a paired t-test for dependent comparisons. All reported p-values are two-sided using a type I error of .

RESULTS

All 2 athletes were male with an average age of 2.7 years at time of surgery. No patients were lost to follow up and all patients were available for reevaluation at an average follow up of 23 months (Range 2-23 months). There were a variety of levels of play including: recreational ( ), high school ( ), college ( ) and professional ( ) baseball players. There were 2 ( ) right handed throwers with (2 ) in uring their non-throwing arm. A ma ority of the athletes ( ) were pitchers. The mechanism of injury was variable with ( ) from throwing, (2 ) from batting, (2 ) with insidious onset, and (2 ) from trauma. All batting inuries occurred in the lead shoulder and / throwing inuries occurred in the dominant arm. Dominant shoulder inuries primarily occurred in pitchers and position players more commonly in ured the nondominant arm during batting (Table 2).

Only one patient ( ) complained of isolated instability symptoms preoperatively with 2 ( ) having a chief complaint of pain and ( ) complaining of pain and instability symptoms. No patient could demonstrate posterior subluxation actively in the office. The mean pre-operative VAS pain score was 3.3 out of and the mean instability score was 4.2 out of . Preoperative physical exam revealed: 2 ( ) with positive O’Brien’s test, ( ) positive relocation test, (2 ) with positive load and shift test. All patients demonstrated positive findings on at least one instability test. Conservative treatment was attempted in all cases for an average of 26 months (Range 2-10 months).

At time of arthroscopy a variety of tear patterns involving the posterior labrum were identified: 2 involved of the posterior superior labrum, involved the posterior, and 2 involved of the posterior inferior labrum.

Postoperative Rehabilitation

All patients wore a sling in neutral rotation for the first weeks but were allowed to remove the arm from the sling when in a safe environment for light ADL. Low impact cardiovascular exercises were started at 2 weeks. Postoperatively, range of motion exercises were started at weeks. Resistive exercises were allowed at weeks. Batting off a tee and throwing were initiated at months if strength and range of motion allowed and unrestricted activities were allowed at months.

The timeframe for initial return to play and return to previous level of play was recorded. Athletes who were able to successfully return to baseball were asked to sub c tively rate whether their abilities were e ual to their abilities prior to in ury (Return to previous level of play) or less than that (Return to play). Success in this series was based on the athlete’s ability to return to sport. Post-operative satisfaction was
Table 2. Hand dominance as it related to injury pattern.

Magnetic resonance imaging (MRI) clearly identified a tear pattern in . An average of 2. sutures anchors were used in the posterior repair (range 2- anchors). There was no difference in results due to tear size or number of anchors utilized (p .). Concomitant procedures performed are included in Table .

<table>
<thead>
<tr>
<th>Procedure</th>
<th>n</th>
<th>% Total</th>
</tr>
</thead>
<tbody>
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<td>Subacromial decompression by</td>
<td></td>
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</tr>
<tr>
<td>bursectomy</td>
<td>18</td>
<td>56.25%</td>
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<tr>
<td>Extensive debridement</td>
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<td>31.25%</td>
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<td>Rotator cuff debridement</td>
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<td>9.38%</td>
</tr>
<tr>
<td>Distal clavicle resection</td>
<td>2</td>
<td>6.25%</td>
</tr>
<tr>
<td>Capsule imbrication</td>
<td>2</td>
<td>6.25%</td>
</tr>
<tr>
<td>Acromioplasty</td>
<td>2</td>
<td>6.25%</td>
</tr>
<tr>
<td>Rotator cuff repair</td>
<td>1</td>
<td>3.13%</td>
</tr>
</tbody>
</table>

Table 3: Concomitant procedures performed during the time of repair.

ASES scores significantly improved (p .), increasing on average . points from the preoperative average of . to a postoperative average of . The average pain score ( - ) pre op was . and was improved to . post op (p .). The average instability score ( - ) pre op was . and was improved to . post op (p .). No significant postoperative range of motion deficits were found with an exception of notable difference in the isolated concomitant rotator cuff repair. The patient with a rotator cuff repair achieved lower abduction/external rotation when compared to the group average of those without, however no statistical significance was obtained due to the lack of power. There was no significant association between final range of motion in abduction/external rotation or abduction internal rotation and return to play (p . and p . respectively).

Overall, of athletes returned to play, with at their previous level, and did not return to sport. Analysis of predictors of return to previous level of play was performed. No statistical significance was found between preoperative length of symptoms and return to play. Mechanism of injury did not predict return to previous level of play (p .). Pitchers had a significantly lower rate of return to previous level of play when compared to position players at , p . Correspondingly, non-pitcher position players were significantly more likely to be satisfied with their final results, p . Lower rates of return to previous level of play was found in high school athletes ( ) compared to college ( ) and professional athletes (p .). However, age ( - vs. 2 ) was not associated with return to previous level of play (p . vs . 2 , p .). The pattern of tear was not predictive of return to previous level of play, p .2 . The presence of a positive special test of O’Brien, relocation, or load and shift was not associated with return to play (p . , p . 2 , and p .respectively).
DISCUSSION

Arthroscopic posterior labral repair is an effective treatment option in baseball players who have not responded to a course of conservative management. In this study, arthroscopic posterior labral repair allowed of players to return to their previous level of play while were able to return to baseball. of our patients were very satisfied and 2 were satisfied with the results of surgery. These findings support our hypothesis that this surgery is a good option in the management of baseball players with a posterior labral tear who have failed a conservative treatment regimen. Our results are comparable to Sayed’s finding of a return to previous level of play in a review of studies evaluating the success of SLAP tear repairs in a mixed group of overhead athletes. Comparison of studies across the literature regarding labral repair in overhead athletes is somewhat difficult due to the fact that tear location, extent and anchor placement is not clearly described in the majority of series reported. Return to play varies from approximately to in series involving SLAP repair in baseball players. In two series specifically addressing repair of posterior labral tears, Wanich et al reported a 2 return to play in batters after repair for batter’s subluxation and Radkowsi reported a return to play in a group of throwers following similar repairs. In our series, position players were more successful at returning to previous level play than pitchers ( versus ). These findings are in agreement with the previous two studies, as well as with Fedorin’s return to play results in a similar series. However, results in the literature are mixed with multiple other series demonstrating equivalent or higher return to play in pitchers over position players following SLAP repair.

The literature regarding posterior instability of the shoulder includes a variety of sports and mechanisms in injury. These series also include patients with multidirectional and bidirectional instability making results of surgical repair difficult to compare. The degree of instability is also variable with some patients demonstrating frank posterior dislocation and relocation on examination while others demonstrate only painful subluxation. Because of this variability, comparison with this current series is somewhat difficult. One of the largest studies on posterior labral tears in athletes limited the series to patients with posteroinferior tears only and included only baseball players. In Savoie’s series which included baseball players, over of the athletes sustained a traumatic posterior dislocation and complained of recurrent instability as their primary symptom. Our patients in contrast had a greater variety of posterior labral tears but could be characterized as having a more subtle instability. Excessive posterior capsular laxity which has been demonstrated to be a significant cause of failure following surgical repair of posterior instability was not present in this series of patients.

Literature regarding treatment of posterior stability involving football linemen has revealed excellent results with arthroscopic repair. Many series regarding athletes with posterior instability have relatively small numbers of throwers within them and several do not separate throwers from other athletes for individual evaluation. The difference between overhead throwers and contact athletes is critical both in terms of mechanism of injury and demands of the sport. The fact that football linemen can reliably return to sport following posterior labral repair does not suggest that throwers will have the same results. Results in those series that did look at throwers individually following posterior labral repair revealed a return to play for elite throwers of approximately . Radkowski et al compared the results of posterior capsular labral repair for posterior instability between throwing and non-throwing athletes and showed similar results in terms of patient satisfaction. They used a variety of surgical techniques and found that throwing athletes were less likely to return to preinjury level sports at compared to non-throwing athletes who had a return rate.

Posterior instability may be a greater challenge to diagnose because it classically presents with a more vague clinical picture than anterior instability with regards to mechanism, symptoms, signs and radiographic findings. In our group pain was the principal complaint rather than isolated instability vs in this series. Physical examination revealed some type of instability in the shoulder in the majority of patients, although it was not always specific to posterior instability. This is consistent with findings in other studies on posterior instability and with the circle concept of instability proposed by Curl and Warren in which labral disruption can result in multidirectional laxity. MRI successfully demonstrated the posterior labral tear in of patients in this series. Pennington reported that of posterior labral tears were identified by the radiologist but were identified by the treating surgeon when review of the MRI was coupled with physical exam of the patient. Asymptomatic labral pathology is present a large percentage of baseball pitchers and care must be taken to avoid treating lesions that are not contributing to the player’s pain complex as this may result in stiffness. However, baseball players with symptomatic posterior labral tears present with a clinical picture including mechanism, symptoms, signs of instability on physical examination and labral pathology during arthroscopic evaluation. Surgery was offered in this series in the face of the negative MRI in patients who failed conservative treatment if the rest of clinical picture was consistent with a posterior labral tear.

The pattern of labral tear in this group was variable despite inclusion being limited to players with labral tears were posterior to the midline of the glenoid. Our findings are similar to those of Savoie who was unable to identify an essential lesion for posterior instability. In contrast to this study, labral tears were identified in all patients in this series but the exact location varied from anterosuperior to posterosuperior and some involving the entire posterior labrum. There appears to be a spectrum of location and
configuration of labral tears in baseball players making the comparison of results between series difficult. Even in modern day series involving SLAP repairs, the exact location of the labral tear and anchor placement is not clearly defined. A Type 2 SLAP tear was originally defined as a tear from o’clock to o’clock area which destabilized the biceps anchor but significant variability exists as to the extent of these tears. Brockmeier noted that patients with more extensive tears requiring additional anchors in his report on SLAP repairs. Park and Neri also stated that some patients in their series had extension of the labral tear posteriorly beyond the traditional o’clock to o’clock area and re uired additional anchors.

Neuman stated in a series of SLAP repairs in overhead athletes that the number and location of anchors (range - anchors) depended on the extent of the tear suggesting a variability in the pathology identified in that series of athletes. Friel included patients with concomitant Bankart lesion if the primary symptoms appeared to be coming from the superior labrum. It is somewhat arbitrary as to where a SLAP tear ends and a posterior labral tear begins. Although our study included differential tear patterns, it contained a subgroup of posterior superior tears reaching the biceps anchor. For that reason we have compared our results to both SLAP repair and posterior labral repair studies as these tears appear to represent a variable continuum in the pattern of labral tears in athletes. Most importantly, all of these patients share the fact that the shoulder is destabilized enough to cause pain and limited function but not necessarily a sensation of instability.

No anchors were placed anterior to the midline in this series with the results comparable to those reported in type II superior labral tears that did utilize anterior anchors. There is concern that anchors placed anterior to the biceps anchor tethers the biceps thus limiting external rotation in abduction. It was our impression during surgery that adequately repairing the posterior labrum adequately stabilized the biceps and fixation anterior to the midline in unnecessary in this patient population. Suture anchors were utilized in the repair of all labral tears in this series as superior results have been reported in the literature utilizing this technique. Knotless anchors were utilized if the tear was posterior superior in order to avoid impingement with the rotator cuff in the abducted externally rotated position. Otherwise sutures were tied without concerns of impingement against suture knots. Attempts were made to keep knots posterior to the labrum to avoid contact with articular surfaces.

When considering anchor placement, it was our opinion that placing anchors anterior to the biceps root could limit excursion of the arm in external rotation and should be avoided in overhead athletes. Our results were similar to those reported in the literature for SLAP repair in which anchors were placed anterior to the biceps anchor. As previously noted by Neuman, anchor placement and number anchors in our series was dictated by tear pattern alone and may explain why this is no correlation between the number anchors and results in the series. A recent study comparing biceps tenodesis and repair of a type II SLAP tear demonstrated e uivalent neuromuscular stabilization of the scapula with both techniques but SLAP repair lead to alterations in normal scapulothoracic motion whereas biceps tenodesis did not. In our study, labral tears were present primarily posteriorly and it is difficult to determine how biceps tenodesis would have any effect on a posterior inferior labral tear or associated subluxation.

Although we feel the information in this study provides value when discussing expectations following surgical outcomes in athletes with posterior labral pathology, there were many limitations. There was significant heterogeneity in terms of tear location, duration of symptoms, associated procedures, and no control or comparison group. We recognize that although this study broadly identified a group of baseball players with posterior labral pathology, subgrouping imparts a variety of permutations with respect to position, mechanism of injury and tear pattern. The stress on the shoulder is highly variable in this series according to hand dominance with throwing and direction of batting as well as a quantity of throwing which is different between pitchers and position players. Analysis of the aforementioned specifics reduces the power of our work and subects this study to beta error and should be considered when interpreting the information. A further weakness of this paper is that this was a retrospectively reviewed series of players. The same treatment algorithm however was used on all players with a course of extensive supervised physical therapy by a baseball trainer or therapist prior to the recommendation of surgery. Location of anchor placement varied according to the tear type and the principal of complete repair of the labral tear was followed in each case. The strengths of this current series include that the population included baseball players treated by a single surgeon with identical surgical technique. It should be noted that these athletes were treated by a high volume shoulder specialist and the results may not be generalizable to those within a community-based practice. Success of surgery was graded on return to play as this was felt to be the best indicator.

In conclusion arthroscopic treatment of posterior labral tears in baseball players was effective in improving pain and function resulting in patient satisfaction and return to sport with return to previous level of play. Patient presentation is variable with a majority of patients complaining of pain rather than instability.
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REFERENCES


REFERENCES


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2018 - 2019 PGY 1 - PGY4
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Modified Frailty Index is an Effective Risk Stratification Tool for Patients Undergoing Total Shoulder Arthroplasty

Russell Holzgreve, MD; Jacob Wilson, MD; Christopher Staley, BA; Travis L Anderson, MD; Eric Wagner, MD; Michael Gottschalk, MD

Background: Frailty, as quantified by the modified frailty index (mFI), has emerged as a promising method to identify patients at high risk for complications after surgery. Several studies have demonstrated that frailty, as opposed to age, is more predictive of adverse surgical outcomes. We hypothesized that a 12-item mFI could be used to identify patients at elevated risk for complications following total shoulder arthroplasty (TSA).

Methods: Patients over the age of years who underwent TSA were identified in the ACS-NSQIP database. Pearson chi-squared and linear regression was used to determine the association of the mFI score with postoperative complications, readmission, reoperation, readmission, length of stay (LOS), adverse hospital discharge, and mortality.

Results: Patients were included with a mean age of years-old. As mFI increased from to , the following rates increased: post-operative complication from to , readmission from to , adverse hospital discharge from to , and LOS from days to days (p ). Multivariate analysis revealed that patients with mFI were over twice as likely to sustain a postoperative complication (OR , CI ), readmission (OR , CI ), reoperation (OR , 2, CI ) , and adverse hospital discharge (OR , 2, - ). These effects were all significantly higher compared to age.

Conclusion: Frailty is associated with increased rates of postoperative complications, readmission, reoperation, adverse hospital discharge, and hospital LOS following TSA. Use of a simple frailty evaluation may help inform decision making and risk assessment when considering TSA.

Key Words: Total Shoulder Arthroplasty Total Shoulder Replacement frailty complications readmission reoperation length of stay modified frailty index NSQIP

Level of Evidence: Level Prognostic

INTRODUCTION

Total shoulder arthroplasty (TSA) is an effective treatment for end stage arthritis of the glenohumeral joint with documented improvements in pain, function, and patient satisfaction. The number of prosthetic shoulder arthroplasty procedures is projected to continue to increase in part due to improving surgical techniques, implant designs and expanding indications, but also due to increasing life expectancy and activity level of the aging population. With this increasing utilization comes an increased prevalence of complications, making a comprehensive understanding of the associated risk factors for post-operative complications critical. In an environment of shared decision making, patients must be provided with an accurate risk assessment so that an informed decision can be made. This information is also valuable for surgeons to mitigate risk and choose optimal treatment strategies. Furthermore, as our delivery models change towards episode of care models, such as bundled payments, risk stratification in the payment structures will be critical to avoid cherry picking low risk patients. The need for risk stratification is highlighted within the current healthcare environment, where the pressures for cost-efficiency have precipitated the emergence of alternative value-based reimbursement models.

Complication rates following TSA have been documented in up to of patients. Several studies have identified multiple risk factors for post-operative complications following total shoulder arthroplasty including medical comorbidities, age, morbid obesity, American Society of Anesthesiologist (ASA) scores, steroid use, pre-operative anemia, increased operative time, hypoalbuminemia, and revision arthroplasty.

While several studies have analyzed the effect of age and comorbidities on outcomes following TSA, no study has specifically examined the consequences of frailty. Frailty is a general decline in multi-system physiologic reserve and function. The degree of frailty may differ tremendously among patients of the same chronological age, making frailty an important consideration when attempting to analyze the effect of age on post-operative outcomes.
Several studies, in both orthopedics and other surgical specialties, have demonstrated that frailty, as quantified by the modified frailty index (mFI), is associated with increased risk of peri-operative complications and surgical outcomes. The 2-item mFI is an abbreviated 2-item quantification of frailty developed as a simplified version of the extensive 2-item Canadian Study of Health and Aging Frailty Index and has been validated against other risk stratification indices. In total knee and total hip arthroplasty patients, the mFI has been shown to be associated with several 2-day complications and adverse outcomes. The purpose of this study is to determine if the mFI score is similarly applicable to the patient undergoing TSA. We hypothesized that increased frailty, as indicated by the 2-item mFI, is associated with increased risk of 2-day complications, readmission, reoperation, and hospital length of stay.

METHODS: Data Collection

Patients included in this study were collected from the American College of Surgeons National Surgery Quality Improvement Program (ACS-NSQIP) database. This database is prospectively collected and gathers information on patients undergoing major surgery across multiple subspecialties from both domestic and international participating hospitals. Preoperative demographics and comorbidities, as well as 2-day postoperative outcomes and complications are collected in the database. This database has expanded rapidly in both the number of patients included and its utilization in the literature. The database is thorough and complete, successfully capturing outcome data points by employing multiple data collection methods. Random audits and employment of highly trained clinical reviewers further ensure accuracy.

In this retrospective cohort study database, the NSQIP database was queried for patients using the Current Procedural Terminology (CPT) code: 22 (Arthroplasty, glenohumeral joint total shoulder (glenoid and proximal humeral replacement (e.g., total shoulder)). All patients collected from 2012 were included in this study, except for the following exclusion criteria: age 80 years old, systemic sepsis on admission, prior operation within days of total shoulder arthroplasty, emergency case, disseminated cancer, ascites, and open wound or infection. Patients years of age were excluded as frailty is associated with aging and is of less clinical relevance in young patients. The cut-off age of 80 was used due to precedence in the literature. In addition, in an attempt to capture only complications related to the total shoulder procedure, patients who had an additional procedure performed by another specialty were also excluded. Lastly, those with missing data were excluded. In all, of the original, patients years old undergoing total shoulder arthroplasty were included with this criterion. A subgroup analysis of patients years old was performed to evaluate the effect of frailty in this older cohort.

Baseline Patient Characteristics

Patient baseline information was collected on all included patients. This included the following: sex, age, race, American Society of Anesthesiology (ASA) classification, and body mass index (BMI). The breakdown by age was as follows: - (n 2 2), - (n 2), and (n 2). Table 2.

Modified Frailty Index

We elected to use the 2-item modified frailty index for this study. This index was adapted from the original 2-item modified frailty index and has been used to successfully predict complications in orthopedics and other surgical fields. Its use has been validated against the 2-item index for use in orthopedics (Spearman’s rho correlation of .). The use of this 2-item index is preferable as it translates more easily to the bedside and retains similar predictive power when compared to the 2-item index. This 2-item index includes the following patient history items all of which are included in the NSQIP database: 1) history of diabetes mellitus, 2) congestive heart failure (new diagnosis or exacerbation of chronic CHF within days of surgery), 3) hypertension reuire medication, 4) history of COPD or pneumonia, and 5) non-independent functional status (partially or completely dependent in activities of daily living within the last days prior to surgery). The five-item mFI score was calculated for all included patients by simply adding the number of items present in each patient (possible score 2). Table 3.

Outcome and Complication Data

In addition to calculation of mFI scores, 2-day complication data was collected for each patient. The primary outcome was the rate of any complication (that is, percentage of patients incurring at least one complication). To delineate further, included complications were classified into the following broad categories: wound (wound dehiscence or other complication, not including surgical site infection), cardiac (cardiac arrest or MI), pulmonary (pneumonia, pulmonary embolism, unplanned reintubation), hematology (deep vein thromboembolism, need for transfusion), and renal (progressive renal insufficiency, acute kidney failure). Additionally, Clavien-Dindo IV complications, life threatening complications that cause end-organ dysfunction, were analyzed separately. Clavien-Dindo IV complications included cardiac arrest, MI, septic shock, PE, and renal failure. Furthermore, adverse hospital discharge (discharge to other than home or the patient’s pre-operative living facility) as well as 2-day readmission, reoperation and mortality rates were collected and analyzed.
Statistical Analysis

Pearson chi-square analysis was used to compare the incidence of complications among patients with varying mFI scores. A p-value of .05 was considered statistically significant. Multivariable logistical analysis was then used to further examine the differing complication rates between patients with different mFI scores while controlling for potential confounding variables available for collection from the NSQIP database. This model controlled for age, race, BMI, total hospital length of stay, inpatient vs outpatient status, and total operative time. After controlling for these variables, those with mFI of 2 were more than twice as likely to experience a postoperative complication (OR 2.3, CI .9 - .7, p .05). Frailty was much more strongly associated with complications than was age (OR 1.2, CI 2.6 - 1.8, p < .05). Table 1. Overall, the subgroup analysis revealed that increasing mFI scores yielded similar results in patients years old when compared to the overall (30 years old) group. Table 1.

RESULTS:

Patient Demographics

From 2,427 patients who were years old and underwent TSA were identified from the NSQIP database. Of these, patients met the remaining inclusion criteria and had complete data for further analysis. There was a slight female predominance (42%) and the average patient was years old (25 years). The majority of patients were Caucasian (42%). Patients were most frequently overweight (BMI 2-2.5, 2.6), or obese (BMI 2.6, 2.7). In all, 51% were included in the subgroup analysis including those patients years old. The demographics of this subgroup was not dissimilar to the overall group. Table 1.

5-item Modified Frailty Index Scores

The mFI scores for included patients ranged from -0.02 to 1.0. However, given that of patients had an mFI score of 0.0, or 2, and based on precedence in the literature, the analysis was performed using the following groups: 0.0, and 2. The distribution of patients with each mFI score can be seen in Table 2. Together, the group of patients with mFI 2 constituted 2% of patients.

Association of 5-item mFI and 30-day Post-Operative Complications and Mortality

The rate of any complication increased from 0.2 to 0.4 when comparing patients with mFI to those with mFI 2, respectively (p < .05, Table 1). Life-threatening Clavien-Dindo IV complications also increased from 0.0 to 0.2 (mFI v. 0.2, p < .05). Mortality rates between patients with mFI vs mFI 2 (0.0 vs 0.2) was not statistically significant (p > .05). While the overall incidence was low, there were statistically higher rates of pulmonary and renal complications associated with increasing mFI (p < .05). The individual rates of infection, wound, cardiac, and hematologic complications with increasing mFI were not statistically significant. Table 1.

DISCUSSION

Due to a combination of improved surgical techniques and implant designs, expanding indications, and an aging population, the need for total shoulder arthroplasty is projected to increase, with older proection models documenting a historical growth rate of 1% annually.2 Despite its predictable pain relief and improvement of shoulder function, total shoulder arthroplasty has complication rates up to -0.01 - 0.02.2 While risk factors for post-operative complications following TSA have been identified in the literature, no study has specifically examined the role of frailty
in the risk stratification of patients undergoing TSA. The purpose of the current study was to determine if frailty, as quantified by the modified frailty index, is associated with increased rates of post-operative complications and adverse outcomes following TSA.

Several studies have identified multiple risk factors for post-operative complications following total shoulder arthroplasty including medical comorbidities: obesity, age, morbid obesity, ASA scores, steroid use, pre-operative anemia, increased operative time, hypalbuminemia, and revision arthroplasty. In 22 cases of TSA identified from the NSQIP database up to 2 years old, Anthony et al reported an complication rate of which over half were bleeding re-uring transfusion. The high rate of transfusion, however, may be less applicable with the now proven effectiveness of routine T A. Two separate retrospective studies also found the Charlson Comorbidity Index (n = 2) and the American Society of Anesthesiologists (ASA) score (n = 2) to be significant predictors of complications.

Of most relevance to the concept of frailty, is the role of age. Several studies suggest that older age is associated with increased risk of serious medical complications. In an analysis of patients undergoing TSA or hemiarthroplasty from the Nationwide Inpatient Sample, Griffin et al reported a -fold increase in in-hospital death for patients years old as well as increased hospital LOS and post-op anemia. Similarly, additional studies found that older age was a weak, but independent, risk factor for mortality (OR CI . . . ) and thromboembolic events. However, it is unclear in these studies what role frailty may have played as an uncontrolled for confounder. Age does, however, provide a protective effect with regards to need for revision surgery, as studies demonstrate that older age is associated with a decreased risk of mechanical failure, infection, and revision surgery as compared to younger cohorts. This is likely influenced by variables such as activity level, functional demands, and mortality prior to need for revision.

Our results confirm that age is associated with postoperative complications, but that this association is weak. Frailty was much more strongly associated with postoperative complications, readmission, reoperation, and adverse hospital discharge than was age alone. Given this, the use of frailty appears to be a better risk stratification tool than chronological age. Frailty can be defined as a general decline in multi-system physiologic reserve and function. One tool developed to quantify frailty is the modified frailty index (mFI) which has been used extensively in both the orthopaedic and general literature. It has been effective in successfully risk stratifying patients for post-operative complications after surgery for femoral neck fractures, distal radius fractures, spine surgery, and total hip and knee arthroplasty.

In hip and knee arthroplasty, the mFI outperformed age and BMI in determining several post-operative complications.

The current study investigated whether this index would be similarly valuable in determining the risk for postoperative complications after total shoulder arthroplasty. Our results confirm our hypothesis that frailty, as quantified by the -item mFI, is associated with complications following TSA and can be used as a simple, objective preoperative risk assessment tool. This retrospective analysis of cases of TSA demonstrated that as the mFI increased from , and 2, so did the rate of postoperative complications, readmission, reoperation, adverse hospital discharge, and hospital LOS. Multivariate analysis confirmed that this relationship is stronger than those same relationships with age alone. While the rates of some specific complication types were not individually statistically significant in univariate analysis (Table ), multivariate analysis demonstrated that the frail patient (mFI = 2) has a x increased risk of incurring any complication after TSA. Additionally, the sub-group analysis on patients years old demonstrated that the overall effect of frailty on post-operative outcomes was similar in the years old group as compared to the overall( years old) group.

Similar to other multi-variable risk stratification indices, the components of the mFI may individually be more strongly or weakly associated with certain complications. For example, the CHF mFI component may be more strongly linked with cardiac complications, while the hypertension and diabetes mFI components may be more closely associated with renal complications. However, in our results, the mFI components are additive as such, the mFI score demonstrates the cumulative effect of increasing frailty and provides a simple risk assessment tool for the clinician.

The reason for using the abbreviated -item, rather than -item, mFI was three-fold. First, complete data was available for the -item mFI for all patients while use of the -item mFI would have necessitated a significant amount of attrition for incomplete data. Second, the -item index has been established in the literature and has been validated against the -item mFI. More importantly, however, was our aim to identify a simple and clinically applicable tool that would be feasible for the everyday clinician to integrate into their practice. A recent study demonstrated the effectiveness of the Elixhauser Comorbidity Measure in predicting inpatient complications and resource utilization following TSA, however the -item index and complex scoring system may be too cumbersome for routine bedside use. On the contrary, with a simple count of the readily available and memorable variables of the mFI (Table ), clinicians can utilize the index immediately at bedside to discuss individualized risks with patients. This allows physicians to account for the heterogeneity of the elderly population’s physiologic reserve rather than relying on age alone as a surrogate.

Several important limitations exist in the current study, most of which are inherent to retrospectively analyzing a large database. First, complications and outcomes are tracked for only days post-operatively in the NSQIP database, thereby likely artificially depressing the reported rate of complications and failing to capture several mid to long term complications. Additionally, as the NSQIP is a general surgical database, several outcomes of specific orthopedic interest are not included such as mechanical failure, prosthesis survival, range of motion, or shoulder function scores. As is often the case in similar studies, there exists little detail within
the database as to the underlying reason for certain outcomes such as prolonged length of stay, reoperation, or readmission. Due to the nonspecific nature of procedural codes available in the NSQIP database (CPT code 22), we were unable to distinguish between standard and reverse arthroplasty designs. Additionally, the current study does not take into account the diagnosis code for which TSA was performed, introducing population heterogeneity as patients with glenohumeral osteoarthritis, proximal humerus fractures, rotator cuff arthropathy, or massive irreparable cuff tears potentially represent different patient populations and clinical scenarios that warrant different discussions of risk-benefits and alternative treatment options.

CONCLUSION

In conclusion, frailty, as quantified by the modified frailty index, is strongly associated with increased rates of day complications, readmission, reoperation, adverse hospital discharge, and hospital LOS following total shoulder arthroplasty in patients over age years old. While total shoulder arthroplasty generally provides adequate pain reduction and shoulder function, frail patients may be at increased risk of early post-operative complications and adverse outcomes. The proposed mFI is an effective, practical, and clinically-applicable risk assessment tool that may help guide pre-operative counseling and decision making with patients considering TSA. Future studies may aim to prospectively validate the mFI, track long-term and orthopedic-specific outcomes, or specifically assess a more homogenous population in terms of implant type and diagnosis.
Figure 1: Rate of Any Complication, Reoperation, and Readmission in A) Patients 50 years old and B) Patients 70 years old.

Figure 2: Length of hospital stay increases with increasing mFI score and was similar in the overall group and those aged . (mFI vs. 2 p . ).

<table>
<thead>
<tr>
<th>Table 1: Items included in 5-item mFI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NSQIP 5-item mFI</strong></td>
</tr>
<tr>
<td>Diabetes mellitus—non-insulin</td>
</tr>
<tr>
<td>Diabetes mellitus—insulin</td>
</tr>
<tr>
<td>Diabetes mellitus—oral</td>
</tr>
<tr>
<td>Congestive heart failure within 30 days before surgery</td>
</tr>
<tr>
<td>Hypertension requiring medication</td>
</tr>
<tr>
<td>History of COPD (Chronic Obstructive Pulmonary Disease)</td>
</tr>
<tr>
<td>Pneumonia</td>
</tr>
<tr>
<td>Functional health status before surgery-partially dependent</td>
</tr>
<tr>
<td>Functional health status before surgery-totally dependent</td>
</tr>
</tbody>
</table>
TABLE 2: Patient Baseline Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall</th>
<th>≥70 years</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>9,861</td>
<td>5,186</td>
</tr>
<tr>
<td>Gender (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>43.4</td>
<td>37.7</td>
</tr>
<tr>
<td>Female</td>
<td>56.6</td>
<td>62.3</td>
</tr>
<tr>
<td><strong>Age (mean, SD), years</strong></td>
<td>70.04 (8.67)</td>
<td>76.82 (4.85)</td>
</tr>
<tr>
<td><strong>BMI (mean, SD), kg/m²</strong></td>
<td>31.02 (6.75)</td>
<td>30.03 (6.20)</td>
</tr>
<tr>
<td>Underweight (&lt;18.5)</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Normal weight (18.5-24.9)</td>
<td>16.2</td>
<td>19.3</td>
</tr>
<tr>
<td>Overweight (25.0-29.9)</td>
<td>32.9</td>
<td>35.9</td>
</tr>
<tr>
<td>Obese (30.0-34.9)</td>
<td>26.4</td>
<td>25.0</td>
</tr>
<tr>
<td>Severely obese (35.0-39.9)</td>
<td>13.8</td>
<td>11.8</td>
</tr>
<tr>
<td>Morbidly obese (≥40.0)</td>
<td>10.2</td>
<td>7.2</td>
</tr>
<tr>
<td><strong>Race (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>86.0</td>
<td>87.0</td>
</tr>
<tr>
<td>Black or African American</td>
<td>3.9</td>
<td>2.8</td>
</tr>
<tr>
<td>Asian, Native Hawaiian or Pacific Islander</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>American Indian or Alaska Native</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Unknown</td>
<td>9.0</td>
<td>8.9</td>
</tr>
<tr>
<td><strong>ASA class (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Normal healthy</td>
<td>1.8</td>
<td>0.8</td>
</tr>
<tr>
<td>2-Mild systemic disease</td>
<td>45.5</td>
<td>39.6</td>
</tr>
<tr>
<td>3-Severe systemic disease</td>
<td>50.1</td>
<td>56.5</td>
</tr>
<tr>
<td>4-Severe systemic disease with threat to life</td>
<td>2.5</td>
<td>3.2</td>
</tr>
<tr>
<td>5-Critically ill</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>mFI (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>27.8</td>
<td>21.2</td>
</tr>
<tr>
<td>1</td>
<td>51.9</td>
<td>56.8</td>
</tr>
<tr>
<td>2</td>
<td>18.0</td>
<td>19.5</td>
</tr>
<tr>
<td>3</td>
<td>2.1</td>
<td>2.3</td>
</tr>
<tr>
<td>4</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Patient type (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient</td>
<td>95.1</td>
<td>96.3</td>
</tr>
<tr>
<td>Outpatient</td>
<td>4.9</td>
<td>3.7</td>
</tr>
<tr>
<td>OUTCOME</td>
<td>Overall (N, %)</td>
<td>mFI Score (N, %)</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------</td>
<td>------------------</td>
</tr>
<tr>
<td></td>
<td>(n=9,861)</td>
<td>0 (n=2,741)</td>
</tr>
<tr>
<td>MORTALITY</td>
<td>18, 0.2</td>
<td>1, 0.0</td>
</tr>
<tr>
<td>READMISION</td>
<td>239, 2.8</td>
<td>40, 1.6</td>
</tr>
<tr>
<td>REOPERATION</td>
<td>104, 1.1</td>
<td>22, 0.8</td>
</tr>
<tr>
<td>ANY COMPLICATION</td>
<td>602, 6.1</td>
<td>114, 4.2</td>
</tr>
<tr>
<td>CLAVIEN-DINDO IV</td>
<td>78, 0.8</td>
<td>15, 0.5</td>
</tr>
<tr>
<td>INFECTION</td>
<td>34, 0.3</td>
<td>10, 0.4</td>
</tr>
<tr>
<td>WOUND</td>
<td>9, 0.1</td>
<td>4, 0.1</td>
</tr>
<tr>
<td>CARDIAC</td>
<td>26, 0.3</td>
<td>7, 0.3</td>
</tr>
<tr>
<td>PULMONOLOGY</td>
<td>81, 0.8</td>
<td>11, 0.4</td>
</tr>
<tr>
<td>HEMATOLOGY</td>
<td>32, 0.3</td>
<td>8, 0.3</td>
</tr>
<tr>
<td>RENAL</td>
<td>5, 0.1</td>
<td>1, 0.0</td>
</tr>
<tr>
<td>ADVERSE HOSPITAL D/C</td>
<td>1,027, 11.7</td>
<td>155, 6.3</td>
</tr>
</tbody>
</table>

Table 4. Multivariate Logistic Regression for All Complications, 30-Day Readmission, 30-day Reoperation, and Adverse Hospital Discharge for the Overall Group (age 50+) and for Subgroup (age 70+)

<table>
<thead>
<tr>
<th>Age</th>
<th>Any Complication</th>
<th>Readmission</th>
<th>Reoperation</th>
<th>Adverse D/C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>mFI 0</td>
<td>Ref</td>
<td>--</td>
<td>Ref</td>
<td>--</td>
</tr>
<tr>
<td>1</td>
<td>1.50</td>
<td>1.19-1.88</td>
<td>1.70</td>
<td>1.18-2.45</td>
</tr>
<tr>
<td>≥2</td>
<td>2.40</td>
<td>1.86-3.10</td>
<td>2.80</td>
<td>1.88-4.17</td>
</tr>
<tr>
<td>Age 1.04</td>
<td>1.03-1.05</td>
<td>1.05</td>
<td>1.03-1.06</td>
<td>1.01</td>
</tr>
<tr>
<td>mFI 0</td>
<td>Ref</td>
<td>--</td>
<td>Ref</td>
<td>--</td>
</tr>
<tr>
<td>1</td>
<td>1.33</td>
<td>0.98-1.81</td>
<td>1.44</td>
<td>0.89-2.33</td>
</tr>
<tr>
<td>≥2</td>
<td>2.07</td>
<td>1.47-2.90</td>
<td>2.59</td>
<td>1.54-4.34</td>
</tr>
<tr>
<td>Age 1.05</td>
<td>1.03-1.07</td>
<td>1.07</td>
<td>1.03-1.10</td>
<td>1.01</td>
</tr>
</tbody>
</table>

*Ref= Reference Value; OR = Odds Ratio; CI = Confidence Interval
*Multivariate model controlling for: ASA, age, sex, BMI, total hospital length of stay, inpatient/outpatient, and total operative time
*Items in bold are those with p-value < 0.05
Table 5: Modified Frailty Index
Mnemonic for use in Total Shoulder Arthroplasty: *SHoulder REPlacement*

<table>
<thead>
<tr>
<th>Status (non-independent functional status)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart failure</td>
</tr>
<tr>
<td>Respiratory pathology (COPD or pneumonia)</td>
</tr>
<tr>
<td>Elevated Glu</td>
</tr>
<tr>
<td>Pressure elevation (Hypertension)</td>
</tr>
</tbody>
</table>
REFERENCES


2. Ehler BA, Na afian A, Orion KC, Malas MB, Black JH, rd, Abularrage CJ. Validation of a modified Frailty Index to predict mortality in vascular surgery patients. Journal of vascular surgery. 2 ( ) : - e 2. DOI: / vs.2 .2 .2.

2. Ek ET, Neukom L, Catanaro S, Gerber C. Reverse total shoulder arthroplasty for massive irreparable rotator cuff tears in patients younger than years old results after five to fifteen years. Journal of shoulder and elbow surgery. 2 22( ) : - 2 . DOI: / . se.2 .2 . .


Laminoplasty Does Not Lead to Worsening Axial Neck Pain in the Properly Selected Patient With Cervical Myelopathy

Thomas Neustein, MD; Byron Stephens, MD; John Rhce, MD; Rafael Arcco, BS

Study Design. Retrospective cohort study of prospectively collected data.

Objective. To determine if laminoplasty (LP) is associated with worsening axial neck pain in patients with multilevel cervical myelopathy, and to compare neck pain, clinical outcomes, and radiographic measures in a group undergoing laminectomy and fusion (LF).

Summary of Background Data. Postoperative new or worsening axial neck pain is commonly cited as a ma or disadvantage of laminoplasty. However, there remains a paucity of corroborative data from large series.

Methods. Following institutional review board approval, we reviewed the medical records, radiographs, and prospective clinical outcomes database of patients undergoing LP and 2 patients undergoing LF for cervical myelopathy with minimum one-year follow-up and average clinical follow-up of 1.7 months. LP was performed in those with neutral to lordotic C2 alignment and who did not comply of diffuse axial pain. Otherwise, LF was performed. Clinical outcomes included visual analogue score (VAS)-neck pain, VAS-total pain, neck disability index (NDI), short form 12, modified Japanese Orthopaedic Association (mJOA), and several radiographic parameters.

Results. VAS-neck did not worsen in LP (−.2, P =. .) and did improve in LF (−.2, P =. .). VAS-total improved significantly in both groups (LP −. ±.2, P =. . LP −. ±. P =. ). NDI improved in both groups, but was significant in only LP (LP decreased −.2.2, P =. . LF decreased . . . , P =. ). mJOA scores improved significantly in both groups (LP improved .2. , P =. . LF improved .2 . , P =. ). There was a small loss of cervical lordosis in both groups that was significant in LP (LP 2.2 loss, P =. . LF 2.2 loss, P =. ).

Conclusion. In a carefully selected group of myelopathic patients without significant diffuse axial pain preoperatively and appropriate sagittal alignment, laminoplasty did not lead to worsening axial neck pain, and it was associated with significant improvements in other clinical and myelopathy outcomes.

Although laminoplasty is not indicated in every myelopathic patient, this study exemplifies its efficacy as a non-fusion operation in the appropriately selected patient and assuages concerns regarding worsening axial neck pain in such patients following surgery.

Key words: axial neck pain, cervical kyphosis, cervical laminectomy and fusion, cervical laminoplasty, cervical spondylotic myelopathy, laminectomy and fusion, laminoplasty, neck pain, open-door laminoplasty, postoperative neck pain.

Level of Evidence: 2.

Cervical open-door laminoplasty (LP) has become an increasingly popular surgical treatment option for the posterior decompression of patients with multilevel cervical myelopathy. Through the creation of an opening trough and a contralateral hinge, open-door laminoplasty increases the volumetric area available for the spinal cord while better maintaining cervical alignment when compared with multilevel laminectomy alone. Compared with posterior laminectomy and fusion (LF), laminoplasty avoids all fusion-related complications and offers potentially shorter operative time, less blood loss, faster recovery, lower implant costs, lower complications, and similar rates of neurologic recovery.

Despite these advantages of laminoplasty, one commonly cited criticism is the potential development of either worsening or new onset axial neck pain postoperatively. The literature demonstrates that patients reporting significant axial neck pain following laminoplasty have lower health-related quality of life scores. Such concerns are often cited by surgeons who recommend alternative posterior approaches, such as LF over LP. However, it remains unclear from previous studies whether or not laminoplasty truly exacerbates axial symptoms, or whether those symptoms represent either a persistence or natural progression of spondylitis. In addition, proper patient selection is also an important consideration that has not been fully investigated in previous studies. Postoperative axial symptoms may be limited by avoiding...
laminoplasty in patients who have a substantial component of preoperative generalized axial pain, or in those who are likely to develop kyphosis. In addition, techniques to limit postoperative loss of lordosis such as C and C laminectomy rather than laminoplasty, avoidance of facet capsule disruption, meticulous repair of extensor muscles and fascia, and early postoperative extensor muscle rehabilitation protocols all likely play a role in prevention or limitation of neck pain following laminoplasty.

In the present study, we sought to determine whether laminoplasty is associated with worsening or new axial pain in a properly selected cohort of myelopathic patients by comparing pain and other clinical outcomes to a cohort undergoing laminectomy and fusion.

MATERIALS AND METHODS
Following institutional review board approval, data were retrospectively reviewed from a list of consecutive patients treated by the senior author. Our inclusion criteria for this study were patients of at least years of age on presentation, minimum of year of clinical and radiographic follow up from date of surgery, and those patients receiving treatment between January, 2 and March, 2. Patients with history of trauma, fracture, infection, congenital abnormality, or tumor were excluded. Patients were selected as appropriate candidates for a posterior cervical decompression if the compressive pathology spanned motion segments and the pattern of cord compression would allow for appropriate dorsal drift of the spinal cord after a posterior decompression (i.e., K-line positive). They were then further selected for cervical laminoplasty if they met two criteria: (1) diffuse or generalized axial neck pain was not a predominant or significant complaint although unilateral radiating neck pain could be a complaint and (2) upright lateral radiographs revealed a neutral to lordotic C2 sagittal angle. Those with a predominant complaint of diffuse or generalized axial pain, or those who demonstrated any amount of C2 kyphosis underwent laminectomy and fusion. In total, patients were included in the laminoplasty group, and patients were included in the laminectomy and fusion group. All laminoplasties were performed as plated, open-door operations. Laminectomy and fusions were performed with a combination of lateral mass, pars, or pedicle instrumentation as anatomically feasible based on preoperative imaging.

Data collected from retrospective chart review included the following: baseline demographic data, including age at time of surgery, sex, diagnoses of diseases, medical history, social history, previous surgical history, and surgical information including estimated blood loss (EBL), length of surgery (minutes), spinal levels, number of surgeries, previous surgeries, and length of hospital stay. Additional information gathered from clinical records included visual analogue score for neck pain (VAS neck), VAS for total pain (VAS total), neck disability index (NDI), short form (SF-) physical and mental component scores (SF- PCS, SF- MCS), and modified Japanese Orthopaedic Association (mJOA) scores. These measurements were collected preoperatively, and then at weeks, months, and 2 months postoperatively. mJOA was interpreted from the clinical notes by reviewers based on the standard mJOA questionnaire.

A radiographic analysis was conducted using measurements made from pre- and postoperative images at each available follow-up interval. Several measurements were made using sagittal radiographs, including C2 to C sagittal Cobb angle, T slope (the angle between a horizontal line and a line through the upper endplate of T), C2 sagittal vertical axis (SVA) (the distance between a vertical plumb-line dropped from the center of the C2 vertebral body and the posterior-superior corner of C), and forward pitch (FP) (the distance between a vertical plumb-line dropped from the center of the C2 vertebral body and the anterior-superior corner of C). Although C2 SVA and FP are very similar, we included FP because the anterior-superior corner of C is often more readily identifiable and less often obscured than the posterior-superior corner (Figure). The pre- and postoperative magnetic resonance imaging studies were also used to measure the axial canal diameter measured at most stenotic level (measured in millimeters) and the Miyaki Spondylosis score, which has been shown to be a reproducible method of objectively quantifying cervical spondylosis.

Figure. Cervical forward pitch a measurement from the anterior-superior corner of C to a plumbline dropped from the center of the C2 vertebral body.
TABLE 1. Baseline Characteristics of Patients Undergoing Laminoplasty (LP) and Laminectomy and Fusion (LF)

<table>
<thead>
<tr>
<th></th>
<th>LP (N = 85)</th>
<th>LF (N = 52)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at surgery, mean (SD)</td>
<td>61.48 (12.05)</td>
<td>62.04 (10.97)</td>
<td>0.78</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>37 (43.5%)</td>
<td>26 (50.0%)</td>
<td>0.46</td>
</tr>
<tr>
<td>Pre OP BMI, mean (SD)</td>
<td>29.97 (5.30)</td>
<td>30.21 (6.16)</td>
<td>0.81</td>
</tr>
<tr>
<td>Follow up (months), median</td>
<td>12.1</td>
<td>12.9</td>
<td>0.31</td>
</tr>
<tr>
<td>Pre OP mJOA, Mean (SD)</td>
<td>13 (3)</td>
<td>12 (3)</td>
<td>0.13</td>
</tr>
<tr>
<td>Pre OP NDI, mean (SD)</td>
<td>35 (18)</td>
<td>43 (20)</td>
<td>0.03</td>
</tr>
<tr>
<td>Pre OP SF PCS, mean (SD)</td>
<td>36.48 (10.66)</td>
<td>30.80 (9.83)</td>
<td>0.008</td>
</tr>
<tr>
<td>Pre OP SF MCS, mean (SD)</td>
<td>46.90 (10.10)</td>
<td>44.58 (11.78)</td>
<td>0.28</td>
</tr>
<tr>
<td>Pre OP VAS neck</td>
<td>1.8 (2.8)</td>
<td>3.3 (3.6)</td>
<td>0.031</td>
</tr>
<tr>
<td>Pre OP VAS total</td>
<td>4.6 (0.39)</td>
<td>5.4 (0.52)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pre OP Miyazaki, mean (SD)</td>
<td>18.30 (3.82)</td>
<td>18.36 (3.43)</td>
<td>0.94</td>
</tr>
<tr>
<td>Pre OP T1slope, mean (SD)</td>
<td>35.65 (9.92)</td>
<td>33.33 (11.15)</td>
<td>0.21</td>
</tr>
<tr>
<td>Pre OP C2–7 SVA, mean (SD)</td>
<td>31.15 (14.86)</td>
<td>36.04 (18.32)</td>
<td>0.09</td>
</tr>
<tr>
<td>Pre OP FP, mean (SD)</td>
<td>15.83 (17.49)</td>
<td>18.23 (19.31)</td>
<td>0.45</td>
</tr>
<tr>
<td>Pre OP axial spinal canal</td>
<td>6.0 (1.5)</td>
<td>6.1 (1.6)</td>
<td>0.41</td>
</tr>
<tr>
<td>Pre OP C2–7 angle, mean (SD)</td>
<td>12.7 (1.12)</td>
<td>4.0 (1.84)</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

SD indicates standard deviation; BMI, body mass index; mJOA, modified Japanese Orthopaedic Association; NDI, neck disability index; PCS, physical component score; MCS, mental component score; SVA, sagittal vertical axis; VAS, visual analogue score; LP, forward pitch.

Bold indicates statistically significant P < .05.

Statistical Analyses
Baseline and preoperative characteristics were compared between the study groups with a two-sided two-sample t test or Wilcoxon rank-sum test for continuous variables and with the chi-square test or Fisher exact test for proportions. To compare longitudinal outcomes between LP and LF, repeated-measures analyses were performed with a means model via the SAS MI ED, Cary, NC Procedure (version 9.3) providing separate estimates of the means by time on study (baseline and -year) and study group (LP and LF). The adjusted model-based means are unbiased with unbalanced and missing data, so long as the missing data are non-informative (missing at random, MAR).

All statistical tests were two-sided and unadjusted for multiple comparisons. VAS-neck pain data were available for a subset of LP and LF patients. Nonparametric methods were used to analyze this data to account for data distribution. Baseline pain scores (and pain at last follow-up) were compared between study groups by the Wilcoxon rank-sum test. Change over time within each study group was tested with the Wilcoxon signed-rank test.

RESULTS
Baseline Characteristics
Preoperatively, there were no significant differences in age, sex, body mass index (BMI), follow up duration, mJOA, and SF-physical component score. Pre and postoperative VAS total scores were available in all patients, and VAS neck pain scores were available in a subset of patients (LP patients and LF patients), with the average clinical follow up of months. There were significant differences in the preoperative NDI, SF-PCS, VAS neck, and VAS total with worse preoperative values in the LF group (Table 2).

<table>
<thead>
<tr>
<th></th>
<th>LP</th>
<th>LF</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operative levels</td>
<td>4.45 ± 0.748</td>
<td>5.73 ± 1.63</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Operative time (minutes)</td>
<td>122.3 ± 25.31</td>
<td>200.0 ± 71.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>EBL (mL)</td>
<td>97.5 ± 73.8</td>
<td>177.0 ± 134.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hospital stay (days)</td>
<td>2.62 ± 1.50</td>
<td>3.90 ± 2.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Deltoid Palsy</td>
<td>3</td>
<td>5</td>
<td>0.13</td>
</tr>
</tbody>
</table>

EBL = estimated blood loss.
The LF group had a mean of \( \pm \) levels fused, whereas the LP group had a mean of \( \pm \) levels decompressed (\( P \). Table 2).

In terms of radiologic parameters, there were no significant differences in Miyaaki spondylosis score, T slope, C2 SVA, forward pitch, or AP spinal cord dimension (Table ). The SVA had a trend towards a difference which was not significant (LP \( \pm \), LF \( \pm \), P \( \).). There was a significant difference in preoperative C2 lordosis (LP \( \pm \).2 LF \( \pm \), P \( \). ).

These results demonstrate that the LF group had worse baseline pain, disability, and overall physical function, as well as less cervical lordosis than the LP group, consistent with the fact that patients were not randomly but rather carefully selected to undergo either LP or LF based on preoperative criteria. However, the overall severity of myelopathy and radiologic evidence of spondylosis were no different between the two groups.

### Pain

VAS neck (a measure of the amount of pain located in the neck only) significantly improved at year in the LP group, from \( \) to \( \) (\( \pm \), P \( \). ) (Figure 2). VAS neck was very slightly less at year in the LP group, from \( \) to \( \), but the difference was not significant (\( \pm \), P \( \). ). Therefore, VAS neck pain scores did not worsen in either group.

VAS total (a measure of total pain throughout the body), however, significantly improved in both groups (Figure ). In the LF group, VAS total improved from \( \) preoperatively to \( \) postoperatively (LF \( \pm \). \( \pm \), P \( \). ). In the LP group, VAS total improved from \( \) preoperatively to \( \) postoperatively (LP \( \pm \), P \( \). ). Therefore, both procedures resulted in significantly less total pain in this population. Approximately, \% of patients ( / patients: 2 / in the LP and / in the LF patients) reported a VAS total score of ero at both baseline and at final follow-up.

### Other Outcome Measures

NDI significantly improved for the LP group from baseline to 2 months (\( \pm \), P \( \). , change of \( \pm \), P \( \). ). In the LF group, NDI also improved in LF but not in a statistically significant manner (\( \pm \), P \( \). , change of \( \pm \), P \( \). ). NDI significantly improved in both groups from baseline to 2 months (LP \( \pm \), P \( \). , change of \( \pm \), P \( \). ). In contrast, SF- PCS (LP \( \pm \), P \( \). , change of \( \pm \), P \( \). ) and MCS (LP \( \pm \), P \( \). , change of \( \pm \), P \( \). ) scores did not significantly improve in either group.

### Radiologic Measures

Radiographically, there was a small but statistically significant loss of lordosis in the LP group (LP \( \pm \), P \( \). , change of \( \pm \), P \( \). ). The LF group also lost a slight amount of lordosis, but this was not significant (LF \( \pm \), P \( \). ). The SVA increased significantly in the LP group (LP \( \pm \), P \( \). ) and decreased significantly in the LF group (LF \( \pm \), P \( \). ) (Table ).

### Perioperative Data

Operative statistics including operative time, EBL, and length of hospital stay differed between the two groups (Table ). The LP group experienced shorter operative time (LP \( \pm \), minutes, P \( \). ), less EBL (LP \( \pm \), mL, P \( \). ) and shorter hospital stays (LP \( \pm \), days, P \( \). ).

Complications did not differ between the groups. Each group experienced one postoperative wound complication,
both of which were wound infections that required repeat operation. The groups also did not differ with respect to postoperative deltoid weakness. Three patients in the LP group experienced postoperative deltoid weakness, while five patients in the LF group noted deltoid weakness (P = 0.3).

**DISCUSSION**

In the present study, we compared pain and other outcomes after laminoplasty versus laminectomy and fusion for cervical myelopathy. VAS neck pain scores actually decreased very slightly in the LP group at year postoperative, although not significantly. VAS total pain did improve significantly. At the same time, important clinical outcomes such as mJOA and NDI scores also improved significantly with laminoplasty.

Figure 5. Line graphs showing the differences in SF PCS (A), SF MCS (B), mJOA (C), and NDI (D) between preoperative and year follow scores in LF (blue) and LP (red) groups. mJOA indicates modified Japanese Orthopaedic Association NDI, neck disability index LF, laminectomy and fusion LP, laminoplasty PCS, physical component scores MCS, mental component scores.

LP was also associated with shorter operative times, less EBL, and shorter hospital stay, with no difference in the rate of perioperative complications such as infection or deltoid weakness. Because there were baseline differences between the LP and LF groups, and because patients were carefully selected to undergo a given operation based on criteria thought to make them better candidates for one procedure versus another, this study does not imply the superiority of one operation versus another in all myelopathy patients undergoing a posterior approach. However, we feel that in the appropriately selected and indicated patient namely, those without a predominant complaint of generalised axial pain but who do demonstrate neutral to lordotic cervical alignment laminoplasty improves clinical outcomes and, contrary to commonly cited concerns, does not worsen or exacerbate patient reported axial neck pain. One impediment to wider acceptance of laminoplasty has been the concern that it exacerbates or creates axial neck pain. Previous literature has failed to resolve this issue. As with all of spine surgery, indications are paramount for maximising outcomes, and we feel that our paper exemplifies the importance of reserving laminoplasty for patients without a chief complaint of diffuse or generalised axial neck pain, as well as appropriate upright neutral to lordotic alignment. Therefore, our finding that laminoplasty does not increase neck pain likely applies only to such an appropriately selected patient, and not necessarily to the general patient with myelopathy. However, in clinical practice, there are many myelopathic patients who do not have substantial axial pain and are otherwise suitable candidates or laminoplasty. We feel that these patients
are well served with a non-fusion operation like laminoplasty if a dorsal approach is deemed sufficient for neurologic decompression.

In this study, VAS neck pain scores demonstrated greater and significant improvement in the LF group versus LP. This finding reinforces the notion that fusion is more likely to improve spondylotic axial symptoms. Thus, in those myelopathic patients who present with significant axial pain, LF, or potentially an anterior operation, may be a better option than LP. However, even in the LF group, the improvement in VAS neck pain did not meet the yielded minimum clinically important difference (MCID) of 2. It is always important when counseling patients that relief of axial symptoms after surgery may not be predictable and incomplete, even with fusion-based operations. VAS-total did improve significantly in both groups (LP ± 2.2, P < 0.0001, LF ± 2.09, P = 0.0181), suggesting relief of neurogenic pain with spinal cord decompression.

Neck disability index, an instrument that exemplifies how neck pain and dysfunction affects a patient’s utility of life, improved significantly for laminoplasty patients (± 2.2, P < 0.0001), but not for laminectomy and fusion patients (± 2.09, P = 0.03). However, NDI still improved by more than the yielded MCID of 2 in both groups. SF-mental and physical component scores, which are perhaps less specific to patients undergoing cervical spine surgery, did not significantly change in either group. With respect to neurologic recovery, both the laminoplasty and laminectomy and fusion groups demonstrated a significant improvement in mJOA scores (LP 2.0 ± 0.2, P < 0.0001, LF 2.0 ± 0.2, P < 0.0001). This result is coincident with findings from prior investigations. Radiographically, there was a small, but statistically significant loss of lordosis in the laminoplasty group (2.2, P < 0.0001). However, it is important to consider that laminoplasty patients, as part of our selection criteria, had significantly more cervical lordosis preoperatively (i.e., they had more to lordosis to lose). Potential loss of lordosis following laminoplasty is a definite concern that should be factored into decision-making when considering laminoplasty versus alternative operations in a given myelopathic patient. C2 SVA and forward pitch are also important considerations in determining the suitability for laminoplasty in a given patient.

Notably, the amount of preoperative spondylosis, as measured by the Miyataki score, did not differ between the laminoplasty versus laminectomy and fusion groups. This finding is consistent with the observation that the severity of radiographic spondylosis does not necessarily correlate with clinical complaints of axial neck pain. Therefore, the amount of radiographic spondylosis should not be a contraindication to laminoplasty. Instead, we believe that appropriate criteria for laminoplasty should be based on clinical complaints of significant axial pain and global sagittal alignment. This study did not, however, examine the impact of other factors, such as spondylolisthesis.

While our study represents a large study comparing patients undergoing laminoplasty and laminectomy and fusion for cervical myelopathy, there are important limitations to consider. The retrospective nature of our study has inherent limitations, including selection bias and the possibility of differential loss to follow up. In this non-randomized series, patients were selected preoperatively by the treating surgeon to undergo either laminoplasty versus laminectomy and fusion based on a number of factors. These factors included the presence of substantial axial pain, as well as presence versus absence of lordosis. Thus, the LF patients had, for example, significantly less preoperative lordosis and worse axial neck pain scores preoperatively. Regardless, we do not feel that this limitation diminishes the primary finding of this study namely, that laminoplasty does not lead to worsening of axial pain in the properly selected patient. Clearly, however, there are patients who may be better suited to alternative, fusion-based operations.

CONCLUSION

In conclusion, the present study demonstrates the clinical efficacy of cervical laminoplasty in the appropriately selected myelopathy patient namely, those without a predominant complaint of general axial neck pain and who demonstrate neutral to lordotic sagittal alignment. In this population, laminoplasty led to a slight, non-significant decrease in neck pain, and a significant decrease in total pain. Importantly, laminoplasty was not associated with a worsening of axial pain. Additionally, other clinical outcomes such as the NDI and mJOA scores improved significantly.
after laminoplasty. Although laminoplasty is not indicated in every myelopathic patient, this study exemplifies its efficacy as a non-fusion operation in the appropriately selected patient and assuages concerns regarding worsening axial neck pain in such patients following surgery.

Key Points

- In a cohort that did not have significant diffuse axial pain preoperatively and had neutral to lordotic alignment, axial pain scores (VAS-neck) did not significantly worsen following laminoplasty.
- Overall pain scores (VAS-total) improved significantly in patients undergoing both laminoplasty and laminectomy and fusion.
- Patients undergoing laminoplasty had significant improvement in neck disability index, whereas those patients undergoing laminectomy and fusion had improvement that was not statistically significant.
- There was a small amount of lost lordosis in both groups, which was statistically significant in patients undergoing laminoplasty.
- In the appropriately selected patient, cervical laminoplasty is a non-fusion operation that does not worsen axial neck pain and achieves improvement in myelopathy as well as other clinical outcomes.

References


Reducing the Reductions: An analysis of Distal Radius Fractures in a Pediatric Emergency Department

Keith Orland, MD; Adam Boissonneault, MD; Andrew Schwartz, MD; Rahul Goel, MD; Nicholas Fletcher, MD, Robert Bruce Jr, MD

Background: Distal radius fractures in children with at least two years of skeletal growth remaining can tolerate moderate degrees of angulation and displacement and still have excellent clinical and radiographic outcomes. We hypothesized that there are a significant number of children under the age of 12 who undergo a closed reduction under conscious sedation in the emergency room for distal radius fractures within acceptable parameters for closed treatment without manipulation.

Methods: This was a retrospective review of consecutive children under years of age that presented to our pediatric emergency department between 2 and 2 with a distal radius (\~{}-ulna) fracture. Coronal and sagittal angulation, as well as degree of shortening were measured for all fractures. Reductions were deemed unnecessary if coronal and sagittal plane angulation measured less than 2° and shortening less than 2 cm on initial X-ray. Our financial analysis was performed using common CPT codes associated with distal radius fractures managed within the emergency department.

Results: 2 from the initial distal radius fractures were included for further analysis. Of the 2 patients, 2 patients (\~{}) underwent closed reduction with conscious sedation in the ED. The total time in the ED was 2 hours for patients who underwent reduction compared to 2.2 (\~{}) hours for those that did not (\~{}). Patients that were transferred from an outside facility underwent a reduction under conscious sedation of the time in contrast, only of non-transfer patients underwent a reduction (\~{}). Of the 2 patients that underwent reduction, (\~{}) were determined to be unnecessary. The mean maximal angulation in either plane for fractures that underwent appropriate reduction was (\~{}-

Conclusions: Our study demonstrated that 2 of distal radius fracture that underwent conscious sedation and closed reduction met appropriate parameters for closed treatment without manipulation. There is a significant difference in rate of unnecessary reductions particularly for children that transfer for care from an outside facility. Improved awareness of these acceptable deformities in young children has potential to limit number of children requiring manipulation with sedation, improve emergency room efficiency, and potential healthcare cost reductions up to 2 million.

Introduction

Fractures in children represent a significant proportion of pediatric Emergency Room (ER) visits in the United States, with forearm fractures being the most common of injuries (\~{}). Acute treatment pathways for pediatric forearm fractures generally include either splint immobilization in situ with Orthopaedic outpatient referral or closed reduction and splinting under conscious sedation in the ER. Although the latter treatment pathway is commonly performed, it is known to be associated with increased costs and complications\~{}. Closed reduction and casting in the ER has been shown to cost significantly more than in situ immobilization in the ED, and almost times as much as that when performed as an outpatient in the pediatric Orthopaedic office\~{}. To assist in clinical decision making regarding which fractures require a closed reduction procedure, multiple studies have defined acceptable parameters for fracture deformity that do not necessitate manipulation \~{}- \~{}. In general, larger angular deformities, particularly at the distal end of the forearm, are accepted for younger patients due to their increased bone remodeling potential.

In children less than years of age, bayonet apposition - fractures with overriding fragments - of the distal radius with displacement and less than 2 degrees angulation may still be treated without any formal closed reduction and have excellent radiographic and functional outcomes\~{}. Despite this, the decision to leave such a deformity in a young child can be met with criticism by patients, families, and ER providers alike.

We hypothesized that a significant number of children with distal radius fractures with acceptable alignment were undergoing unnecessary reductions with conscious sedation despite the evidence supporting in situ immobilization. Additionally, we felt there would be a correlation between patients that were transferred from outside hospitals and overtreating distal forearm fractures.
Materials and Methods

This was a retrospective case series of consecutive patients seen at a single institution pediatric emergency department between 2 and 2 for closed distal radius fracture with or without an associated ulna fracture. Patients were captured for review based on the ICD- codes S 2. A, S 2. A, S 2, A S 2. 2 A, S 2. A, S 2. 2 A, S 2. A, S 2. A, S 2. 2 A, S 2. A, S 2. A, S 2. A, S 2. 2 A, S 2. A, S 2. 2 A. Inclusion criteria were children ten years or younger who presented to our pediatric emergency department with an isolated metaphyseal distal radius fracture or a distal radius and ulna both bones forearm fractures. Exclusion criteria were any children that were admitted (n ) diaphyseal or proximal radius and/or ulna forearm fractures (n ), or physeal in ury of the distal radius (n ). Severely displaced or angulated ulna fractures that re uired reduction were also excluded from our analysis(n ). We also excluded any patients that were found to be improperly coded and captured from our ICD- ury (n 2). Any duplicate patients (n ) that had multiple emergency room encounters were only included once for statistical analysis. (Figure ).

Figure . Exclusion Criteria

Of the initial patients, there were 2 patients that were included for further statistical analysis. Clinical data was obtained via patients Electronic Medical Record including age, gender, and primary payor status. Total time in the emergency room was obtained by time stamps for admission and discharge from the emergency department. If a patient transferred from an outside facility or clinic, the transfer facility and county information was recorded. For children who underwent a fluoroscopically guided closed reduction, analgesia type was recorded (bier block/hematoma block/conscious sedation). If reduction was performed with conscious sedation, total sedation time was documented as was the medication(s) used for sedation and any associated adverse events during or after sedation.

Radiographic assessment of the 2 distal radius fractures were analyzed by three authors (AS, KO, RG) using standard electronic tools available in the Picture Archiving Communication System (PACS). Shortening, angulation, and the presence or absence of an ulna fracture were recorded for all fractures. Blinded intra and interobserver reliability was performed for validation of radiographic measurements. We defined any patient that underwent a closed reduction under conscious sedation as unnecessary as having shortening less than cm, or angulation 2 in the sagittal or coronal plane based on pre-existing literature.

Financial analysis for an episode of care of a distal radius fracture in the emergency department was completed with the use of CPT codes associated with closed reduction and manipulation. We obtained CPT cost data for initial uiry radiographs, IV medication for sedation, fracture care associated with manipulation as well as use of portable fluoroscopy machine.

Clinical data and raw radiographic measurements were used to determine means and standard deviations. Independent samples t-test were used to compare radiographic and clinical data between patients that underwent reductions and those that did not. Pearson’s chi-squared tests were used for categorical data to determine significance of transferring to reduction. Univariate logistic regression analysis was performed to determine odds for an unnecessary reduction dependent on transfer status. All statistical analyses were performed with Stata statistical software (StataCorp. 2 . Stata Statistical Software: Release . College Station, T : StataCorp LP.).

Results

Of the 2 patients that met our inclusion criteria were male and 2 were female. The mean age for the entire cohort of patients was 2 years ( years). For payor types, ( ) were privately insured and ( ) had Medicaid or were uninsured. Of the 2 distal radius fractures, (2) had an associated ulna fracture (Table ). These fractures ranged from buckle to complete ulna fractures. The overall rate of children who underwent conscious sedation in the ED was (2/2). Maximum angulation (coronal or sagittal plane) was 2.2 ( ) for fractures that were reduced, compared to (2) for those that were not reduced (P . ). There was a significant difference in time spent in the ED for children who underwent closed reduction . hours (2 hr) compared to 2.2 hours ( hr) for those who did not (p . ).

The overall rate of transfer from an outside facility was 2 ( /2). Patients that were transferred from an outside facility underwent a reduction under conscious sedation ( / ) of the time. In contrast, of non-transfer patients ( / ) underwent a reduction with conscious sedation (p . ) (table 2). There was no significant correlation between patient insurance status and transfer from outside facility (p . ).
When considering only patients that underwent closed reduction with conscious sedation in the ED, 2 of 2 (100%) were determined to be unnecessary reductions as previously defined. The mean maximum angulation of the radius in either plane for fractures that underwent appropriate reduction was 0 (0) compared to 0 (0) for fractures that were unnecessarily reduced (p = .). There was no significant difference in mean shortening of distal radius fractures between those appropriately and unnecessarily reduced, 0 cm versus 0 cm respectively (p = .). Of the patients that underwent an unnecessary reduction, 2 (100%) were transfers from an outside facility. Using a logistic regression model, patients that presented as transfers were twice as likely to undergo an unnecessary reduction (OR 2.0, CI: 1.0-3.9, p = .02). For transfer patients that underwent a closed reduction, the unnecessary reduction rate was 2 (100%), when compared to 2 (0%) for non-transfer patients that underwent a closed reduction (p = .02) (Table 1).

We also investigated the events associated with conscious sedation for children who underwent closed reductions. Total mean sedation time was 2 minutes (2 minutes). The overall sedation complication rate in our cohort of patients was 2 (100%). There was no significant difference in overall complication rates for patients that underwent appropriate versus unnecessary reductions, 2/2 versus 2 (0%) respectively (p = .). Severe complications in our cohort included stridor and hypoxia. There was a rate of severe complications in our patients (of 2).

Financial analysis demonstrated significant cost to closed reduction and manipulation under conscious sedation in the emergency department, equating to . This cost includes initial radiographs of the forearm and wrist, the cost of sedation, the use of portable fluoroscopy machine for reduction, as well as the fracture charge based on CPT codes for each. This is nearly eight times as costly when compared to outpatient cast immobilization.

Discussion

Distal radius fractures of the forearm are the most common fracture type, representing nearly 2 of all fractures. Using epidemiologic estimates for children under the age who all had excellent functional and radiographic outcomes with closed treatment without reduction2. They showed in their series that obtaining gentle correction of angulation within degrees without analgesia was not difficult during in-office cast application.

Our study has shown that 2 of all distal radius fractures that underwent closed reduction with sedation in our emergency department could have potentially been managed with in-situ immobilization and gentle correction in office. This would have reduced the family and patient’s ED visit by nearly 2 hours in addition, it would improve the ED workflow by reducing the personnel and resources required to run a sedation. In a similar study by Do et al. all patients in their series had no significant clinical deformity or residual functional deficit when redisplaced distal radius fractures were treated without remanipulation. On average, angulation for unnecessarily reduced distal radius fractures in our series was 2, falling within the limits of their defined safe criteria of degrees angulation to heal without any clinical deformity. With reported rates of redisplacement of 2 - after initial manipulation, improving awareness of remodeling potential alone for these fractures can limit the need to closely monitor these in 2 years for the risk of redisplacement2.

Manipulation under conscious sedation carries both significant benefit and risk. While IV sedation is effective in pain control and muscle relaxation, several reports have shown adverse events associated with sedation to be near, with serious complications including hypoxia and strider to be as high as 2. Our study is in line with this previous data, with a total cohort sedation complication rate of ., with of them qualifying as serious events.

In addition to decreasing total time in ED and reducing the risks associated with manipulation and sedation, a shift in this acute treatment algorithm has significant potential cost saving for healthcare payors and the healthcare system in general. Financial analysis revealed the cost for a closed reduction and manipulation under conscious sedation in our emergency department to be . This is similar to previously published data on average cost of ED Fracture management of . Significant cost savings have been shown when comparing closed reduction and manipulation in the ED versus splinting and outpatient referral for moderately displaced distal radius fractures2. Our study shows nearly an eight-fold increase in cost when comparing office visit with cast immobilization to closed reduction and sedation in the emergency department. Of all presenting distal radius fractures in our series, were reduced unnecessarily (2/2). With an estimate of 2, distal radius fractures in children under the age who all had excellent functional and radiographic outcomes with closed treatment without reduction2. They showed in their series that obtaining gentle correction of angulation within degrees without analgesia was not difficult during in-office cast application.

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would equate to potential healthcare savings of nearly 2. While this figure is just an estimate, it is indicative of the significant cost and resources associated with these fractures. With improved treatment algorithms, there is substantial opportunity for equivalent outcomes with reduced cost.

Our institution is a large, tertiary referral pediatric hospital in a large metropolitan city. Transfers from outside institutions to our facility are not uncommon since it is a non-profit, academic institution with a vast array of subspecialists. In general, patients with public or no insurance, or those requiring sub-specialist or higher acuity care, have high rates of transfer from one facility to another. Our data showed no significant difference in transfer rates based on private vs public/uninsured. There was a significant difference in the rate of reductions for children that were transfer patients compared to non-transfer, respectively. When comparing the unnecessary reductions, children that transferred were twice as likely to undergo an unnecessary reduction, independently based on transfer status alone. To our knowledge, this is the first study identifying rates of reduction for patients that transfer for fracture care. The discrepancy in overall reduction rates and rates of unnecessary reductions is likely in part due to the expectation created by staff as well as family of a patient with a displaced fracture. Appropriate phone consultation with an on-call orthopedist prior to transfer could save significant time, cost, and hospital resources.

This study does have its limitations. The retrospective nature of this study alone is a limitation. We obtained our patient data set via a query of common ICD codes, though this is likely not exhaustive and may not capture all distal radius fractures that presented to our institution during this time period. We found that 2 patients were not coded correctly during our initial review, which suggests that there are certainly several distal radius and distal radius/ulna fractures that were not captured in this review on miscoding alone. Secondly there is potential observer bias and nonobjective evaluation of radiographs amongst the authors. Our attempt in mitigating this bias, however, was by blinded inter-observer reliability testing which proved to be excellent.

In conclusion, our data suggests that a significant number of children presenting to the emergency department with distal radius fractures could be immobilized and seen in office instead of undergoing conscious sedation and manipulation, when you take into consideration their age and fracture characteristics. With distal radius fractures representing one of the most common causes for pediatric ED visits in the United States, refining the treatment algorithm for such a prevalent injury boasts significant opportunity to provide value-based healthcare going forward. With continued education towards hospital staff, family, and patients regarding the remodeling potential of these fractures, Orthopaedic physicians have the potential to improve emergency room care for children presenting with distal radius fractures as well as drastically reducing the cost associated with these injuries.
Table 2: Characteristics of Reduced vs Non-Reduced Cohorts

<table>
<thead>
<tr>
<th></th>
<th>Reduced (n=142)</th>
<th>Non reduced (n=116)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time in ED</td>
<td>4.3 hr ± 1.2 hr</td>
<td>2.2 hr ±1.3hr</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Maximum Angulation</td>
<td>26.2° (±11.7 °)</td>
<td>9.1 °(±8.2 °)</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Transfer</td>
<td>57/61 (93%)</td>
<td>4 /61 (7%)</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Non-Transfer</td>
<td>85/197 (43%)</td>
<td>112/197 (57%)</td>
<td></td>
</tr>
</tbody>
</table>

Table: Characteristics of Appropriate and Unnecessary Reduction

<table>
<thead>
<tr>
<th></th>
<th>Appropriate</th>
<th>Unnecessary</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Angulation</td>
<td>30.6 ° (±10.3 °)</td>
<td>13.9 °(±4.5&quot;)</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Shortening</td>
<td>26.2° (±11.7 °)</td>
<td>0.3 (± 0.5) cm</td>
<td>p=0.306</td>
</tr>
<tr>
<td>Transfer</td>
<td>63% (36/57)</td>
<td>37% (21/57)</td>
<td>P=0.026</td>
</tr>
<tr>
<td>Non-Transfer</td>
<td>80% (68/85)</td>
<td>20%(17/85)</td>
<td></td>
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</tbody>
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REFERENCES


Distressed Community Index as a Composite Score for Social Determinants of Health Predicts Loss to Follow Up and Readmission in Orthopaedic Trauma Patients

Andrew Schwartz, MD; Alexandra Ernst, BS; Wesley Brown, BS; Tony Huynh, MD; Ruth Park, MD; Mara Schenker, MD

Abstract

Introduction
Trauma care ranks second in US health expenditures, accounting for approximately 2. billion in 2022. As healthcare reimbursement transitions toward value-based models, individualizing reimbursement for patient factors may enhance the sustainability of this approach. Medicare payments have been risk-adjusted for demographic and clinical diagnoses (age, gender, comorbidities), however, recent evidence supports adding socioeconomic risk factors. To examine socioeconomic distress or wellbeing, the Economic Innovations Group has produced a Distressed Communities Index (DCI) that incorporates metrics into a standardized quantification of economic health. We sought to evaluate an interplay between DCI, healthcare utilization and complications in an orthopaedic trauma population.

Materials and Methods

Patients aged - presenting for a new surgically-treated orthopaedic injury to a large, American College of Surgeons-designated level I, urban trauma center were enrolled. Socioeconomic status, environment/housing, and health care access/utilization were surveyed on admission. The DCI score was derived from the survey, and categorized into quintiles: prosperous, comfortable, mid-tier, at-risk, and distressed. Each of the metrics were also subanalyzed ed. Follow-up surveys were administered, and medical records were reviewed for any surgical or non-surgical complication following initial hospitalization. Loss to follow-up was defined as never returning to the orthopaedic department for an outpatient appointment after discharge.

Results

Of patients live in a zip code categorized as distressed by DCI (compared to of Atlanta population). Patients living in the most distressed communities were associated with African American race (p < .05), living alone (p < .05), being religious (p < .05), being unemployed or disabled (p < .05), and concerns over safety within their neighborhood (p < .05). Loss to follow-up was associated with living in a community with low rates of high school graduation (p < .05), Hispanic populations (p < .05), addiction to alcohol or illicit drugs (p < .05), religious beliefs influencing medical decisions (p < .05), not owning a cell phone (p < .05), or not having access to internet (p < .01). Loss to follow up and distressed community liver were both associated with readmission (p < .01 and p < .05 respectively). A multivariate model, controlling for age, race, gender, comorbidities, and severity, found that for every -point increase in DCI, patients are.2 times more likely to never come to clinic after discharge (p < .01).

Discussion
This prospective study provides novel insight into nonmedical drivers of outcomes in the orthopaedic trauma population and is the most comprehensive aggregation of social risk factors in any surgical population. In the orthopaedic trauma population, composite measures of economic health, based on location of residence, are predictive of loss to follow-up. Measures to promote postoperative care after orthopaedic trauma in distressed populations may facilitate interventions to prevent or minimize costly postoperative complications. Further, our study supports DCI is a valid tool to augment the growing body of data on risk-adjusted reimbursement models.

INTRODUCTION
Trauma care is the second greatest cost contributor to US health expenditures, accounting for approximately 2. billion in 2022. As healthcare transitions towards value-based models, there is a need to account for patient differences when measuring quality and calculating payments. Since 2012, Medicare payments have been risk-adjusted for demographic and clinical diagnoses (age, gender, co-morbidities), however, recent evidence supports adding socioeconomic risk factors. In 2014, Congress passed the IMPACT Act (Improving Medicare Post-Acute Care Transformation Act) that required the Department of Health and Human Services to assess any relationships between social risk factors in patients and physician performance within current federal compensation paradigms. Social risk factors were associated with poor outcomes, and providers caring those with the greatest number of social risk factors performed the worst on standard quality metrics, resulting in critical safety-net systems incurring financial penalties assessed by our current value-based model. Currently, Centers for Medicare and Medicaid Services (CMS) lacks social determinant data including wealth, acculturation, gender identity, sexual orientation, living alone, level of social support and other environmental factors (Figure 1).
The Economic Innovation Group (EIG) validated a Distressed Communities Index (DCI) database to quantify economic and social disparities by calculating a score ranging from 1 to 7, based on community factors including education level, employment, housing, ob potential, business development, poverty rate and median income. DCI generates a current pro section of distress level within a IP code, county or congressional district, where each locale is classified by quintile as prosperous, comfortable, mid-tier, at-risk, or distressed.

Social determinants of health are being studied in various patient populations, including general surgical and trauma patients. Trauma is one of the strongest drivers of racial disparities in mortality. Further, trauma is not a random occurrence, with a disproportionate impact on several populations: psychiatric illness, substance use disorders, income and low education level are all associated with sustaining traumatic inuries of all types and elective orthopaedic procedures. Further, the downstream impact of trauma affects at-risk populations disproportionately. Several studies have demonstrated an exacerbation of pre-injury chronic pain and psychiatric illnesses after surgical treatment for trauma. Active smoking and uncontrolled diabetes, which are more prevalent in distressed communities, increase the risk of surgical site infection. From a social standpoint, education level, age, employment, and number of inuries affects a patient’s ability to comprehend and safely comply with postoperative instructions.

This raises the concern that socially distressed patients are both more likely to experience orthopaedic trauma, and also more likely to have a complicated postoperative course. Social risk factors contributing to health disparities and poor outcomes needs to be assessed at several levels: individual patient factors, the patient’s environment, their healthcare provider, the health system in which they seek care, and non-medical, societal influences around their treatment. Current methods to measure uality of care around orthopaedic trauma can vary widely in both accuracy and reliability, despite being a labor- and time-intensive endeavor, potentially offering room for improvement to optimize patient care. As such, orthopaedic trauma surgeons providing care to the highest-risk populations are potentially incurring penalties despite providing life-saving treatments. Thus, we propose that value- and utility-driven reimbursement metrics would benefit from a rapid assessment of social, non-medical determinants of health. Further, early identification of patients with known non-medical drivers of poor postoperative outcomes may facilitate cost-effective interventions to maximize long-term uality in these populations. This prospective study aims to implement DCI as a rapid metric to risk-stratify patients according to their social determinants of health after orthopaedic trauma.

MATERIALS AND METHODS

Patient Population
Study participants were recruited on initial admission from the emergency department a high-volume, high-acuity, government-funded, urban, American College of Surgeons-designated Level trauma center. Inclusion criteria were age over years, English language fluency, and suffering from at least one new orthopaedic injury requiring at least one same-admission orthopaedic procedure including surgical treatment of fractures or dislocations penetrating inuries septic arthritis or oint soft tissue injuries.

Exclusion criteria included the inability to autonomously consent as a result of any acute or chronic medical or cognitive condition. Vulnerable populations were also excluded from enrollment, which included incarcerated patients or those without legal decision-making autonomy.

Consent
This study was approved by our institutional review board. Informed consent was obtained verbally with an electronic consent form. Patients were given time for clarification and offered the right to refusal to participate at any time point in the study. There was no form of compensation for participants.

Study Design
The study is a prospective cohort design and included the initial hospital stay after inury and postoperative follow-up as dictated by need for wound care, radiographic assessment of healing, and or changes in weight-bearing recommendations. The complete survey (described below) was administered by a study team member during initial inpatient stay, and a condensed survey was employed at postoperative clinic appointments. Additional data collection included evaluation of the institutional medical record, an institutional trauma registry database monitored daily by dedicated hospital staff, and the EIG DCI database. Patients who were unsure of their home ip code provided their current address, which was cross-referenced to obtain the ip code.

Independent Variables
The survey comprised of data points that were adapted from standardized questionnaires from the Centers for Disease Control (CDC) 2 , National Institute of Health (NIH)2, and World Health Organisation (WHO). Further, we administered the PHQ-2 and PC-PTSD-2 standardi ed and validated depression and post-traumatic stress disorder screening tools, respectively. The NIH tobacco surveillance tool2 and opioid use disorder DSM-V diagnostic criteria2. We also collected the Injury Severity Score (ISS), a sum of squares of the highest abbreviated inury score (AIS) codes in each of the three most
severely inury ISS body regions, ranging from to . . . . ISS body regions include head/neck, face, chest, abdomen, extremities, and external. To quantify patient’s comorbidities, we used the modified Frailty Index (mFI), an average of variables modified from the Canadian Study of Health and Aging Frailty Index (CSHA-FI).

**Primary Outcome**
Loss to follow up is the primary outcome of interest, analyzed through three metrics: patients who never present for scheduled ambulatory clinic visits after surgery, patients who did not attend an appointment after the first postoperative days, and the number of days between discharge and the patient’s last follow up appointment. These were then compared to number of readmissions and readmissions specifically related to the primary orthopaedic in ury.

**Secondary Outcome**
The relationship between DCI and patient demographics and socioeconomic metrics was calculated in order to validate DCI as a surrogate for social determinants of health.

**Statistical Analysis**
SPSS was used for all statistical analysis. Descriptive statistics were performed to assess the patient population, assess kurtosis and skewness, and evaluate for collinearity. Based on skewness and kurtosis, DCI was considered to be normally distributed. Chi-square test, two-tailed T-tests, and one-way ANOVA tests were conducted to evaluate associations between participant characteristics and outcome variables. Logistic and linear regression were both performed to build models for the various outcome variables. ISS, BMI, gender, race, MFI, education and age were used for controls when modeling.

**Data Safety and Management**
All patient data was collected through RedCap and met all HIPAA patient privacy and security requirements with a password protected, encrypted database only accessible to active study team members.

**RESULTS**

**DCI and patient demographics**

Patients were enrolled from May to August, . . . . DCI score ranges from to . . . . (2)Caption), dividing the normally distributed cohort between the three most prosperous and two most distressed quintiles, at-risk and distressed. Examining the means for the metrics of DCI by quintile indicate increasing distress throughout the metrics (Table ).

When comparing demographic factors and mean DCI, there was no significant difference between genders (p . . .), marriage/partnership status (p . . .), age (p . . .), or BMI (p . . .) (Table 2). African American patients (2.2 2.2) and Hispanic patients (2.2 2.2) had a higher mean DCI than other races and ethnicities (p . . .). No significant difference was found in mean DCI when examining tobacco use, illicit drug use, alcohol consumption, opioid prescriptions misuse and prior addiction history (Table 2). However, patients who went to the ED in the past six months because of pain had a higher mean DCI (2 vs. . p . . .).

There was no significant correlation between DCI and patient’s frailty, as measured by mFI (Table 2). Average DCI was similar in those with positive depression or PTSD screenings and those without (p . . and p . . . respectively). There was no significant difference in mean DCI among in ury type or mechanism and there was no correlation between DCI and in ury severity score (ISS).

**Relationship between DCI and socioeconomic factors**

Those that are religious had a higher mean DCI (. . . vs . . . 2) (Table 2). Higher mean DCI was associated with not owning a car or having access to the internet (p . . and p . . . respectively). Unemployed and disabled patients had a higher average DCI as well (. . vs. . . 2) (p . . .). There is a significant difference in DCI between those who live alone (. . . 22) and those that do not live alone (. . . 2) (Table 2). The mean DCI between different types of health insurance is also significantly different (p . . .) Higher mean DCI was associated with patients living in unstable housing (. . . vs. . . . 2 2 2 . . .). There is a significant difference in DCI between those that feel safe in their neighborhood (. . . 22) and those that do not feel safe (. . . 22) (p . . .).

**Patient Follow-Up**

The mean follow-up in clinic was days ( . ) ranging from to . . . . days between their surgery and their most recent clinic appointment. 2 patients never made a follow up appointment or communicated with the orthopaedic department in any way post-discharge. 2 (2.2) did not return to clinic after days, (2.2) after days, and ( . . ) after days. Lack of cell phone or internet access was associated with never following up after discharge (p . . and, p . . 2 , respectively) (Table ). The relative risk of not returning to clinic is 2.2 times greater when a patient does not have a car (p . . .). Having a yearly income less than , having less than in one’s savings account increased the risk of not coming to clinic by and times, respectively (p . . and p . . .).

Substance use also plays a significant role in patients never coming to clinic after their hospitalization. History of substance use disorder (p . . 2) and treatment for substance use disorders (p . . .) are both significantly associated with never returning to clinic after discharge. Loss to follow-up was associated with living in a community with low rates of high school graduation (p . . .) and Hispanic populations (p . . .). Not attending scheduled appointments after days was significantly
associated with many of the same variables as the loss to follow up outcome variable (Table ). Being discharged to a skilled nursing facility (SNF) increased the risk of never coming back to clinic by 2 times (p .). Additionally, being discharged to a SNF was associated with 2 times greater risk of not returning to clinic after days (p .2).

Primary Outcome
In unadusted linear regression, patients in the top of distressed communities have a . times greater chance of not returning to clinic after discharge (p .). After risk adustment with clinical and patient factors, DCI was a significant predictor to four outcomes including never returning to clinic, loss to follow up after days, loss to follow up after days, and readmission related to the primary orthopaedic in uary (Table ). When comparing two ad cent DCI uintiles, the odds of never coming to clinic after discharge is . times greater in the more distressed uintile (p .). The most distressed uintile has .2 times higher odds of not coming to clinic after discharge than the most prosperous DCI uintile. This trend continues through the follow up period, the th uintile is . times more likely to not come to clinic after days than the st uintile (p .2) (Figure 2).

Secondary Outcomes
In chi-s uare analysis, patients who live in the most distressed communities have a . greater risk to be readmitted for their initial orthopaedic in uary then patients living in other areas (p .). When adust ing for risk factors, DCI uintile was a significant predictor of readmission due to the primary orthopaedic in uary or uncontrolled pain from the in uary (Table ). Patients in one ad cent, higher uintile had 2. times higher odds of being readmitted than a patient in the one ust below (p .2). When comparing the odds between the 2nd and th uintile, those in the more distressed uintile had a . greater chance of readmission.

The mean number of readmissions per a patient is significantly higher in patients who never came to clinic and those that stopped attending clinic after days (p . and p ., respectively). In unadusted linear regression, examining the number of readmissions a patient had in the past nine months, never coming to clinic was not statistically significant. However, after risk adustment, loss to follow up became a significant predictor of increased readmission rates (Table ).

DISCUSSION
Our findings demonstrate that DCI is a valid predictor of poor outpatient follow up and readmission after orthopaedic trauma. Increased level of communal distress was associated with never presenting for initial follow up, even for standard suture removal, and an insufficient duration of follow up to properly monitor for early signs of complications, progression of bony healing, and safe advancement of weight-bearing status for fracture care. Further, we have successfully validated DCI as a rapidly applicable surrogate for an orthopaedic trauma patient’s social health. A high DCI, indicating greater levels of distress in the patient’s ip code, was closely associated with living alone, being unemployed, and feeling unsafe in their community.

The patients in the more distressed communities have a higher proportion of minorities races and ethnicities, have strong religious beliefs, live alone and are single. In addition, those in the most distressed communities are more likely to have unstable housing and not have access to a car or the internet. Prior to enrollment in the study, patients with higher DCI were more likely to go to the ED due to pain. In unadusted analysis, patients in these two high risk uintiles are greater than .2 times more likely to be readmitted related to their primary orthopaedic in uary and nearly times more likely to never come to clinic after being discharged. As such, DCI, a marker of a community’s distress level, seems to be a valid application of the appraisal an individual’s socioeconomic, non-medical drivers of worsened postoperative outcomes after orthopaedic trauma.

Patients that never returned to clinic are more likely to have a prior alcohol or substance use disorder, have less than in savings, make less than a year, and do not own a car, cellphone or internet. Those who did not return to clinic are more likely to not feel accepted in their community. Being placed in a skilled nursing facility increased the risk of never returning to clinic by 2. times. In unadusted and adusted analysis, loss to follow-up is a valid predictor of readmission rates. When controlling for gender, race, age, BMI, comorbidities, and ISS, DCI was a significant predictor for loss to follow up and readmission due to the primary orthopaedic in uary. For every DCI uintile, a patient is over . times less likely to return to present to clinic after discharge and 2. times more likely to re uire a hospital readmission. Again, we see that a patient’s DCI seem so to be more predictive of loss to follow up then any single social risk factor alone. DCI is a useful summative surrogate for a patient’s overall social wellbeing, particularly with known factors that have been previously shown to be associated with loss to follow-up.2

DCI has a high-fidelity relationship with a patient’s social demographic predictors of outcomes after orthopaedic trauma, greater than that of any individual demographic features. Interestingly, DCI is not associated with a patient’s comorbidity burden yet is highly associated with dynamic socioeconomic demographics and composite markers of an available support structure. This also indicates a relative patient homogeneity within a ip code, likely representing an interplay between the factors that resulted in a patient’s place of residence, and the influences of the culture around them. Unfortunately, prior literature shows a loss to follow up being associated with more ED presentations and more complications.2 Thus, DCI is predictive of a postoperative course that carries both high clinical risk to the patient, and the potential for significant resource utilization by a hospital system. This is particularly
troubling given the current push for a value-driven care system, when our most distressed patients were more severely ured and less likely to be have a third-party payer to fund their expensive orthopaedic care.

Limited research within orthopaedic trauma or other subspecialties have examined social determinants of health, often not addressing many of the overarching categories. Orthopaedic trauma research has focused on comorbid risk factors such as obesity, diabetes and smoking related to fracture incidence and surgical site infections. Elective procedures including joint arthroplasty and spine, examined relationships between psychiatric illness, functional scores, pain and post-operative outcomes. Emotional and mental health related to pain and function has been studied in general trauma surgery. However, as additional work continues to investigate the often treatable or optimizable factors, cognitive, and emotional risk factors for negative outcome, it is critical to consider non-medical factors that can contribute to postoperative course differences in two patients with similar bills of health.

In a prospective method, these results assess socioeconomic status, substance use, social support, race, religion, gender and more looking beyond functional status and pain level. In response to the IMPACT Act and CMS, the National Academy of Sciences, Engineering and Medicine (NASEM) evaluated social risk factors negatively impact patient outcomes, physician performance and hospital metrics when controlling for other variables including injury, comorbidities and healthcare specific metrics. Our findings reflect studies in general surgery and cardiothoracic surgery, patients in the top 2 distressed communities according to DCI were associated with increased healthcare cost and post-operative complications. However, the highly predictive nature of DCI of a patient’s social determinants of post-orthopaedic trauma course also offers an opportunity for improvement. Because DCI is a snapshot of a small geographic region and the people who reside there, it offers a small catchment area to enact change. Mobile crisis units have proven effective at keeping another marginalized group, psychiatric patients, from experience exacerbations, while doing so cost-efficiently. Thus, not only does DCI offer an easily calculated measurement of a patient’s social risk, it also offers a narrow geographic region to effect change on our findings through local outreach.

Several limitations are present in this study, common to many prospective cohort studies. Subject bias in who agreed to be a part of this study, recall bias from what patients chose to share, and collection bias with multiple researchers visiting patients. Examining loss to follow increases reporting bias since social risk factors were not assessed over time from the patient and only electronic medical were used to assess outcomes and reasons for loss to follow up.

CONCLUSION

Health equity cannot be achieved if healthcare providers, systems, and government agencies do not acknowledge how non-medical social determinants of health affect patients in a multifaceted way. The study shows that DCI is a comprehensive metric for social risk factors and is a valid predictor in loss to follow up and readmission. This is the first study of its kind to study all aspects NASEM outlined as possible predictors of poor patient outcomes and healthcare quality metrics. This study supports the previous national recommendations to incorporate social determinants of health into value-based payment programs. Our data suggests that DCI is not associated with comorbidity burden in our population. As such, a comprehensive quantification of a patient’s risk factors for loss to follow up and readmissions requires data presented in this study to be combined with the growing body of literature assessing the risk of a patient’s frailty to increase the predictive value of patient characteristics. However, our data can be used not only to highlight patients at risk for poor surgical outcomes and high resource utilization, but also merit consideration for risk-stratified reimbursement scheme. As there is a growing body of literature on the medical and toxic risk factors for a poor postsurgical outcome, it is also crucial to identify the non-medical and potentially actionable drivers of an equally problematic result. We propose routine inclusion of DCI when quantifying a patient’s pre-ury risk to facilitate continued care, particularly within the context of offering a highly local ed region to maximi e outreach.

Statement on DCI

The findings expressed in this publication are solely those of the authors listed above and not necessarily those of The Economic Innovation Group. The Economic Innovation Group does not guarantee the accuracy or reliability of, or necessarily agree with, the information provided herein.
Figure 1. Distribution of Distressed Community Index

![Distribution of Distressed Community Index](image1)

Figure 2. Odds ratios for selected outcomes by DCI quintile

![Change in Odds Ratio by difference in DCI quintile](image2)
Table 1.
Components of Distressed Community Index (DCI) by quintile

<table>
<thead>
<tr>
<th>Distress Score</th>
<th>Quintile 1 (N=12)</th>
<th>Quintile 2 (N=24)</th>
<th>Quintile 3 (N=22)</th>
<th>Quintile 4 (N=40)</th>
<th>Quintile 5 (N=34)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing vacancy rate (%)</td>
<td>6.58 ± 1.94</td>
<td>7.73 ± 1.61</td>
<td>9.78 ± 3.29</td>
<td>14.57 ± 3.18</td>
<td>21.76 ± 6.76</td>
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<tr>
<td>Poverty rate (%)</td>
<td>9.13 ± 2.65</td>
<td>15.10 ± 5.86</td>
<td>16.33 ± 2.19</td>
<td>23.53 ± 4.02</td>
<td>31.48 ± 7.77</td>
</tr>
<tr>
<td>Median income ratio (%)</td>
<td>156.37 ± 18.79</td>
<td>114.23 ± 14.89</td>
<td>98.97 ± 7.08</td>
<td>82.97 ± 8.45</td>
<td>62.92 ± 15.86</td>
</tr>
<tr>
<td>Change in employment (%)</td>
<td>17.03 ± 9.17</td>
<td>18.97 ± 11.84</td>
<td>10.02 ± 15.75</td>
<td>12.23 ± 10.82</td>
<td>6.55 ± 10.23</td>
</tr>
<tr>
<td>Change in establishment (%)</td>
<td>11.50 ± 3.01</td>
<td>8.00 ± 8.88</td>
<td>8.50 ± 4.94</td>
<td>7.19 ± 5.62</td>
<td>-1.05 ± 5.72</td>
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<tr>
<td>Adults not working (%)</td>
<td>21.89 ± 4.94</td>
<td>24.92 ± 3.25</td>
<td>28.88 ± 2.13</td>
<td>31.68 ± 3.49</td>
<td>38.42 ± 6.44</td>
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<tr>
<td>No high school degree (%)</td>
<td>6.56 ± 2.20</td>
<td>11.02 ± 3.16</td>
<td>12.78 ± 3.78</td>
<td>14.21 ± 5.41</td>
<td>17.07 ± 4.48</td>
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<tr>
<td>Total population (%)</td>
<td>31650 ± 23889</td>
<td>38969 ± 17834</td>
<td>44328 ± 14707</td>
<td>38752 ± 18479</td>
<td>37726 ± 16761</td>
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</table>

*a* average median income over state median income  
*b* change over a 5 year period (2006-2012)  
*c* from 2006-2012
<table>
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<tr>
<th>Variable</th>
<th>p-value</th>
<th>p-value</th>
<th>Variable</th>
<th>p-value</th>
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<td>Age&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.13</td>
<td>0.132</td>
<td>Internet in the home</td>
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<td>BMI&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.094</td>
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<td>Male</td>
<td>56.29 (25.04)</td>
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<tr>
<td>Gender</td>
<td></td>
<td></td>
<td>Female</td>
<td>63.75 (25.55)</td>
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<td></td>
<td></td>
<td></td>
<td>Male</td>
<td>56.29 (25.04)</td>
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<td>Race</td>
<td></td>
<td>0.01</td>
<td>Own car</td>
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<td>Male</td>
<td>56.29 (25.04)</td>
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<td>Female</td>
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<td>Depression screen</td>
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<td>Positive</td>
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<td>PTSD screen</td>
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<td>Health insurance</td>
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<td>59.32 (24.68)</td>
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<td>Uninsured</td>
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<td>Positive</td>
<td>58.83 (26.98)</td>
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<td>Religious</td>
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<td>0.006</td>
<td>Live alone</td>
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<td>Negative</td>
<td>46.15 (25.83)</td>
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<td>Dual Eligible</td>
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<td>61.76 (24.75)</td>
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<td>Relationship status</td>
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<td>Single</td>
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<td>Married</td>
<td>52.63 (24.25)</td>
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<td>ISS&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>High school or less</td>
<td>61.66 (25.42)</td>
<td></td>
<td>mFI&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>Some college education</td>
<td>54.73 (25.03)</td>
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<td>Injury characteristic</td>
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<td></td>
<td>0.001</td>
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<tr>
<td>No</td>
<td>56.41 (25.11)</td>
<td></td>
<td>Time until eviction without an income</td>
<td></td>
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<tr>
<td>Yes</td>
<td>61.38 (25.60)</td>
<td></td>
<td>&gt; 1 month</td>
<td>52.52 (23.66)</td>
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<tr>
<td>Current illicit drug use</td>
<td>0.632</td>
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<td>&lt; 1 month</td>
<td>66.78 (24.81)</td>
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<td>No</td>
<td>58.51 (25.28)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>60.84 (26.0)</td>
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</tr>
<tr>
<td>Excessive alcohol consumption&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.476</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>55.65 (27.44)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>60.12 (23.95)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>continuous variables were compared to DCI using correlation
<sup>b</sup>more than 14 alcohol beverages per a week for men, more than 10 for women
Table 3.
Predictors of loss to follow up at discharge and loss to follow up after 30 days

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Loss to follow up at discharge</th>
<th>Loss to follow up after 30 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative Risk</td>
<td>95% CI</td>
</tr>
<tr>
<td>Not owning a cell phonea</td>
<td>4.44</td>
<td>1.92-10.20</td>
</tr>
<tr>
<td>Not having access to internet</td>
<td>2.38</td>
<td>1.09-5.18</td>
</tr>
<tr>
<td>Not owning a car</td>
<td>2.17</td>
<td>1.00-4.74</td>
</tr>
<tr>
<td>Not feeling accepted by neighbors</td>
<td>2.65</td>
<td>1.08-6.49</td>
</tr>
<tr>
<td>History of addiction</td>
<td>3.23</td>
<td>1.52-6.85</td>
</tr>
<tr>
<td>Treatment for substance use disorder</td>
<td>4.69</td>
<td>2.29-9.62</td>
</tr>
<tr>
<td>Less than $500 in savings</td>
<td>3.41</td>
<td>1.00-5.01</td>
</tr>
<tr>
<td>Yearly income less than $5,000</td>
<td>2.43</td>
<td>1.00-5.88</td>
</tr>
<tr>
<td>Percent of the neighborhood without a high school diploma</td>
<td>-3.66</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Percent of the neighborhood that identifies as Hispanic</td>
<td>-2.13</td>
<td>0.046</td>
</tr>
<tr>
<td>Discharged to skilled nursing facility</td>
<td>2.49</td>
<td>1.10-5.68</td>
</tr>
<tr>
<td>Number of readmissionsb</td>
<td>6.416</td>
<td>.013</td>
</tr>
</tbody>
</table>

aFischer Exact Test 2 sided <.05
bContinuous variables were analyzed with linear regression

Table 4.
Unadjusted and adjusted outcomes

<table>
<thead>
<tr>
<th>Logistic regression</th>
<th>Univariate Odds Ratio</th>
<th>95% CI</th>
<th>P-value</th>
<th>Multivariate Odds Ratio</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never came to clinic DCI quintile</td>
<td>1.34</td>
<td>.91-1.99</td>
<td>0.144</td>
<td>1.77</td>
<td>1.04-3.2</td>
<td>0.036</td>
</tr>
<tr>
<td>Less than 30 days of follow up DCI quintile</td>
<td>1.41</td>
<td>.97-2.06</td>
<td>0.073</td>
<td>1.69</td>
<td>1.08-2.65</td>
<td>0.022</td>
</tr>
<tr>
<td>Less than 90 days of follow up DCI quintile</td>
<td>1.17</td>
<td>.90-1.52</td>
<td>0.241</td>
<td>1.41</td>
<td>1.03-1.94</td>
<td>0.032</td>
</tr>
<tr>
<td>Readmission for orthopaedic injury DCI quintile</td>
<td>1.38</td>
<td>.83-2.3</td>
<td>0.221</td>
<td>2.33</td>
<td>1.11-4.89</td>
<td>0.026</td>
</tr>
</tbody>
</table>

Linear regression

<table>
<thead>
<tr>
<th>Number of readmissions Loss to follow up</th>
<th>95% CI</th>
<th>P</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.249</td>
<td>.15-1.49</td>
<td>0.017</td>
<td>0.25</td>
<td>.18-1.49</td>
</tr>
</tbody>
</table>
Supplemental Figure. Serial Radiographs over time of a single pin and double pin animal. These are the radiographs taken at two week intervals of an animal in the single pin cohort and the double pin cohort. Of note, the staples in the single pin cohort were removed immediately prior to the radiograph being taken at the two week period.

Supplemental table. Arthrodesis Rates between the single pin and dual pin fixation groups.

<table>
<thead>
<tr>
<th></th>
<th>Single Pin fixation (n)</th>
<th>Dual Pin fixation (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fused (of oint surface)</td>
<td>2 / 8.33</td>
<td>100</td>
</tr>
<tr>
<td>Not Fused (of oint surface)</td>
<td>2 / 91.67</td>
<td>0</td>
</tr>
</tbody>
</table>
REFERENCES


2. elle BA, Buttacavoli FA, Shroff JB, Stirton JB. Loss of Follow-up in Orthopaedic Trauma: Who Is Getting Lost to Follow-up J Orthop Trauma. 2012. 22 (2): -.


Provider Variability in Emergency Department Opioid Administration to Patients with Two Common Orthopaedic Injuries

R. Matthew Wham, MD; Adam Boissonneault, MD; Mara L. Schenker, MD

Introduction.

More than people die every day from opioid-related events, the leading cause of accidental death in the United States. The problem has reached such a magnitude that in 2, President Trump declared the opioid crisis a national Public Health Emergency in an effort to garner more awareness and funding in order to assist in tackling this significant crisis. The President’s Committee on Combating Drug Addiction and the Opioid Crisis is driving policies for expansion of drug treatment centers, enhancement of prescriber education, and dedication of substantial research funding through the Centers for Disease Control and the National Institutes of Health. Because it is commonly thought that opioid dependence often begins through an initial exposure to a physician-prescribed opioid, limiting or eliminating such exposure entirely has the potential to play an integral role in addressing this public health crisis.

In the orthopaedic trauma population, the first exposure to a physician-prescribed opioid is often through the Emergency Department (ED). It has been previously shown that there is a wide variation in rates of opioid prescribing among physicians practicing within the same ED, and that rates of long-term opioid use increase in those patients who have received treatment from so-called high-intensity opioid prescribers. Such high-intensity prescribing practices persist despite recent data suggesting nonopioid analgesics are noninferior to opioids in the treatment of acute extremity pain in the ED. There is therefore a need for better understanding of the spectrum of provider variability in opioid prescribing and administration during such visits. This information would ideally be leveraged toward individualized prescriber education directed toward diminishing opioid administration from high-intensity utilizers and incorporating less commonly used adjuvant pain medications.

The cause of variability in the quantity of opioids administered during a patient encounter is multifactorial. Certainly the severity and quantity of the patient’s inuries play a role, as do other patient factors such as comorbidities, prior use of opioid analgesics, and likely a multitude of additional patient characteristics. Previous data have shown, however, that independent of these factors, there is a wide spectrum of opioid administration among providers themselves in the Emergency Department.

The purpose of our study is therefore to better characterize the spectrum of provider variability in the amount of opioid analgesics administered during ED stays for common orthopaedic injuries. We performed a retrospective review to quantify the total dose of opioids received by patients presenting to the ED for operative ankle and distal radius fractures in morphine milligram equivalents (MMEs) as well as which provider(s) were responsible for opioid prescribing.

Materials and Methods.

Following approval of the institutional review board, the billing database at a single, large, Level I, urban trauma center was queried for current procedural terminology (CPT) codes associated with operative fixation of distal radius and ankle fractures. CPT codes 22, 22, 22, 22, 22, 22 were included in the query. All patients in the database were treated at a single institution between 2 and 2. The database query yielded a total of 2 patients.

Electronic medical records were retrospectively reviewed to identify the total number of morphine milligram equivalents that each patient received during their initial ED visit for their injury. Patients who obtained an appointment in the office without first presenting to the ED were excluded. Note was also taken of whether or not the patient received a refill of opioid pain relievers prior to undergoing operative fixation of their fracture. In order to assess provider variability in prescribing practices and the quantity of opioids administered in the ED, the attending emergency room provider and consultant (typically an orthopaedic surgery resident) were also recorded.

For each patient in the database, note was taken of the patient’s prior history of opioid use (if known) as well as whether or not the patient was on opioids when they sustained their injury. Comorbid conditions were also tabulated. These included: pain disorder diagnosis, presence of musculoskeletal disease, fibromyalgia, neuropsychiatric disease, the use of stimulants, or history of sickle cell disease. Finally, in an effort to account for an increase in MMEs administered secondary to the presence of additional injuries, patients presenting with multiple traumatic inuries were classified in a polytrauma category.
and where available the Injury Severity Score (ISS) was recorded. The information above was used to create a database from which statistical analysis could be performed. Only data for patients with an accurate ISS measure were used in statistical analysis.

Statistical Analysis.
In our approach to reduce selection bias, the assumption was made that within the same hospital, patients do not choose specific emergency medicine providers or orthopaedic resident providers. Results are communicated in terms of the mean and median MME administered to patients in the cohort. Independent samples t-test was used to analyze MMEs based on subsets of patients categorized by their ISS.

Results.
The initial database query for CPT codes related to ankle and distal radius fractures yielded 2 patients. Of these, we were excluded on the basis of not having received their initial emergency care within our hospital system. In our data analysis, we only included patients with accurate ISS data within the trauma registry, thus 22 additional patients were excluded. Therefore, the total patient population included in our study is 2 patients.

<table>
<thead>
<tr>
<th>502 Patients included based on CPT query</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 Excluded due to lack of initial presentation in ED</td>
</tr>
<tr>
<td>486 Patients’ initial encounter in ED</td>
</tr>
<tr>
<td>228 Patients without ISS score</td>
</tr>
</tbody>
</table>

Figure 1. Flow chart of patients included in retrospective analysis.

The mean MME administered for all patients included in the study was (SD 2.2). The median MME was (range - ). There was an inverse relationship between a patient’s ISS and the MME that they received during their ED encounter, although this relationship was not statistically significant (R - , p .2).

Independent Samples t-test
There was no significant difference in mean MME delivered in the ED between patients that had ISS when compared to those patients with ISS less than or equal to 2. The mean MME administered for patients with ISS less than or equal to 2 was (SD 2.2) compared to (SD 2.) for those that had ISS greater than (p .2). Furthermore, there was also no significant difference in mean MME delivered in the ED between patients that had ISS 2 versus those who had ISS less than or equal to 2. The mean MME for patients with ISS of 2 or less was (SD 2.2) compared to (SD 2.) for those with ISS greater than (p .2). (Figure 2)

Analysis of Variance
Patients were categorized into three groups based on their injury severity score: Group 1 had an ISS less than or equal to (n 2), Group 2 had an ISS between 1 and 2 (n ), and Group 3 had an ISS equal to or greater than 2 (n ). Comparing these groups, there was no statistically significant difference in the mean MME that they received in the ED (p .2).

High Intensity versus Low Intensity Providers
Given that the median MME provided to the patient population in this study was , we adopted the method employed by Barnett et al. and defined a high-intensity provider as a physician whose average administration of MME was above this median threshold, and a low-intensity provider as one below this threshold. Notably, we only included providers with at least three documented encounters (in order to establish a pattern and mitigate the effect of outliers). Thus, the total number of high-intensity providers included in statistical analysis was 22, and the number of low-intensity providers was .

The mean MME administered by high-intensity providers was (SD 2 ) compared to (SD 2 .) for low intensity providers, which was statistically significant (p .). Furthermore, there was no significant difference in the mean ISS of patients treated by high- and low-intensity providers. The mean ISS of patients treated by high-intensity prescribers was (SD ) compared to (SD 2) for low-intensity prescribers (p . ), suggesting that in uro severity did not explain the disparity in prescribing patterns. When controlling for ISS, patients were three times more likely to receive over MME during their ED encounter when treated by a high-intensity prescriber (OR2 , CI . - p . ).

Influence of Orthopaedic Resident Involvement
We performed a subgroup analysis of patients with ISS less than or equal to (n 2 ). These patients represent relatively simple in uro patterns where orthopaedic resident involvement and their ability to use regional anesthesia effectively could influence the total MME administered. High- and low-intensity encounters in this subgroup were again defined based on their relationship to the mean MME for the total patient population. There were total high-intensity encounters in this subgroup and low-intensity encounters.

In this cohort, when patients were treated with a high-intensity Emergency Medicine prescriber, the likelihood of receiving greater than MME during their encounter was again nearly three times higher (OR 2, CI . - p . ). In contrast, there was no significant increased risk of receiving over MME when patients were cared for by a high-intensity orthopaedic resident provider (OR , CI . p . ). In fact, when a low-intensity orthopaedic resident...
prescriber is involved in an encounter, the risk of receiving greater than MME by a high-intensity Emergency Medicine prescriber is mitigated and becomes nonsignificant. There is no increased risk of a patient receiving over MME during an encounter by a high-intensity Emergency Medicine provider after controlling for involvement of a low-intensity orthopaedic resident (OR .2, Cl . . p . ).

Discussion.

Our retrospective review and analysis suggest that there is no correlation between a patient’s in ury severity and opioid administration patterns during their ED visit. Furthermore, similar to conclusions reached by Barnett et al., we have shown that patients under the care of high-intensity Emergency Medicine prescribers are much more likely to receive higher doses of opioid analgesics, though this risk may be mitigated by involvement of orthopaedic residents.

Strengths and Weaknesses of this Study

In this retrospective review, we examined the provider variability in opioid analgesic prescribing to patients presenting to a large, urban, Level trauma center with operative ankle or distal radius fractures. 2 patients’ electronic medical records were reviewed and data were collected regarding total MMEs administered during their initial ED visit, patient comorbid conditions, current or previous use of opioid pain medications, and identity of provider(s) involved in the patient’s care. The information gleaned from this review is relevant to efforts meant to achieve analgesia while minimizing rates of opioid dependence.

This study does have several limitations. By the nature of the study we are limited by the information available to us during retrospective chart review. We were only able to capture data that is present within the electronic medical record at the trauma center in question and therefore if patients received additional opioid prescriptions elsewhere this will not be reflected in our data. Another weakness of our study is that the time spent in the ED for each patient was not recorded as a data point. While it would be useful to quantify the MMEs a patient receives per hour in order to eliminate excessive MMEs secondary to increased length of stay, we were unfortunately unable to do this with adequate accuracy due to the limitations of the electronic medical record. Additionally, more patients would have to be included in our study in order to achieve adequate power for subgroup analysis of patient comorbidities and examine the relationship of mental illness, stimulant use, and prior opioid use to MMEs received in the ED for our patient cohort. Finally, we did not collect a data point representing the use of adjuvant methods of analgesia such as hematomas blocks, nerve blocks, or nonopioid medications. We can conjecture, however, that low-intensity resident providers achieved this status through the use of such approaches. The strengths of our study include its novelty, as no one has previously quantified the variability of opioids administered to patients with these common orthopaedic injuries nor the effects of orthopaedic resident involvement in patient care.

Effects of Injury Severity on Opioid Administration

Our study demonstrated that there was no significant difference in the mean MME delivered in the ED for patients that had ISS compared against those with ISS less than or equal to . In fact, there was a trend toward an inverse relationship between a patient’s in ury severity and the total amount of opioids administered, though this was not statistically significant. Previous studies have shown that opioid prescriptions given at discharge are partially influence by a patient’s in ury severity2, however no study that we are aware of has examined the relationship of a patient’s in ury severity to the amount of opioids administered during their Emergency Department encounter. There are several reasons why a more severely in ured patient may receive fewer MMEs: the focus of the treatment team may be more directed toward stabilizing a patient for emergency surgery rather than analgesia. Furthermore, some patients are intubated on arrival and initiated on non-opioid sedative and analgesic drips. Additional studies are required to further examine the relationship between a patient’s in ury severity and the amount of opioid analgesics they receive in the ED.

Effects of High- Versus Low-Intensity Prescribers

Similar to Barnett et al., our data indicate that certain providers can be categorized into high- and low-intensity groups. Patients in our cohort were three times more likely to receive more than MMEs during their encounter if they were cared for by high-intensity providers when compared to low-intensity providers. Much is being written about the necessity of addressing the amount of opioids administered for both acute and chronic pain in the United States. It has been shown that patients cared for by high-intensity prescribers are more likely to progress to long-term opioid use than those cared for by low-intensity prescribers. Given the burden of ankle and distal radius fractures in the U.S., this knowledge may represent yet another opportunity for improvement and prescriber education aimed at addressing high-intensity prescribing practices.

Effects of Orthopaedic Resident Involvement

Perhaps most intriguing is our finding that when analgesic patients with a lower ISS, the involvement of an orthopaedic resident in a patient’s care is protective of the administration of high amounts of MMEs. This is likely multifactorial. At our institution, typically the only provider equipped to administer regional anesthesia in the ED for fracture reductions is the orthopaedic resident on call. Our data suggest that the use of such adjuvant measures of analgesia may be protective of high-intensity opioid prescribing. Indeed, past studies have concluded that nonopioid analgesics are noninferior to opioids in the treatment of acute extremity pain. This knowledge may guide future efforts to limit or eliminate the use of opioid analgesics in the care of the orthopaedic patient in the ED using multimodal analgesia strategies.

Conclusion

In conclusion, we found that there was no relationship between a patient’s in ury severity and the amount of opioid analgesics that they receive during their Emergency Department
encounter, and even discovered a trend toward fewer opioids administered to more severely injured patients. Furthermore, patients cared for by so-called high-intensity Emergency Medicine prescribers were three times more likely to receive greater than MMEs in the ED than those cared for by low-intensity prescribers. This effect appears to be mitigated by involvement of orthopaedic residents. Future research may reveal whether or not prescriber education efforts directed toward high-intensity prescribers or adjunctive analgesic modalities can help to limit exposure to opioids and ultimately decrease rates of long-term use and dependence.
Figure 2. Demonstrates the total amount of MME administered in the ED according to each patient’s Injury Severity Score.
REFERENCES


Hypoalbuminemia is an Independent Risk Factor for 30-Day Mortality, Postoperative Complications, Readmission, and Reoperation in the Operative Lower Extremity Orthopedic Trauma Patient

Jacob Wilson, MD; Matt Lunati, MD; Zachary Grabel, MD; Christopher Staley, BA; Andrew Schwartz, MD; Mara Schleker, MD

Abstract:
Introduction: Malnutrition, as indicated by hypoalbuminemia, is known to have detrimental effects on outcomes following arthroplasty, geriatric hip fractures, and multiple general surgeries. Hypoalbuminemia has been examined in the critically ill but has largely been ignored in the orthopedic trauma literature. We hypothesized that admission albumin levels would correlate with postoperative course in the non-geriatric lower extremity trauma patient.

Methods: Patients with lower extremity (including pelvis and acetabulum) fracture who underwent operative intervention were collected from the ACS-NSQIP database. Patients years-old were included. Patient demographic data, complications, length of stay (LOS), reoperation and readmission rates were collected, and patient modified frailty index scores (mFI) were calculated. Poisson regression with robust error variance was then conducted, controlling for potential confounders.

Results: Patients with albumin available were identified and 2.2 had hypoalbuminemia. Hypoalbuminemic patients had higher rates of postoperative complications (2. v. 2, aRR .2) including increased rates of: mortality (2. v. aRR .2, CI 2. v. ), sepsis (2. v. aRR 2. ) and reintubation (2. v. aRR .). Reoperation (2. v 2, aRR .) and readmission (2. v. aRR 2. ) rates were also higher in patients with low albumin.

Conclusion: Hypoalbuminemia is a powerful predictor of acute postoperative course and mortality following surgical fixation in non-geriatric, lower extremity orthopedic trauma patients. Admission albumin should be a routine part of the orthopedic trauma workup. Further study into the utility of supplementation is warranted as this may represent a modifiable risk factor.

Keywords: Malnutrition orthopedic trauma complications, albumin

Level of Evidence: III, prognostic

INTRODUCTION
Malnutrition is common in surgical and hospital patients and is a well-established risk factor for morbidity. Albumin is often used as a marker for chronic nutritional status. Hypoalbuminemia has been associated with poor outcomes in both orthopedic and general surgery. Within orthopedics, extensive literature in the spine, total joint arthroplasty, and geriatric hip fracture realms supports the idea that hypoalbuminemia (albumin g/dl) is associated with post-operative complications. Recently, Blevins et al demonstrated that out of five commonly used nutrition biomarkers, low albumin had the highest specificity and positive predictive value for the development of prosthetic joint infection. From a biological perspective, malnutrition and protein deficiency are known to have detrimental effects on fracture healing. Perhaps most pertinent to this discussion, it is known that hypoalbuminemia increases both complications and mortality following surgery for hip fracture in the geriatric cohort. However, the data regarding the effect of hypoalbuminemia on outcomes after surgery for orthopedic trauma is lacking.

A recent systematic review on the effect of malnutrition in the orthopedic trauma patient suggested that malnutrition may be associated with increased wound complications, fracture nonunion, and immobility-associated decubitus ulceration. However, most of the studies included only hip fracture patients, which generally consists of a frail, geriatric cohort. Ultimately, the authors noted high utility literature on the subject is scarce and concluded that further study was needed.

The purpose of this investigation is to determine the impact of hypoalbuminemia on postoperative complication rate, length of stay (LOS), reoperation rate, and readmission rate in non-geriatric (years) patients with lower extremity orthopedic trauma. We hypothesized that hypoalbuminemia is associated with adverse outcomes in patients who undergo surgery for lower extremity orthopedic trauma.
Methods:

Data Collection

Patients included in this study were collected from the American College of Surgeons-National Surgery Quality Improvement Program (ACS-NSQIP) database. The NSQIP database is a widely utilized, prospectively-collected database that collects preoperative and -day postoperative outcome data for patients undergoing surgical operations. This includes patients across multiple subspecialties who have undergone procedures performed at both academic and private institutions. The database has excellent follow-up and captures of -day outcomes by observing in-hospital morbidity and mortality through contacting patients via writing and phone call at the end of the -day period.

In the present study, the NSQIP database was searched for appropriate patients using Current Procedural Terminology (CPT) codes. Patients undergoing operative intervention for lower extremity orthopedic trauma (pelvis and acetabulum to ankle) were included. This included the following CPT codes grouped into broad categories for some aspects of analysis: hip (2 2, 2 2, 2 2, 2 2, 2 2, 2 2,) ankle/pilon (2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2,) femoral shaft (2 2, 2 2, 2 2) tibial shaft (2 2, 2 2) knee periartricular (2 2, 2 2, 2 2, 2 2,) pelvis and acetabulum (2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2, 2 2,). Geriatric patients (years-old) were excluded from analysis. Lastly, patients meeting sepsis or pre-sepsis criteria prior to surgery were excluded.

Patient Demographic Information

Patient demographic and comorbid data was collected and compiled. These included: sex, age, race, American Society of Anesthesiology (ASA) classification, body mass index (BMI), wound classification, and smoking status. The following comorbidities were also collected for each patient and were included if present within the days preceding surgery: dyspnea on exertion (DOE), diabetes mellitus (DM), congestive heart failure (CHF), anemia (defined as hematocrit in men and in women), hypertension (HTN), acute renal failure, and chronic obstructive pulmonary disease (COPD). Additionally, given the known association with postoperative complications in this cohort, we calculated the -item modified frailty index (mFI) scores as previously described for each patient. Briefly, this index includes the following patient history items: DM, CHF, HTN, COPD, transient ischemic attack (TIA) or cerebrovascular incident (CVA), non-independent functional status, MI, peripheral vascular disease, CVA with neurological deficit, angina or prior percutaneous coronary intervention, and impaired sensorium. The number of items present for each patient were then tabulated and divided by to calculate each patient’s mFI score. This data was compiled and used in multivariate analysis.

Additionally, preoperative albumin levels were collected for each patient. Serum albumin levels were available for patients who had an albumin level drawn within days of the procedure. In all cases, this study utilized the albumin level drawn most proximally to the procedure. Based on extensive precedence in the literature, albumin levels were categorically defined as hypoalbuminemia (g/dl), normal albumin (g/dl), or missing albumin if unavailable.

Outcome and Complication Data

In order to assess outcomes, -day postoperative complication data was collected for each patient. The collected complications included anemia during transfusion, cardiac arrest during cardiopulmonary resuscitation, unplanned intubation, cerebrovascular accident, deep vein thrombosis (DVT), pulmonary embolism (PE), myocardial infarction (MI), pneumonia, sepsis, surgical site infection (SSI), urinary tract infection (UTI), renal insufficiency, readmission, and reoperation. Additionally, data for total complications was analyzed as well as Clavien-Dindo IV complications (life threatening complications with end-organ dysfunction). For this study, a patient was considered to have incurred a Clavien-Dindo IV complication if they had: cardiac arrest, MI, sepsis, PE, or renal failure. Lastly, length of stay was collected.

Statistical Analysis

Statistical analysis was performed using IBM SPSS (IBM Corporation, Armonk, NY) statistical software. For the purposes of analysis we utilized Poisson regression with robust error variance as an alternative to typical multivariate regression as initially described by et al and recently employed by Bohl et al. This method allows for direct reporting of relative risks and avoids the potential for overestimation of risk as readers often misinterpret odds ratios as relative risks. This method of analysis as an alternative to standard linear regression of binary data has become widely accepted and utilized. After identifying those patients with and without available albumin levels, bivariate Poisson regression with robust error variance was conducted to assess association between availability of albumin and baseline patient characteristics and subse uently to assess the association of hypoalbuminemia with baseline characteristics. This multivariate analysis controlled for all baseline characteristics including: age, sex, BMI, mFI, DM, CHF, DOE, HTN, open wound or infection, COPD, current smoking status, anemia, acute renal failure, and region of injury. A p-value of less than was considered significant for this analysis. Analysis was then performed comparing postoperative complication rates between patients with hypoalbuminemia and normal albumin levels again using multivariate Poisson regression with robust error variance. In addition to the control variables mentioned above, length of stay and operative time were also controlled for in this analysis as they were felt to possibly effect complication rates. Risk of death was then analyzed using the same method comparing patients with hypoalbuminemia to those with normal albumin and then another analysis examined albumin as a continuous variable. All patients where included in every
analysis and patients without available albumin were coded using a missing variable. Length of stay was analyzed using a nonparametric t-test as this variable was not normally distributed.

Results:

Patient Demographics and Baseline Characteristics

From 22 patients years old who underwent operative intervention of a lower extremity fracture were identified from the NSQIP database. The average patient in our cohort was 72 years old (72 years old excluded) and was overweight by BMI (average BMI 27.2). There was a slight female predominance at 2:1. The majority of patients had more one frailty comorbidity (Table 1).

Availability of Albumin Levels and Risk Factors For Hypoalbuminemia

Of the patients identified, 22 had albumin levels available for analysis. Our analysis demonstrated that patients were more likely to have albumin levels available if they were: older, female, had a very low (2 kg/m2) or very high (kg/m2) BMI, or had a higher mFI. Specifically, albumin was more commonly available for patients with the following comorbidities: DM, CHF, DOE, HTN, open wound or infection, COPD, current smoking status, anemia, or acute renal failure. Of the regions of injury, ankle fracture patients had the lowest proportion of patients with albumin available, and the albumin levels of patients compared to ankle fracture patients (Table 1). Multivariate analysis revealed that patients who were years-old, had a BMI 2 kg/m2 or kg/m2, had an mFI score of , had an open wound or infection, were active smokers, were anemic, had acute renal failure, or had a fracture other than an ankle fracture or tibial shaft fracture were more likely to have hypoalbuminemia. (Table 2) In this cohort, hypertension was inversely associated with hypoalbuminemia (RR .2, CI .2-.2, p .). Hypoalbuminemia, Postoperative Complications and Risk of Mortality

Overall, 22 patients with albumin available for analysis were found to have hypoalbuminemia. The mean albumin level was 2.2 (SD 2.2). The distribution of albumin levels can be seen in Figure a. Patients with hypoalbuminemia were found to have higher rates of postoperative complications compared to patients with serum albumin . g/dl (v. , respectively, RR .2, CI .2-.2, p .). Figure b. Specifically, these patients had significantly increased rates of the following complications: anemia re-feeding transfusion, cardiac arrest, re-feeding resuscitation, renal insufficiency, sepsis, unplanned intubation, and UTI (p ., Table 1).

Patients with hypoalbuminemia had higher rates of Clavien-Dindo IV complications when compared to those with normal albumin (. v., respectively, RR .2, CI .2-.2, p .). This translated into an increased risk of mortality (.2 (albumin . g/dl) v. (. albumin . g/dl), RR .2, CI .2-.2, p .). This association was also found when examining albumin as a continuous variable as risk of mortality was inversely correlated with serum albumin concentration (RR .2, CI .2-.2, p .). Figure c.

Hypoalbuminemia, Readmission, Reoperation, and Length of Stay

Patients with serum albumin . g/dl, when compared to normal albuminemic patients, were also found to have increased risk for readmission within days (. v., respectively, RR .2, CI .2-.2, p .) and reoperation (. v., respectively, RR .2, CI .2-.2, p .). Figure d. Additionally, hypoalbuminemia was associated with longer lengths of stay as those with albumin . g/dl had a mean LOS of (. ) days while those with normal albumin had a mean LOS of (. ) days (p .). Figure e.

Discussion:

Hypoalbuminemia is often used as a surrogate marker for malnutrition and is a common risk factor in surgical and hospital progress patients. Total oint arthroplasty, hip fracture, and spine literature suggest low albumin levels are associated with adverse postoperative outcomes. A recent study investigated the effect of hypoalbuminemia in total arthroplasty patients and showed it was associated with higher intensive care admission rate, hospital readmission rate, and emergency room visits resulting in a mean -day charge increase of .2. Koval et al. demonstrated that hypoalbuminemia is associated with increased risk of mortality, increased length of stay, and inability to regain preoperative independence in hip fracture patients. Bohl et al. demonstrated an association with -day mortality and complications in hip fracture patients. Similar relationships exist in patients after undergoing spine surgery. However, the relationship between hypoalbuminemia and postoperative course in a young orthopedic trauma cohort is not well reported.

Malnutrition is an important risk factor to recognize, as it is potentially modifiable. While the nature of trauma precludes the ability to pre-habilitate or correct nutritional status preoperatively, there has been suggestion that postoperative supplementation can reduce the incidence of complications in patients with hip fractures. Beyond short term complications, correction of malnutrition is likely important for achieving bone union in the setting of fracture care and reversal of malnutrition could conceivably reverse its
detrimental effects. However, there is a limited evidence for or against nutritional supplementation after orthopedic trauma.

Our patient population had an average age of years old, an average BMI of 2, and most patients had fracture or one frailty comorbidity (Table 1). This distinguishes our group from prior studies. Additionally, the relatively younger age and healthy nature of the study cohort diminishes potential confounding factors that may affect patient outcomes.

The results of this investigation demonstrate that hypoalbuminemia is independently associated with increased postoperative morbidity. This includes increased rates of overall complications (including significantly increased rates of anemia re-uring transfusion, cardiac arrest re-uring resuscitation, renal insufficiency, sepsis, unplanned intubation, and UTI), Clavien-Dindo IV (life-threatening) complications and mortality. Hypoalbuminemia was also associated with increased day readmission rate, reoperation rate, and hospital length of stay (LOS). These relationships were strong, and even when controlling for confounders, hypoalbuminemia had a relative risk of for mortality.

It is worth noting that while hypoalbuminemia is typically associated with malnutrition, it also acts as an acute phase reactant. Both trauma and surgery cause an increase in the body’s inflammatory products and can lead to a reduction in protein in the acute phase due to an overly catabolic and hypermetabolic response to stress. These acute changes in serum marker levels may challenge the validity of the traditional methods for malnutrition assessment, such as albumin. However, our data demonstrates that, although we cannot empirically prove that albumin is an accurate marker of nutrition in the acute trauma setting, it is still reliably prognostic for morbidity.

There are several limitations in this study, the majority of which are inherent to large database studies and the NSQIP database, in particular. The NSQIP database only includes complications observed within days of surgery. This may falsely lower the number of complications for analysis as late complications are not available. In addition, many orthopedic outcomes of interest are not collected by the database and functional outcome data is not available and cannot be analyzed in this study. Additionally, only 2 of patients studied had albumin levels available for analysis. This is a significantly lower percentage of recorded albumin levels than the hip fracture population studied by Bohl et al. where of patients had available albumin levels. We speculate that the lower percent of recorded albumin is likely due to the study population being a younger, generally healthier population in which preoperative albumin levels are not standard of care. This created a potential selection bias as those with increasing frailty (as indicated by mFI) were more likely to have albumin available for analysis. However, patients with all mFI scores were well represented in the group analyzed and frailty was controlled for in the multivariable analysis to help mitigate this influence.

In conclusion, this investigation demonstrates hypoalbuminemia was associated with a significant increase in complications, including mortality, increased hospital length of stay, readmission rates, and reoperation rates for patients who underwent surgery for lower extremity orthopaedic trauma. Although this study cannot determine whether albumin is a reliable marker for nutrition status in the orthopaedic trauma patient, this study reveals it has strong prognostic implications and may be a useful indicator of patients re-uring special ed postoperative pathways to prevent undue outcomes. While prior studies have established a decrease in complications due to nutritional supplementation after hip geriatric hip fracture, further work is needed to delineate whether albumin is a modifiable risk factor in the setting of orthopaedic trauma.

<table>
<thead>
<tr>
<th>Table 1: Hypoalbuminemia Rates</th>
<th>Hypoalbuminemia Rates</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Demographic Characteristic</td>
<td># of patients Initially Identified</td>
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<td>---------------------------</td>
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<tr>
<td>Overall</td>
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<tr>
<td>Age</td>
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<td>18 to 25</td>
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</tr>
<tr>
<td>26 to 35</td>
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<td>56 to 65</td>
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<td>Ankle</td>
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<td>Knee periarticular</td>
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<td>Femur</td>
<td>231</td>
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<tr>
<td>Tibia</td>
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<tr>
<td>Pelvic and acetabulum</td>
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</table>

Relative risks are presented with the 95% confidence intervals in parentheses.
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<tr>
<th>Risk Factors</th>
<th>Percentage of Patients with Hypoalbuminemia (%)</th>
<th>Multivariate Comparisons</th>
<th>P value</th>
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<td>18 to 25</td>
<td>12.3</td>
<td>Reference</td>
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<td>26 to 35</td>
<td>15.1</td>
<td>Reference</td>
<td></td>
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<td>36 to 45</td>
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<td>Reference</td>
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</tr>
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<td>46 to 55</td>
<td>29.4</td>
<td>Reference</td>
<td></td>
</tr>
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<td>56 to 65</td>
<td>36.2</td>
<td>Reference</td>
<td></td>
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<td></td>
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</tr>
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<td>Male</td>
<td>27.4</td>
<td>Reference</td>
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<td>Female</td>
<td>31.2</td>
<td>1.11 (1.03 to 1.20)</td>
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<td>BMI</td>
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<td>55.6</td>
<td>1.61 (1.39 to 1.87)</td>
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<td>18 to 19.9 kg/m²</td>
<td>35.0</td>
<td>1.28 (1.16 to 1.43)</td>
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<td>20 to 24.9 kg/m²</td>
<td>23.6</td>
<td>Reference</td>
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<td>1.01 (0.88 to 1.15)</td>
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<td>≥35 kg/m²</td>
<td>33.8</td>
<td>1.24 (1.07 to 1.44)</td>
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<td>0.00</td>
<td>19.5</td>
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<td>0.09</td>
<td>33.0</td>
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<td>0.18</td>
<td>44.5</td>
<td>1.99 (1.64 to 2.41)</td>
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<td>0.27</td>
<td>48.8</td>
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<td>≥0.36</td>
<td>56.3</td>
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<td>Diabetes mellitus</td>
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<td>No</td>
<td>26.1</td>
<td>Reference</td>
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<tr>
<td>Yes</td>
<td>44.2</td>
<td>1.16 (1.03 to 1.30)</td>
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<td>Congestive heart failure</td>
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</tr>
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<td>No</td>
<td>29.2</td>
<td>Reference</td>
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<td>Yes</td>
<td>61.4</td>
<td>1.20 (0.96 to 1.51)</td>
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<td>Dyspnea on exertion</td>
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<td>28.7</td>
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<td>Yes</td>
<td>47.3</td>
<td>1.13 (0.99 to 1.30)</td>
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<td>Hypertension</td>
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<td>0.001</td>
</tr>
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<td>No</td>
<td>24.1</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>37.4</td>
<td>0.81 (0.72 to 0.92)</td>
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<td>Open wound or infection</td>
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<td>&lt;0.001</td>
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<tr>
<td>No</td>
<td>28.4</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>49.7</td>
<td>1.42 (1.26 to 1.60)</td>
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<tr>
<td>Chronic obstructive pulmonary disease</td>
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<td></td>
<td>0.25</td>
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<td>No</td>
<td>27.9</td>
<td>Reference</td>
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<tr>
<td>Yes</td>
<td>49.5</td>
<td>0.92 (0.81 to 1.06)</td>
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<td>Current smoker</td>
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<td>&lt;0.001</td>
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<td>No</td>
<td>27.0</td>
<td>Reference</td>
<td></td>
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<tr>
<td>Yes</td>
<td>34.4</td>
<td>1.22 (1.12 to 1.32)</td>
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<td>Anemia</td>
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<td>&lt;0.001</td>
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<td>27.7</td>
<td>Reference</td>
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<td>Yes</td>
<td>53.1</td>
<td>1.41 (1.27 to 1.56)</td>
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<td>29.3</td>
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<td>Yes</td>
<td>74.4</td>
<td>1.54 (1.22 to 1.94)</td>
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</table>
Table 2. Analysis of Risk Factors for Hypoalbuminemia (serum albumin ≤ 3.5 g/dl)

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Percentage of Patients with Hypoalbuminemia (%)</th>
<th>Multivariate Comparisons</th>
<th>P value</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td>Relative Risk (95% CI)</td>
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<tr>
<td>Region of Injuries</td>
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<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hip</td>
<td>43.6</td>
<td>1.79 (1.60 to 2.01)</td>
<td></td>
</tr>
<tr>
<td>Ankle</td>
<td>17.8</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Knee periarticular</td>
<td>27.0</td>
<td>1.34 (1.16 to 1.56)</td>
<td></td>
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<tr>
<td>Femur</td>
<td>37.5</td>
<td>1.67 (1.41 to 1.97)</td>
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<tr>
<td>Tibia</td>
<td>20.3</td>
<td>1.12 (0.91 to 1.37)</td>
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<tr>
<td>Pelvic and acetabulum</td>
<td>35.1</td>
<td>1.62 (1.20 to 2.17)</td>
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</tbody>
</table>

Prevalence of hypoalbuminemia = patients with serum albumin <3.5 g/dL divided by the # of patients with available serum albumin. Adjusted for all other risk factors listed in this table.

Table 3. Hypoalbuminemia and Morbidity Following Lower Extremity Orthopaedic Trauma

<table>
<thead>
<tr>
<th>Complications</th>
<th>Normal Albumin (n= 3,995)</th>
<th>Hypoalbuminemia (n=1,678)</th>
<th>Missing Albumin (n= 11,837)</th>
<th>Relative Risk*</th>
<th>P value</th>
</tr>
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<tbody>
<tr>
<td>Significant Association:</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Anemia requiring transfusion</td>
<td>322 (8.1%)</td>
<td>362 (21.6%)</td>
<td>394 (3.3%)</td>
<td>1.47 (1.28 to 1.69)</td>
<td>&lt;0.001</td>
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<tr>
<td>Cardiac arrest requiring cardiopulmonary resuscitation</td>
<td>6 (0.2%)</td>
<td>16 (1.0%)</td>
<td>9 (0.1%)</td>
<td>3.45 (1.20 to 9.93)</td>
<td>0.022</td>
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<tr>
<td>Renal Insufficiency</td>
<td>2 (0.1%)</td>
<td>11 (0.7%)</td>
<td>3 (0.0%)</td>
<td>6.10 (1.19-31.28)</td>
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<tr>
<td>Sepsis</td>
<td>18 (0.5%)</td>
<td>26 (1.5%)</td>
<td>23 (0.2%)</td>
<td>1.99 (1.03-3.86)</td>
<td>0.041</td>
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<td>Unplanned intubation</td>
<td>15 (0.4%)</td>
<td>39 (2.3%)</td>
<td>19 (0.2%)</td>
<td>2.95 (1.49-5.84)</td>
<td>0.002</td>
</tr>
<tr>
<td>Urinary Tract Infection</td>
<td>51 (1.3%)</td>
<td>57 (3.4%)</td>
<td>54 (0.5%)</td>
<td>1.58 (1.04-2.41)</td>
<td>0.033</td>
</tr>
</tbody>
</table>

No Significant Association: | | | | | |
| Cerebrovascular accident | 2 (0.1%) | 1 (0.1%) | 4 (0.0%) | 0.62 (0.02 to 24.3) | 0.801 |
| Deep vein thrombosis | 28 (0.7%) | 16 (1.0%) | 51 (0.4%) | 1.01 (0.52 to 1.94) | 0.989 |
| Myocardial infarction | 10 (0.3%) | 6 (0.4%) | 10 (0.1%) | 0.65 (0.18 to 2.38) | 0.520 |
| Pneumonia | 27 (0.7%) | 37 (2.2%) | 34 (0.3%) | 1.75 (0.98 to 3.13) | 0.059 |
| Pulmonary embolism | 15 (0.4%) | 10 (0.6%) | 47 (0.4%) | 0.86 (0.35 to 2.08) | 0.732 |
| Infection | 72 (1.8%) | 56 (3.3%) | 169 (1.4%) | 1.38 (0.94 to 2.02) | 0.101 |

All values are presented as n (%).

*Multivariate analysis adjusted for region of injury, body mass index, length of stay, total operative time, sex, age, smoking status, modified frailty index, and the presence of an open wound, dyspnea, diabetes, congestive heart failure, anemia, hypertension, acute renal failure, and chronic obstructive pulmonary disease. The values are reported as relative risk, with the 95% CI in parentheses. P<0.05 considered significant.
Figure: A. Distribution of serum albumin concentrations for patients included in study, B. Risk of complication by preoperative serum albumin, C. Risk of mortality by preoperative serum albumin, D. Risk of reoperation by preoperative serum albumin, and E. Length of stay by preoperative serum albumin.


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2. ou G: A modified poisson regression approach to prospective studies with binary data. Am J Epidemiol 2: -

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Spero Karas	Associate Professor, Sports Medicine
Sameh Labib	Associate Professor, Sports Medicine/Foot & Ankle
John Louis-Ugbo	Assistant Professor, Foot & Ankle
Michael Maceroli	Assistant Professor, Trauma
T. Scott Maughon	Assistant Professor, Sports Medicine
Clifton Meals	Assistant Professor, Hand & Upper Extremity
Keith Michael	Assistant Professor, Spine
David Monson	Assistant Professor, Musculoskeletal Oncology
Thomas Moore, Jr.	Assistant Professor, Trauma
Shervin Oskouei	Assistant Professor, Musculoskeletal Oncology
Diane Payne	Assistant Professor, Trauma/Hand & Upper Extremity
Mathew Pombo	Assistant Professor, Sports Medicine
Steven Presciutti	Assistant Professor, Spine
Daniel Refai	Assistant Professor, Spine & Neurosurgery
Nickolas Reimer	Assistant Professor, Musculoskeletal Oncology
William Reisman	Assistant Professor, Trauma
John Rhee	Associate Professor, Spine & Neurosurgery
James R. Roberson	Robert P. Kelly Professor, Adult Reconstruction
Gerald Rodts	Professor, Spine & Neurosurgery
Christopher Sadlack	Assistant Professor, Adult Reconstruction
Mara Schenker	Assistant Professor, Trauma
Richard Thomas	Assistant Professor, Trauma
Eric Wagner	Assistant Professor, Hand & Upper Extremity
Nick Willett, PhD	Assistant Professor, Research
Brent Wise	Assistant Professor, Trauma
John W. Xerogeanes	Professor, Sports Medicine
S. Tim Yoon	Professor, Spine
Kelly Visiting Professors

1978  William Murray MD
       Professor & Chairman of The
       Department of Orthopedic Surgery at
       UCSF.

1979  Robert E. Leach MD
       Boston University

1980  Carl L. Nelson MD
       Chairman of the Department of
       Orthopaedic Surgery at the
       University of Arkansas for Medical
       Science

1981  Sir John Charnley
       Wrightington Hospital
       Professor Emeritus of the University of
       Manchester, the Royal College of
       Surgeons of England and Ireland, and
       the Universities of Edinburgh and
       Glasgow.

1982  Howard H. Steel MD
       Shriner’s Hospital-Philadelphia

1983  Robert H. Fitzgerald, Jr. MD
       Chairman- Wayne State University

1984  Joseph Schatzker MD
       Professor Emeritus of Surgery at the
       University of Toronto

1985  Larry Matthews MD
       The University of Michigan

1986  John P. Kostuik MD
       Professor Johns Hopkins University
       School of Medicine

1987  Richard H. Gelberman MD
       Washington University, Department
       of Orthopaedic Surgery

1988  J. Leonard Goldner MD
       Duke University

1989  Henry J. Mankin MD
       Massachusetts General Hospital

1990  Bernard F. Morrey MD
       Professor & Chairman, of Orthopaedics at
       the Mayo Clinic

1991  Gary G. Poehling MD
       Professor of Orthopaedic Surgery at
       Bowman Gray School of Medicine

1992  Michael W. Chapman MD
       Professor & Chairman,
       Department of Orthopaedic Surgery
       University of California at Davis

1993  Michael F. Schafer MD
       Ryerson Professor & Chairman
       Department of Orthopaedic Surgery
       Northwestern School of Medicine

1994  James R. Urbaniak MD
       Virginia Flowers Baker Professor &
       Chief of Orthopaedic Surgery, Duke
       University Medical Center

1995  Dan M. Spangler MD
       Professor & Chairman of Orthopaedic
       Surgery & Rehabilitation, Vanderbilt
       University

1996  James H. Herndon MD
       David Silver Professor & Chairman of
       Orthopaedic Surgery, University
       Pittsburgh’s Medical School & Chief of
       Orthopaedics & Rehabilitation at the
       UPMC.

1997  S. Terry Canale MD
       Professor, Department of Orthopaedic
       Surgery, University of Tennessee College
       of Medicine.

1998  Angus M. McBryde, Jr. MD
       Professor & Chairman, Orthopaedic
       Surgery, The Medical University of
       South Carolina.

1999  L. Andrew Koman MD
       Professor & Chairman, Department of
       Orthopaedic Surgery, Duke University
       Medical Center

2000  Louis U. Bigliani MD
       Frank E. Stinchfield Professor &
       Chairman Department of
       Orthopaedic Surgery College of
       Physicians & Surgeons

2001  Robert S. Adelaar MD
       Professor & Vice-Chairman,
       Department of Orthopaedic Surgery
       Medical College of Virginia

2002  John S. Gould MD
       Alabama Sports Medicine
2003  Freddie H. Fu MD  
Professor & Chairman, Department of Orthopaedic Surgery  
University of Pittsburgh

2004  Peter Stern MD  
Professor & Chairman  
University of Cincinnati

2005  James N. Weinstein DO  
Chairman Department of Orthopaedics  
Dartmouth College

2006  Marc F. Swiontkowski MD  
Chairman Department of Orthopaedics  
University of Minnesota

2007  Michael Coughlin MD  
Coughlin Foot and Ankle Clinic at St. Alphonsus Hospital  
Boise, Idaho

2008  Michael Simon MD  
Chairman, Department of Orthopaedics  
University of Chicago

2009  Richard J. Hawkins MD,  
Clinical Professor, University of Colorado Clinical Professor, Team Physician: Denver Broncos, Colorado Rockies & UT Southwestern. Principal, Steadman Hawkins Clinic of the Carolinas

2010  Joseph A. Buckwater, MD  
Professor & Head of The Department of OrthopaedicSurgery

2011  Jesse B. Jupiter,MD  
Professor of Orthopaedic Surgery at Massachusetts General Hospital

2012  J.A. “Tony” Herring, MD  
University of Iowa Hospitals & Clinic  
Chief of Staff, Emeritus at Texas Scottish Rite Professor of Orthopaedic Surgery University of Texas Southwestern Medical School

2013  Steven Garfin, MD  
Professor and Chair Department of Orthopaedic Surgery at UCSD

2014  William Levine, MD  
Frank E. Stinchfield Professor and Chairman, Department of Orthopedic Surgery Columbia University Medical Center

2015  Kevin Bozic, MD, MBA  
Inaugural Chair of the Department of Surgery and Perioperative Care, and Professor of Orthopaedic Surgery at the Dell Medical School University of Texas at Austin

2016  Samir Mehta, MD, MBA  
Associate Professor, Department of Orthopaedic Surgery  
Chief, Orthopaedic Trauma and Fracture Service University of Pennsylvania

2017  Mark E. Baratz, MD, M  
Program Director, Orthopaedic Surgery Hand Fellowship, Clinical Professor and Vice Chairman, Department of Orthopaedics, University of Pittsburgh Medical Center

2018  Michael Vitale, MD, MPH  
Ana Lucia Professor of Pediatric Orthopaedic Surgery & Neurosurgery  
Vice Chair, Quality & Strategy, Orthopaedic Surgery, Columbia University Medical Center

2019  Robert Anderson, MD  
Bellin Health Titletown Sports Medicine and Orthopaedic Clinic  
Green Bay, WI  
Chairman, Foot and Ankle  
Subcommittee for the NFL  
Co-Chair, NFL Musculoskeletal Committee  
Team Physician, Green Bay Packers  
Co-Founder, OrthoCarolina Foot and Ankle Fellowship
Meet the Class of 2024!

Amalie Erwood  
Atlanta, GA

Helyn Grissom  
Glen Ridge, NJ

Scott Holmes  
Hurricane, WV

Corey Jones  
Melbourne, FL

Aman Sharma  
Atlanta, GA

Brianna Siracuse  
Short Hills, NJ
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