Emory University School of Medicine
Department of Orthopaedics

The Kelly Society
Orthopaedic Journal
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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 Day Visiting Professor. Dr. Vitale clearly ranks as a leader in Orthopaedics today, and I am particularly grateful to Dr. Vitale for being with us and enriching our educational program.

I also want to acknowledge the 15+ years of dedicated and unselfish service Dr. Jim Roberson has provided to the Department, and the tremendous growth and expansion that has taken place under his Chairmanship. We can all be proud of how the Department has changed and grown. We have seen the faculty more than double in size, including a stable, excellent group of full time Grady faculty. In addition to being among the most clinically busy services at Grady and the VA Hospital, the MSK service line has become a critically important component of Emory Healthcare with approximately 1 out of every 3.5 new patients to Emory entering through Orthopedics.

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 are now also undergoing 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.
Kelly Days 2018 is truly a special event! It is an honor to host Dr. Michael Vitale as the 2018 Kelly Visiting Professor. Among is innumerable accomplishment, Dr. Vitale is widely recognized for his innovative work focusing patient safety and quality improvement in pediatric spinal surgery. 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. Vitale, thank you!

Most importantly, Kelly Day weekend gives us the opportunity to recognize the accomplishments of five very special individuals. Although Anuj, Jimmy, Laura, Robert, and Will are very unique as individuals, they share a very common thread: THEY CARE!

Over the past 5 years, they have dedicated almost every waking hour to the pursuit of knowledge, skill and the care of their patients. When an individual was faced with adversity, they responded by caring for each other. They have defined what it means to be a team. In my mind, they embody our Residency Program’s ultimate objective: To be the kind of doctor you want for your own family.

Please join me this weekend in celebrating the achievements of this outstanding group!

Tom
Dr. Michael G. Vitale is a leading New York Pediatric Spine Surgeon. He is the Ana Lucia Professor of Pediatric Orthopaedic Surgery at Columbia University Medical Center, Director of the Division of Pediatric Orthopaedic Surgery, and the Chief of the Pediatric Spine and Scoliosis Service at Morgan Stanley Children’s Hospital of New York – Presbyterian.

He specializes in spine surgery as well as non-operative treatment of complex pediatric scoliosis and other spinal disorders. He has a special interest in the treatment of patients with Early Onset Scoliosis. As a leading spine surgeon, he has pioneered numerous innovative surgical techniques, and has developed spinal instrumentation systems to improve the care of children with scoliosis.

Dr. Vitale received his Masters of Public Health from Columbia University Joseph Mailman School of Public Health and his Doctor of Medicine from the College of Physicians and Surgeons of Columbia University, which was followed by a residency in Orthopaedic Surgery at Columbia-Presbyterian Medical Center and a one year fellowship at the Children’s Hospital of Los Angeles in University of Southern California.

Currently, he serves as the director of the Pediatric Orthopaedic Research Group, and has over 100 peer reviewed research publications in the field of pediatric orthopaedics, including a number of efforts leading national guidelines aimed at improving quality and safety of pediatric spine surgery. He has received numerous national awards from the Pediatric Orthopaedic Society of North America including the Arthur H. Huene Memorial Award, the Angela M Kuo Award Young Investigator Award, the Robert Hensinger Scientific Paper Award, as well as the Hansjorg Wyss Research Award, the Frank Stinchfield Research Award, the Rosamond Kane Award in Pediatric Orthopaedic Surgery, and the Harrison McLaughin Award. Additionally, he is the recipient of the Castle Connolly’s Top Doctors award for 5 consecutive years and has been named in 50 Physicians in the US in the area of Scoliosis Care by Becker’s Spine Review.

Dr. Vitale also serves numerous roles in the national governance of the field—currently serving on the Board of Directors of the Pediatric Orthopaedic Society of North America, chairing the International Pediatric Orthopaedic Society, leading the efforts of the Scoliosis Research Society on Advocacy for Unmet Needs of Children for Pediatric Medical Devices, serving on the Executive Committee of the Children’s Spine Study Group, and is a Member of the International Pediatric Orthopaedic Think Tank.

He also leads the Conservative Treatment of Scoliosis Center, with Co-Director Hagit Berdishevsky. One of the only programs of its kind, the Center focuses on avoiding surgery with attention to scoliosis specific Schroth physical therapy and state-of-the art expert brace options including the Rigo System Cheneau brace. For the youngest children with scoliosis, Dr. Vitale runs an active Mehta casting program and has successfully used this method to reverse spinal curvature in numerous patients.

Most recently, he has developed a career interest in the area of Quality Improvement, leading the research arm of the Pediatric Orthopaedic Society of North America’s Committee on Quality, Safety, and Value, serving as the Medical Director of New York Presbyterian’s Initiative to Make Care Better, and serving as the Chief Quality Officer of the Department of Orthopaedic Surgery at Columbia University Medical Center.

Dr. Vitale is an avid skier, marathon runner, and recreational triathlete. Most of all, he enjoys spending time with his wife and four sons.
Craig Kronenberger, also known as the “The Fist” is a reputation and crisis management expert.

With more than twenty years of experience in digital communications, Craig has championed and led strategy for clients such as Paul Allen, Sheikh Al Amoudi, the White House, Disney, Amazon, GE and the country of Belize.

A serial entrepreneur and communications innovator, Craig has started companies spanning video distribution, online gaming, digital marketing to technology patents. Building on the expertise gleaned from his entrepreneurial endeavors, Craig also gained deep in-house, agency experience and served as the Global Managing Director of Strategic Growth at Edelman, the largest private communications firm in the world. At Edelman, Craig focused on identifying, operationalizing and incubating emerging capabilities for the firm. His work included areas in paid advertising, digital crisis, analytics and search marketing.

Craig also led the Southeast region for iCrossing, where he developed and on-boarded the global search governance program for Coca-Cola, which encompassed more than 200 countries and multiple brands and divisions. Craig was also instrumental in leading the digital strategy for several of CNN’s key digital products including video integration.

Prior to these roles, Craig served as Global Practice Lead for Search Marketing at Modem Media/Digitas, where he was instrumental in localizing media practices in Europe and the U.S. As practice lead, Craig led the development of the global search strategy for HP and General Motors. Prior to leading the search practice, Craig helped build the Delta’s first direct marketing initiative online, which drove over $150M in airline ticket sales through the integration of paid media and a new booking engine.

Craig received his BFA in Electronic Media and graduated from the University of Cincinnati’s Conservatory of Music.

Craig is also a co-owner of Paid Search Engine Tools, which holds several patents in search technology and bid management. He has been repeatedly recognized in the media as a leader and visionary within the digital space and has appeared on The Today Show, Wall Street Journal and CNN. Sharing his expertise with future communicators and strategists, Craig has also taught and lectured at Emory University, University of Cincinnati, Florida State and Georgia Tech.
2018 KELLY DAY AGENDA

Friday, June 8, 2018

7:00 AM  Registration & Breakfast

7:45 AM  Welcoming Remarks
Scott Boden, MD
Professor and Interim Chairman
Department of Orthopaedic Surgery
Emory University School of Medicine

Resident Research Presentation: Session I

8:00 AM  The Impact of Prophylactic Intraoperative Vancomycin Powder on Microbial Profile, Antibiotic Regimen, Length of Stay, and Reoperation Rate in Elective Spine Surgery
Zachary Grabel, MD, PGY 3

8:10 AM  Closed Suction Drainage in Acetabular Fracture Surgery: Is it Time We Take a Page from Our Arthroplasty Colleagues?
Adam Boissonneault, M.B.Ch.B., PGY 3

8:20 AM  Risk of Osteonecrosis and Complications after Delayed Treatment of Pediatric Humeral Lateral Condyle Fractures
William Carpenter, MD, PGY 5

8:30 AM  Utility of Intra-wound Vancomycin Powder in Arthroplasty Surgery
Nick Patel, MD, PGY 3

8:40 AM  Discussion:
Dr. Michael Vitale and Emory Faculty

Pediatric Case Presentation

9:00 AM  Early Onset Scoliosis
Presenter: Dr. Sandra Hobson, PGY 4
Panel: Robert Bruce, Nicholas Fletcher, Michael Vitale, Michael Schmitz

9:30 AM  Coffee Break

CHOA Lecture

9:45 AM  Pediatric Femoral Shaft Fractures in 2018: The State of the Art
Michael Schmitz, MD
Chief of Orthopaedics
Children’s Healthcare of Atlanta
Resident Research Presentation: Session II

10:20 AM  Utilization Patterns, Efficacy, and Complications of Venous Thromboembolism Prophylaxis Regimens in Primary Hip and Knee Arthroplasty as Reported by ABOS Part II Candidates
Robert Runner, MD, PGY 5

10:30 AM  A University-Based Orthopaedic ‘Focused Factory:’ Does It Provide Better Outcomes?
Jimmy Daruwalla, MD, PGY 5

10:40 AM  A Reproducible and Reliable Localization Technique for Lumbar Spine Surgery that Minimizes Unintended Level Exposure and Wrong Level Surgery
Anuj Patel, MD, PGY 5

10:50 AM  Predictors of Extended Length of Stay after Posterior Spinal Fusion for Neuromuscular Scoliosis
Laura Bellaire, MD, PGY 5

11:00 AM  Discussion: Dr. Vitale and Emory Faculty

2018 Kelly Day Lecture

11:15 AM  Introduction of 2018 Kelly Visiting Professor
Nicholas Fletcher, MD

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

Co-Director, Division of Pediatric Orthopedics
Chief, Pediatric Spine and Scoliosis Service
Morgan Stanley Children’s Hospital of New York – Presbyterian

Lunch Presentation:

12:30 PM  “Your Reputation Matters….Don’t Blow it!”
Craig Kronenberger
President, Stripe Reputation
**Resident Research Presentation: Session III**

1:20 PM  
**Total Disc Replacement Adjacent to a Multilevel Fusion in the Cervical Spine: A Biomechanical Study**  
Dale Segal, MD, PGY 3

1:30 PM  
**Ultra sound Guided Aspiration of Wrist Ganglion Cysts does not Reduce Recurrence**  
Gregory Kurkis, MD, PGY 3

1:40 PM  
**Increased Resource Utilization in Medicaid Patients following Primary Total Hip Arthroplasty**  
David Shau, MD, MBA, PGY 3

1:50 PM  
Discussion: Vitale and Emory faculty

**Quality Improvement & Patient Safety Symposium**

2:00 PM  
**Managing Orthopaedic Complexity: People, Protocols and Systems**  
Moderators: Tom Bradbury and Nick Fletcher  
Panel: Michael Vitale, Scott Boden, Will Reisman, Michael Schmitz, Bob Bruce

**Department of Orthopaedics Seed Grant & Basic Science Presentations:**

2:50 PM  
**Update and Introductions**  
Hicham Drissi, PhD  
Nick Willet, PhD

3:00 PM  
**Bone Marrow Aspirate Concentrate “Monotherapy” use in the Adult Rat Cartilage Defect Repair Model: Intraarticular versus Intraosseous Injection.**  
*Briggs Ahearn, MD, PGY 4*  
*Sameh Labib, MD*  
*Associate Professor, Sports Medicine & Foot and Ankle Surgery*

3:10 PM  
**PRIYA: Preventing Reinjury In Young Athletes**  
*Neeru Jayanthi MD*  
*Associate Professor of Orthopaedics*  
*Associate Professor of Family Medicine*  
*Emory University School of Medicine*  
*Emory Sports Medicine Center*

3:30 PM  
Closing Remarks  
*Scott Boden, MD and Thomas Bradbury, MD*

**CME credits will be issued in January 2019.**  
Please remember to provide your email address to receive your statement.
<table>
<thead>
<tr>
<th>Name</th>
<th>Fellowship Match</th>
<th>Medical School</th>
<th>Hometown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laura Bellaire, MD</td>
<td>Fellowship Match: University of Utah Salt Lake City, UT</td>
<td>Medical School: Emory University, School of Medicine Atlanta, GA</td>
<td>Hometown: Atlanta, GA</td>
</tr>
<tr>
<td>William Carpenter, MD</td>
<td>Fellowship Match: NYU/ Insall Scott Kelly Institute New York, NY</td>
<td>Medical School: Auburn University, Auburn, AL</td>
<td>Hometown: Waco, TX</td>
</tr>
<tr>
<td>Jimmy Daruwalla, MD</td>
<td>Fellowship Match: Curtis National Hand Ctr. Baltimore, MD</td>
<td>Medical School: Emory University, School of Medicine Atlanta, GA</td>
<td>Hometown: Rockville, MD</td>
</tr>
<tr>
<td>Anuj Patel, MD</td>
<td>Fellowship Match: Harvard University Boston, MA</td>
<td>Medical School: University South Alabama Mobile, AL</td>
<td>Hometown: Gadsden, AL</td>
</tr>
<tr>
<td>Robert Runner, MD</td>
<td>Fellowship Match: Hoag Institute Orthopaedic Specialty Institute Irvine, CA</td>
<td>Medical School: Emory University, School of Medicine Atlanta, GA</td>
<td>Hometown: Atlanta, GA</td>
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</tbody>
</table>
Laura Bellaire, MD  PGY-5

Pediatric Orthopaedic Surgery Fellowship
University of Utah
Salt Lake City, UT

EDUCATION:
Emory University School of Medicine
Atlanta, GA
Doctor of Medicine, May 2013

Yale University, New Haven, CT
Bachelor of Arts, May 2009

PUBLICATIONS


PENDING PUBLICATIONS

Skaggs D, Andras L, Fletcher N, Choi P, Bellaire L, Tolo V, “Don’t You Wish You Had Fused to the Pelvis the First Time: A Comparison of Reoperation Rate and Correction of Pelvic Obliquity.”
  • Podium presentation given at Scoliosis Research Society annual meeting on September 8, 2017
  • Publication pending in Spine (submitted 5/18/18)

Bellaire L, Bowman C, Fletcher N, Bruce R, “Is early discharge possible following posterior spinal fusion for neuromuscular scoliosis?”
  • Podium presentation at the 2017 EPOSNA meeting
  • Winner of the Kelly Society annual research award 2016

Fletcher N, Bellaire LL, Borden T, Bruce R, “Predictors of length of stay following posterior spinal fusion in neuromuscular scoliosis

  • Podium Presentation at the Georgia Orthopaedic Society annual meeting
  • Accepted for publication in the Journal of Orthopaedic Trauma, pending edits.
Predictors Of Hospital Length Of Stay Following Neuromuscular Spinal Fusion

Nicholas D. Fletcher, MD, Laura L. Bellaire, MD, Eric Dilbone, MD, Laura Ward, Robert W. Bruce Jr. MD

ABSTRACT:

Background: Patients with neuromuscular scoliosis (NMS) who undergo posterior spinal fusion (PSF) have historically stayed in the hospital for greater than one week after surgery. These patients’ comorbidities, nutritional and respiratory compromise, and larger rapidly progressive curves put them at greater risk of complications and prolonged stay. Accelerated discharge (AD) protocols have the ability to reduce hospital length of stay without increasing complications, however a small subset of patients is not well suited to rapid mobilization and early discharge.

Methods: 197 patients with NMS underwent PSF between 2005 and 2013 by two surgeons. These patients were divided into quartiles based on their hospital length of stay (LOS), and their charts were retrospectively reviewed for preoperative, intraoperative, and postoperative factors that were associated with their LOS.

Results: Neuromuscular diagnosis, age at surgery, gender, and the need for tube feeds were not significant predictors of length of stay. Severely involved CP patients were more likely to have extended stays (p=0.02). Major coronal Cobb angle and pelvic obliquity were also significantly higher amongst those with extended stays (p=0.002, p=0.02). Patients with lengthier surgical times, higher numbers of levels fused, presence of a pulmonary complication, need for intraoperative and postoperative blood transfusion, and need for ICU admission were significantly more likely to fall into the extended LOS group (p<0.05).

Conclusions: Several variables have been identified as significant predictors of hospital LOS after PSF for NMS. Further study is needed to identify whether benefit exists to excluding such patients from an AD pathway and whether investing greater resources in optimizing these high risk patients preoperatively with further testing and medical interventions would be of value.

Level of Evidence: Therapeutic Level III

MANUSCRIPT:

Introduction

There are multiple reasons why neuromuscular scoliosis (NMS) patients have historically required longer hospital stays after posterior spinal fusion (PSF) than their typically healthy adolescent idiopathic scoliosis (AIS) counterparts. NMS patients have higher rates of comorbidities including seizure disorder, mental retardation, reflux, and reactive airway disease. Many require tube feeds to maintain adequate levels of nutrition or tracheostomies to maintain adequate oxygenation. Those with more involved disease are unable to ambulate. Contractures and spasticity can make hygienic care difficult for their families and caregivers. All of these factors contribute to increased rates of intraoperative and postoperative complications including infection, wound dehiscence, pseudarthrosis, difficulty feeding, urinary tract infection, and respiratory failure. Historic literature cites complication rates as high as 60-70% amongst NMS patients.1-4

Historically, length of stay (LOS) amongst NMS patients has far exceeded LOS cited for AIS patients after PSF. A national database study completed in 2006 assessed 1570 NMS patients who underwent PSF and found mean LOS to be 9.2 days.5 Another national study completed ten years later in 2016 found that, over the course of the study period, which included 2154 NMS patients who underwent PSF, mean LOS declined from 9.1 to 6.7 days.6 Other smaller institutional studies in the past decade cite LOS’s ranging from 8 to 17 days, demonstrating that LOS varies considerably across regions and institutions.7-9

LOS at our institution is shorter than published averages, and an accelerated discharge (AD) pathway was implemented for NMS patients in 2008 which shortened stays further. Prior to 2008, LOS amongst patients with GMFCS 4 or 5 cerebral palsy (CP) averaged 4.9 days, and after 2008 it decreased to 4.0 days.10 In further assessing our NMS population, we found that the majority of patients stayed in the hospital for 3 to 6 days after surgery after implementing the AD pathway; however, a small number of outlier patients had very extended stays in excess of 20 days. These patients skewed our
mean LOS. We hypothesized that a small subset of NMS patients were not as well-suited for rapid mobilization, early resumption of feeds and discontinuation of drains and catheters as the majority of other patients. By reviewing the charts of NMS patients who underwent PSF, we sought to identify variables that increased risk of extended LOS after surgery, so that these patients might be better optimized and counseled appropriately prior to surgery.

**Methods**

A retrospective chart review was performed for all patients with an underlying neuromuscular diagnosis who underwent posterior spinal fusion by one of two surgeons between the years of 2005 and 2013. This list totaled 233 patients. Patients undergoing revision surgery or placement or adjustment of growth-friendly instrumentation were excluded from this study. Patients who had anterior spinal procedures were also excluded. This left 197 patients who met inclusion criteria.

The patients included in this study encompassed a wide range of neuromuscular diagnoses including but not limited to cerebral palsy (CP), muscular dystrophy, genetic and chromosomal syndromes, spina bifida, Chiari malformations, syringomyelia, traumatic brain injury, spinal cord injury, spinal muscular atrophy, and Rett syndrome. We assessed patients’ preoperative demographics and comorbidities, as well as feeding and respiratory status. GMFCS level was determined by attending physician and documented in the patient’s preoperative note. Patients with CP were stratified into two groups: less severely involved patients with ambulatory capacity (GMFCS 1-3) and more severely involved patients who were largely unable to ambulate (GMFCS 4-5). Coronal and sagittal Cobb angles and pelvic obliquity were measured on each patient’s non-traction preoperative radiographs.

Next, we reviewed patients’ operative notes, anesthesia documentation, order summaries, and progress notes during their hospital stay to determine estimated blood loss (EBL), surgical time, number of levels fused, presence of intraoperative and postoperative complications, need for transfusion of blood products, need for and length of ICU admission, and hospital length of stay. We also reviewed their postoperative clinic notes for presence of complications and readmissions.

We then divided patients into one of three groups based on their LOS, with patients staying less than 3 days falling into the first quartile, patients staying 3-7 days in the middle two quartiles, and patients staying greater than 7 days falling into the fourth quartile. After stratifying patients into these 3 groups, we analyzed each group to assess for variables that were predictive of LOS group.

**Results**

Roughly half of the patients included in this study were female (56%), and mean age at the time of surgery was 13.2 years. Fifty-three percent of included patients required a feeding tube for nutrition. The majority were stable on room air and did not require supplemental oxygen or tracheostomy prior to surgery. The majority of CP patients were nonambulatory, with 84% rated as GMFCS 4 or 5. Average max coronal Cobb angle was 63 degrees prior to surgery, and mean pelvic obliquity was 17 degrees. Length of surgery and EBL, and postoperative variables are described in Table 2.

**Table 1. Baseline patient characteristics**

<table>
<thead>
<tr>
<th>Category</th>
<th>N (%) or Mean (Std)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at time of surgery (years)</td>
<td>13.2 (3.2), (n=197)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>110/197 (56%)</td>
</tr>
<tr>
<td>Male</td>
<td>87/197 (44%)</td>
</tr>
<tr>
<td>Feeding status</td>
<td></td>
</tr>
<tr>
<td>Feeding tube</td>
<td>80/170 (53%)</td>
</tr>
<tr>
<td>PO</td>
<td>80/170 (47%)</td>
</tr>
<tr>
<td>Respiratory status</td>
<td></td>
</tr>
<tr>
<td>Room Air</td>
<td>185/197 (94%)</td>
</tr>
<tr>
<td>Supplemental O2</td>
<td>7/197 (4%)</td>
</tr>
<tr>
<td>Tracheostomy Dependent</td>
<td>5/197 (2%)</td>
</tr>
<tr>
<td>GMFCS (CP only)</td>
<td></td>
</tr>
<tr>
<td>1-3</td>
<td>22/136 (16%)</td>
</tr>
<tr>
<td>4-5</td>
<td>114/136 (84%)</td>
</tr>
<tr>
<td>Max cobb angle (deg)</td>
<td>63.4 (18.3), (n=197)</td>
</tr>
<tr>
<td>Degree of pelvic obliquity (deg)</td>
<td>16.9 (14.6), (n=182)</td>
</tr>
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</table>
Table 2. Admission characteristics

<table>
<thead>
<tr>
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<th>N (%) or Mean (Std)</th>
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<tbody>
<tr>
<td>EBL</td>
<td>612.1 (486.3), (n=194)</td>
</tr>
<tr>
<td>Length of surgery</td>
<td>4.3 (1.3), (n=197)</td>
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<tr>
<td>Number levels fused</td>
<td>14.5 (2.8), (n=196)</td>
</tr>
<tr>
<td>Pulmonary complications</td>
<td>29/197 (15%)</td>
</tr>
<tr>
<td>Required ICU</td>
<td>24/164 (15%)</td>
</tr>
<tr>
<td>Number of patients required blood transfusion intraop</td>
<td>36/195 (18%)</td>
</tr>
<tr>
<td>Units transfused intraoperatively</td>
<td>1.4 (1.2), (n=36)</td>
</tr>
<tr>
<td>Number of pts requiring blood transfusion postop</td>
<td>29/195 (15%)</td>
</tr>
<tr>
<td>Units transfused postop</td>
<td>1.4 (0.8), (n=29)</td>
</tr>
</tbody>
</table>

We found that patients had a median LOS of 4 days, and a mean LOS of 5.4 days. While the vast majority of patients are clustered with length’s of stay from 3-7 days, we found that several significant outliers existed. Of the 197 patients included in our analysis, 6 had stays in excess of 20 days, with the longest stay being 51 days (see Table 3).

Table 3. Distribution of hospital LOS

![Distribution of hospital LOS](image)

Most demographic variables were not predictive of hospital LOS. Patients’ type of neuromuscular disease, gender, age at surgery, and dependence on tube feeds for nutrition were not predictive of ultimate LOS. Respiratory status, including the need for supplemental oxygen or tracheostomy prior to surgery, trended toward but did not meet statistical significance (p=0.08).

Several preoperative characteristics, however, did correlate. Patients with more involved CP (GMFCS 4-5) were significantly more likely to fall into the extended stay group, with 90% of CP patients requiring LOS >7 days being severely involved, as compared to 10% of those patients with LOS> 7 days being GMFCS 1-3 (p=0.020). Maximum preoperative coronal Cobb angle was also predictive of LOS, with mean Cobb angle sequentially increasing by LOS group (p=0.002). Preoperative pelvic obliquity also increased sequentially, with a mean angle of 12 deg amongst those patients with LOS <3 days as compared to 21 deg amongst those with LOS >7 days (p=0.017).
Table 4. Relationship between baseline demographics and LOS groups

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<tr>
<th></th>
<th>&lt;3 days</th>
<th>3-7 days</th>
<th>&gt;7 days</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Age at surgery</td>
<td>13.3 (3.4), (n=56)</td>
<td>13.0 (2.9), (n=111)</td>
<td>13.7 (3.6), (n=30)</td>
<td>0.5642</td>
</tr>
<tr>
<td>Sex</td>
<td>Female 38/56 (68%)</td>
<td>58/111 (52%)</td>
<td>14/30 (47%)</td>
<td>0.0870</td>
</tr>
<tr>
<td></td>
<td>Male 18/56 (32%)</td>
<td>53/111 (48%)</td>
<td>16/30 (53%)</td>
<td></td>
</tr>
<tr>
<td>Diagnosis Group</td>
<td>1 32/56 (57%)</td>
<td>89/111 (80%)</td>
<td>21/30 (70%)</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>2 17/56 (30%)</td>
<td>13/111 (12%)</td>
<td>4/30 (13%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 0/56 (0%)</td>
<td>1/111 (1%)</td>
<td>1/30 (3%)</td>
<td></td>
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<tr>
<td></td>
<td>4 1/56 (2%)</td>
<td>2/111 (2%)</td>
<td>0/30 (0%)</td>
<td></td>
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<tr>
<td></td>
<td>5 4/56 (7%)</td>
<td>0/111 (0%)</td>
<td>0/30 (0%)</td>
<td></td>
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<tr>
<td></td>
<td>6 0/56 (0%)</td>
<td>3/111 (3%)</td>
<td>2/30 (7%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 2/56 (4%)</td>
<td>3/111 (3%)</td>
<td>2/30 (7%)</td>
<td></td>
</tr>
<tr>
<td>GMFCS Level, cp only</td>
<td>1-3 10/30 (33%)</td>
<td>10/86 (12%)</td>
<td>2/20 (10%)</td>
<td>0.0202</td>
</tr>
<tr>
<td></td>
<td>4-5 20/30 (67%)</td>
<td>76/86 (88%)</td>
<td>18/20 (90%)</td>
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<tr>
<td>Feeding tube</td>
<td>RA 53/56 (95%)</td>
<td>107/111 (96%)</td>
<td>25/30 (83%)</td>
<td>0.0863</td>
</tr>
<tr>
<td></td>
<td>Supp O2 2/56 (4%)</td>
<td>2/111 (2%)</td>
<td>3/30 (10%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trach 1/56 (2%)</td>
<td>2/111 (2%)</td>
<td>2/30 (7%)</td>
<td></td>
</tr>
<tr>
<td>Max Cobb angle</td>
<td>56.6 (16.9), (n=56)</td>
<td>65.3 (18.8), (n=111)</td>
<td>68.8 (15.6), (n=30)</td>
<td>0.0027</td>
</tr>
<tr>
<td>Degree pelvic obliquity</td>
<td>12.6 (14.1), (n=55)</td>
<td>18.0 (13.9), (n=98)</td>
<td>21.3 (16.4), (n=29)</td>
<td>0.0171</td>
</tr>
</tbody>
</table>

A number of intraoperative variables were found to correlate with LOS. Length of surgery was significantly longer in the prolonged LOS group, measuring an average of 1.5 hours longer amongst patients with extended stays than those with short stays (p<0.001). Number of levels fused was also significantly higher amongst the extended LOS group (p<0.001). Those patients who experienced pulmonary complications or required ICU admission were significantly more likely to fall into the extended LOS group. Estimated blood loss (EBL) during surgery trended higher but did not meet statistical significance (p=0.06).

Table 5. Relationship between intraoperative and postoperative variables and LOS groups

<table>
<thead>
<tr>
<th></th>
<th>&lt;3 days</th>
<th>3-7 days</th>
<th>&gt;7 days</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of surgery</td>
<td>3.6 (1.2), (n=56)</td>
<td>4.5 (1.1), (n=111)</td>
<td>5.1 (1.6), (n=30)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>EBL</td>
<td>481.4 (428.5), (n=55)</td>
<td>662.7 (507.8), (n=109)</td>
<td>667.9 (475.7), (n=30)</td>
<td>0.0617</td>
</tr>
<tr>
<td>No. Levels Fused</td>
<td>12.9 (3.8), (n=55)</td>
<td>15.1 (2.0), (n=111)</td>
<td>15.3 (1.7), (n=30)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Intraop Complications</td>
<td>2/55 (4%)</td>
<td>27/111 (24%)</td>
<td>7/29 (24%)</td>
<td>0.0037</td>
</tr>
<tr>
<td>Pulmonary complication</td>
<td>1/56 (25)</td>
<td>16/111 (14%)</td>
<td>12/30 (40%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Required ICU</td>
<td>4/55 (7%)</td>
<td>13/92 (14%)</td>
<td>7/17 (41%)</td>
<td>0.0025</td>
</tr>
<tr>
<td>Time in ICU</td>
<td>0.8 (0.5), (n=8)</td>
<td>3.5 (1.7), (n=13)</td>
<td>3.3 (2.0), (n=6)</td>
<td>0.0250</td>
</tr>
<tr>
<td>Neurologic deficits</td>
<td>1/56 (2%)</td>
<td>4/111 (4%)</td>
<td>2/30 (7%)</td>
<td>0.4206</td>
</tr>
<tr>
<td>Infection, delayed healing</td>
<td>1/55 (2%)</td>
<td>1/95 (1%)</td>
<td>2/22 (9%)</td>
<td>0.1062</td>
</tr>
<tr>
<td>Required ABX</td>
<td>2/56 (4%)</td>
<td>9/102 (9%)</td>
<td>3/23 (13%)</td>
<td>0.2476</td>
</tr>
<tr>
<td>Required OR</td>
<td>0/53 (0%)</td>
<td>2/106 (2%)</td>
<td>2/26 (8%)</td>
<td>0.0759</td>
</tr>
<tr>
<td>Decubitus ulcers</td>
<td>0/56 (0%)</td>
<td>1/110 (1%)</td>
<td>1/25 (4%)</td>
<td>0.3301</td>
</tr>
<tr>
<td>Cutout loosening</td>
<td>0/46 (0%)</td>
<td>2/94 (2%)</td>
<td>0/21 (0%)</td>
<td>1.0000</td>
</tr>
<tr>
<td>Bleeding</td>
<td>0/55 (0%)</td>
<td>0/111 (0%)</td>
<td>1/25 (4%)</td>
<td>0.1309</td>
</tr>
<tr>
<td>Intraop transfusion</td>
<td>2/55 (4%)</td>
<td>27/111 (24%)</td>
<td>7/29 (24%)</td>
<td>0.0037</td>
</tr>
<tr>
<td>Postop transfusion</td>
<td>2/55 (4%)</td>
<td>20/111 (18%)</td>
<td>7/29 (24%)</td>
<td>0.0079</td>
</tr>
<tr>
<td>Intraop transfusion units</td>
<td>1.0 (0.0), (n=2)</td>
<td>1.4 (1.4), (n=27)</td>
<td>1.1 (0.4), (n=7)</td>
<td>0.7800</td>
</tr>
<tr>
<td>Postop transfusion units</td>
<td>1.0 (0.0), (n=2)</td>
<td>1.3 (0.7), (n=20)</td>
<td>1.7 (1.1), (n=7)</td>
<td>0.4251</td>
</tr>
</tbody>
</table>
Conclusions
Understanding the factors that prolong hospital stay amongst patients with NMS allows physicians to better counsel patients and their families prior to surgery. Patients with more involved CP and patients with more severe curves and pelvic obliquity are more likely to require extended stays. Greater numbers would be needed to determine whether type of neuromuscular diagnosis is also a risk factor. Recent literature cites mean length of stay for patients with spinal muscular atrophy after PSF is as high as 17 days, suggesting that diagnosis may be an important factor, however greater study numbers would be needed to determine the significance of this variable.9

This data begs the question of whether patients with multiple risk factors should be excluded from AD pathways. We have found that that our AD pathway not only shortens LOS but also reduces some complications including pulmonary complications, which have historically been the most prominent complication following PSF for NMS. It is unclear whether delaying mobilization, resumption of feeds, and removal of drains and catheters would benefit these high risk patients. It is equally likely that their risk of prolonged stay and complications would be unchanged if excluded from an AD pathway. Again, further study is needed in this area.

Intraoperative and postoperative findings can also drive hospital stay. Length of surgery, numbers of levels fused, and the need for blood transfusions are all significantly linked to prolonged stays. Pulmonary complications and ICU admission are also significantly more common in the extended stay group. These factors should serve as red flags for those patients who require additional time and resources. Early vigilance and interventions may serve to minimize the complications that drive hospital LOS.

It would also be reasonable to consider whether high risk patients should undergo additional measures preoperatively to optimize them for surgery. For example, formal preoperative pulmonary function testing, respiratory treatments, and preoperative placement of feeding tubes may provide great benefit to a small subset of patients. These measures are not without cost to patients and healthcare centers, but may allow for fewer postoperative issues and improved outcomes. Limiting such interventions to those patients who stand to gain the greatest benefit will focus healthcare dollars and the efforts and time of patients' families where they matter most.

References
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PEER-REVIEWED PUBLICATIONS


PENDING PUBLICATIONS


Carpenter W, Sirmon B, Mansour A, Fletcher N. “Delayed Treatment in Lateral Condyle Fractures.”


PRESENTATIONS:


BOOK CHAPTERS:


The Impact Of Socioeconomic Status On Time To Treatment In Pediatric Lateral Condylar Humerus Fractures And The Implications Of Delay In Surgical Treatment On Complications

William Carpenter, M.D. , Keith Orland M.D. , Nick Fletcher, M.D. , Allison Spitzer

Purpose: The objective of this study was to identify the correlation between delayed surgical treatment and complications in lateral condylar humerus fractures and to identify potential socioeconomic factors contributing to delayed treatment.

Methods: A retrospective review of lateral condylar humerus fractures treated at two large urban pediatric hospitals from 2009-2012 was performed. Fractures were classified according to the Jakob classification and baseline demographics and socioeconomic variables were collected. Time from identification of lateral humeral condyle fractures in the emergency room to surgical fixation was recorded in all patients treated surgically as well as all complications.

Results: 282 lateral humeral condyle fractures were identified, of which 195 received surgical intervention. 40 (20%) of patients received delayed treatment compared with 145 (80%) of patients who received treatment on their first visit. There was no significant difference found between patients who received delayed treatment and socioeconomic factors such as insurance status (p=0.35), language (p=0.09), and distance traveled to the hospital (p=0.40). Overall the delayed treatment cohort developed a higher incidence of complications compared with patients receiving treatment on the first visit (34.5% vs 19.35). Post-operative elbow stiffness was the most common complication identified (10% delayed treatment vs 4.5% first visit) with no significant difference between the two cohorts. Other complications include infection (2.5% vs 1.9%), symptomatic hardware (0% vs 1.3%) and osteonecrosis (8.0% vs 0%) within the delayed treatment and first visit cohort respectively.

Conclusion: There was no identified correlation between socioeconomic factors and delayed treatment. Overall, there was an increased incidence of complications within the delayed treatment cohort with elbow stiffness being the most common.
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CURRENT RESEARCH PROJECTS
“Cellular Characterization of Rotator Cuff Muscle Atrophy.” Supported by the American Shoulder and Elbow Society 2016 Research Grant. In collaboration with the biomechanical engineering lab of Dr. Johnna Temenoff at The Georgia Institute of Technology. Principal investigator: Dr. Claudius D. Jarrett, MD.

“Surgical Outcomes at an Academic Orthopaedic Surgery Specialty Hospital.” Principal investigator: Dr. Scott Boden, MD.

“Perioperative Dexamethasone as Part of a Multi-modal Pain Regiment in Total Knee Arthroplasty.” Principal investigators: Dr. Thomas Bradbury, MD and Dr. James Roberson, MD

AWARDS & HONORS
Resident/Fellow Research Paper Award
Eastern Orthopaedic Association Annual Meeting, Miami Beach, FL

October, 2017

Thomas E. Whitesides, M.D. Resident Research Award, Third Place
Georgia Orthopaedic Society Annual Meeting, Sea Island, GA

October, 2017

Delegate to Resident Leadership Forum
American Orthopaedic Association, Charlotte, NC

June, 2017

Resident Research Award
Kelly Society Research Symposium, Emory University School of Medicine

June, 2016
A University-Based Orthopaedic ‘Focused Factory:’ Does It Provide Better Outcomes?

Jimmy Daruwalla, MD, Poonam Dalwadi, BS, Scott D. Boden, MD, Michael B. Gottschalk, MD

Abstract
Recent publications on specialty hospitals and ‘focused shop’ surgical facilities have reported improved outcomes compared to general, multi-specialty hospitals. However, the validity of these data has been questioned. Specifically, critics claim that these hospitals selectively choose only the healthiest patients and the most straightforward of cases. Additionally, many of these facilities are physician-owned, further introducing potential bias into reported outcomes. Our study sought to clarify this debate by comparing the outcomes of total joint arthroplasty performed at our general university hospital versus when performed at our orthopaedic-dedicated focused facility, which undertakes a high case and patient complexity and is not physician-owned. Our retrospective database study demonstrated a significantly lower rate of periprosthetic joint infection (p = .0059), pulmonary embolism (p = .0001), and myocardial infarction (p = .0003) following total joint arthroplasty performed at our university’s orthopaedic-focused facility compared to our university’s general hospital. We also observed a decreased average length of stay by almost one full day. Rates of DVT were not statistically different between the two facilities (p = .9563). Our data help to support the theory that certain adverse outcomes after total joint arthroplasty are decreased when performed at an orthopaedic-focused hospital versus when done at a general hospital. Our study, based in a university hospital system, also helps to account for potential biases, such as the selective treatment of healthier patients with less complicated pathology, in prior work that demonstrates superior outcomes associated with specialty-focused hospitals.

INTRODUCTION
The recent development of surgery specialty hospitals has sparked controversy not only within academic institutions, but also in the political and public realms1-3. Advocates for the development of specialty surgery hospitals claim that these facilities can provide higher quality care in a more efficient manner by focusing available resources on a smaller number of services and procedures. Thus, patients treated in these hospitals may theoretically enjoy better care, comfort, and convenience, all with fewer complications3-4. Opponents say specialty surgery hospitals lead to the overuse of medical care and threaten the welfare of general hospitals5. Specialty hospitals have also been accused of “cherry picking”, i.e. focusing on the most profitable patients by selectively treating those who are well-insured (e.g. not accepting Medicare/Medicaid) and from higher socioeconomic classes. Such a practice would introduce bias into previous data demonstrating improved outcomes in specialty hospitals5-7. More complex and challenging patients may also be referred away from these hospitals, further biasing reported outcomes8-9. Additionally, as many specialty hospitals are physician-owned, potential conflicts of interest that influence practice patterns are also a point of contention5,10. As the United States’ health care system struggles to balance access to care, quality, and cost, the debate on the utility of specialty surgery hospitals is more relevant than ever.

Nevertheless, the impact of specialty surgery hospitals on the quality, efficiency, and cost of delivering surgical health care is largely unknown. Moreover, very few studies have assessed outcomes in specialty orthopaedic hospitals, the largest category of specialty hospitals11. In one study, there was a 40% decreased risk of adverse outcomes after total hip or knee arthroplasty when performed in specialty hospitals compared to general hospitals8. Another study demonstrated that, as the degree of orthopaedic specialization increased across hospitals, the odds of adverse outcomes decreased progressively4. While these studies present promising data on the potential benefit of specialty surgery hospitals, they include data from many private,
physician-owned orthopaedic specialty hospitals that are susceptible to the potential biases outlined above. As such, these studies do little to refute the arguments that certain confounders, such as the selective admission of healthier and well-insured patients, have a significant impact on the results. In fact, Cram et al. found that patients undergoing surgery at orthopaedic specialty hospitals had fewer comorbid medical conditions and were more likely to live in areas with higher home values and per capita incomes8, supporting the criticism that specialty hospitals demonstrate better outcomes in part by selectively treating healthier and better-insured patients. Interestingly, no academic or university specialty hospitals were included in this analysis.

To date, no study has compared the outcomes of orthopaedic procedures performed at a university-based general versus orthopaedic-focused hospitals. Thus, the purpose of our study is to compare the rates of adverse outcomes and length of stay (LOS) following total hip and knee arthroplasty when performed at our orthopaedics hospital versus when performed at our general university hospital. We believe that comparative outcomes data from our university-based orthopaedics hospital would be uniquely suited to address the potential biases from prior studies on specialty hospitals, since patients with all insurance payers, including Medicare and Medicaid are treated. Furthermore, as the hospital is part of the university system, physician ownership is also not a potential bias. Finally, our university-based orthopaedic hospital is a tertiary- and even quaternary-referral center, where case complexity is often extremely high; a multitude of challenging, revision procedures are performed regularly. An increased case complexity, and therefore complication rate, is a well-accepted characteristic of academic teaching hospitals. In fact, recent changes to the payment system by the Centers for Medicare and Medicaid Services (CMS) have increased reimbursements to teaching hospitals since these facilities generally admit more severely ill patients.

We hypothesize that patient outcomes after total hip and knee arthroplasty will be improved in patients undergoing surgery at our orthopaedic-focused hospital versus those patients undergoing the same surgeries at our general university hospital. This data will lend support to the argument that the improved outcomes associated with specialty orthopaedic hospitals are due to the inherent benefits of hospital specialization and independent of factors like case complexity and patients’ insurance type.

**METHODS**

**Participant Selection**

After Institutional Review Board approval of this retrospective cohort study, we identified all patients who underwent a primary or revision total hip or knee arthroplasty at our university’s orthopaedics and spine hospital from September, 2008 (the date the hospital opened) through October, 2012. We also identified patients undergoing the same procedures at our university’s general hospital until August, 2008 (when our service moved to the specialty hospital). Data collection from the general hospital was started from January, 2004, in order to collect data over the same length of time from both hospitals. Patients were identified from the Emory University Information Technology Medical Coding database with the use of the Current Procedural Terminology (CPT) codes and International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure codes. The medical records of these patients were reviewed for the outcome measures of interest (listed below), again using CPT and ICD-9-CM codes, which can be pulled using the data warehouse.

**Outcome Measures and Control Data**

Our primary outcome measures are a set of postoperative complications, including periprosthetic infection, pulmonary embolism (PE), deep vein thrombosis (DVT), and myocardial infarction (MI). We also reported on length of stay (LOS). All events were considered complications if they happened within 90 days after surgery, with the exception periprosthetic infection, for which there was no time limit.
The same surgeons performed all procedures at both hospitals. Thus, to serve as a control for other factors that may account for an improvement in outcomes besides the transition from a general to specialty hospital, such as increasing surgeon experience, we also collected the same data from another general university hospital within our academic system from January 1, 2004 to October, 2012 and assessed for a trend in the same outcome measures over this time. Using publicly-available data on the internet, we obtained the case mix index (CMI) for other academic and private hospitals in our city and state so that we could compare the relative case complexity of our hospital to regional norms.

**Statistical Analysis**

The incidence of each postoperative complication was calculated for the two hospitals being compared. Differences between the outcomes of patients in the orthopaedic specialty hospital and those in the general hospital were compared with the use of Chi Square Analysis (N > 10 frequency) and Fisher’s exact test (N < 10 frequency). JMP Pro 12 (Cary, NC) was used to calculate the statistics.

**RESULTS**

Within our data collection period, a total of 7461 total hip or knee arthroplasty procedures, including primary and revision cases, were performed. 3704 total hip or knee arthroplasty procedures were performed at our university specialty hospital and 3757 procedures were performed at our general hospital.

Periprosthetic joint infection occurred in 0.60% of patients at the orthopaedics hospital, compared to 1.3% of patients at the general hospital (p = .0059). PE occurred in 5 (0.13%) patients at the specialty hospital and in 26 (0.69%) at the general hospital (p = 0.0001). DVT occurred in 33 (0.89%) patients at the orthopaedics hospital, compared to 22 (0.59%) at the general hospital (p = 0.9536). Finally, we observed 8 (0.22%) MIs in patients at the orthopaedics hospital versus 30 (0.80%) patients at the general hospital (p = 0.0003). Length of stay significantly reduced from an average of 3.55 days at the general hospital to 2.34 days at our orthopaedics hospital.

Data from a second, ancillary general university hospital was analyzed as a control to show that time alone (a surrogate for surgeon experience) did not account for an improvement in outcomes in our data. We saw no difference in adverse outcomes following total joint arthroplasty performed before versus after September, 2008 (the time when our orthopaedics service moved from the main general hospital to the orthopaedics hospital). Specifically, there was no difference in the frequency of periprosthetic joint infection (p = 0.7868), PE (p = 0.8011), or DVT (p = 1.000).

Average CMI for our university-based orthopaedics hospital was 2.8203. The average CMI for a sample of hospitals in our metro area outside of our university system was 2.6162 (range: 2.4993–2.7853). When parsing out our average CMI data by payer type, CMI for patients with private insurance was 2.1777, while CMI for patients covered by CMS was 2.253.

**DISCUSSION**

As hypothesized, we demonstrate that the incidence of several major adverse outcomes following total joint arthroplasty is lower when performed at an orthopaedics specialty hospital than when performed at a general hospital. Specifically, we found significantly lower rates of periprosthetic infection (p = .0059), PE (p = 0.0001), and MI (p = 0.0003). We also demonstrated a lower average length of stay by more than one full day. Given the devastating nature of infections in the setting of total joint arthroplasty, we are very encouraged by these findings, which reflect what we have observed anecdotally since transitioning the arthroplasty service to the orthopaedics specialty hospital.
In a climate of increasing healthcare costs and a focus on evidence-based therapies, efforts to find value in our healthcare practices are more critical than ever. As such, the development of specialty hospitals was designed to streamline and expedite patient care, thereby improving outcomes. However, despite a rise in the number of these facilities in operation, published literature validating their efficacy is relatively sparse. Furthermore, the existing data that does support specialty hospitals has been criticized, mostly pertaining to biases in patient selection. Thus, our study was designed to investigate the potential efficacy of an orthopaedic specialty hospital in improving postoperative outcomes while attempting to control for these biases. As a university based orthopaedic specialty hospital that serves as a tertiary and quaternary referral center for much of the southeastern United States, case complexity and patient comorbidity is higher than average. Accordingly, we observed a higher CMI (2.8203) in our university-based orthopaedic specialty hospital compared to all other local and regional hospitals outside of our university system for which data was publically available (average = 2.6162). Thus, our 90-day complication and CMI data support the claim that, even in the setting of increased case complexity, our transition to a dedicated orthopaedic specialty hospital resulted in a lower rate of complications. This was observed all while also enjoying a shortened average length of stay.

Most likely, the decrease in adverse postoperative outcomes and improvements in LOS observed in this study is the multifactorial, cumulative effect of many policies and interventions delivered in a team-based approach. The delivery of such a coordinated and cooperative approach to healthcare is facilitated by specialty hospitals, where a narrower scope of practice allows providers and ancillary staff to focus on more targeted tasks to improve care. For example, it is possible that the initiation of physical therapy on postoperative day zero may have contributed to the lower incidence of PE and shortened LOS observed in our study. Rarely occurring at our general hospital, it is commonplace at our orthopaedics hospital for patients to get out of bed on postoperative day zero with their therapists, who are more comfortable and attuned to arthroplasty-specific protocols and patients. Similarly, possible explanations for a decrease in infection rate seen at our orthopaedics hospital include shorter operative times and/or a concerted focus on pre-, intra-, and post-operative prophylaxis techniques, though our study is not designed to answer these theories.

No significant difference (p = .9536) in the rate of postoperative DVT was observed. We hypothesize that the occurrence of a DVT is perhaps mostly related to factors intrinsic to a patient’s physiology rather than the implementation of various prophylactic measures. Thus, hospital factors may not have as much of an influence on its incidence. It is important to note that our pharmacologic prophylaxis protocol did not change after the transition from our general hospital to the orthopaedics hospital.

The same surgeons who were performing total hip and knee arthroplasties at our general hospitals performed the surgeries studied at our orthopaedics hospital. This helps exclude a potential confounding variable from our data. To help demonstrate that increasing surgeon experience over time did not account for the decrease in postoperative adverse outcomes, we studied the trend in these same outcomes at a different general university hospital over the same time period. We saw no difference in the rate of infection, DVT, PE, or sepsis over time at this hospital. These data help support the theory that the improvement in outcomes observed at our specialty hospital are likely not due to improvement in surgeon technique over time.

Several limitations of our study design and data are worth noting. Firstly, it is a retrospective, database study and thus susceptible to several inherent biases that cannot be controlled for. As a database study, we assume that all CPT/ICD-9 codes were entered accurately, though variation in documentation can easily result in under- or over-reporting of complications. Future studies should aim to prospectively collect such data, as well as obtaining patient reported clinical outcome measures.
CONCLUSION

Our data help to support the theory that adverse outcomes after total joint arthroplasty are decreased when the procedure is performed at an orthopaedic-focused hospital versus when done at a general hospital. Our study, based in a university hospital system, also helps to eliminate potential biases, such as the selective treatment of healthier patients with less complicated pathology, from prior work that demonstrate superior outcomes associated with specialty hospitals.

REFERENCES

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Observed Patterns of Cervical Radiculopathy: How often do they differ from standard distribution? NASS Annual Meeting Orlando, FL October, 2017
Open Reduction Internal Fixation with Primary Total Hip Arthroplasty for Posterior Column Posterior Wall Acetabular Fracture. - Atlanta Trauma Symposium  Atlanta, GA May, 2015
A Reproducible And Reliable Localization Technique For Lumbar Spine Surgery That Minimizes Unintended-Level Exposure And Wrong-Level Surgery

Anuj Patel, MD, Robert P. Runner, MD, Poonam Dalwadi, BS, Matthew Pombo, MD, Kyle Hammond, MD Study Coordinators: Patricia Bush Ed.D

BACKGROUND CONTEXT: Exposure of unintended levels (defined as a spinal segment outside the intended surgical levels) is unnecessary and potentially adds to operative time and patient morbidity. Wrong-level surgery (defined as decompression, instrumentation, or fusion of a spinal segment not part of the intended surgical procedure) clearly adds to morbidity as well as putting the surgeon at medicolegal risk.

PURPOSE: To describe a localization technique for posterior lumbar spine surgery to minimize both unintended-level exposure and wrong-level surgery.

STUDY DESIGN: Consecutive case series

PATIENT SAMPLE: 1,986 consecutive posterior thoracolumbar operations performed from January 2010 to January 2017 using this technique were reviewed.

OUTCOME MEASURES: The primary outcome measure was the incidence of unintended-level exposure and wrong-level surgery.

METHODS: This localization technique was consistently used for determination of skin incision, soft tissue dissection, and identification of spinal levels for all patients undergoing posterior lumbar surgery during the time interval noted. Two spinal needles are inserted under sterile technique 3cm lateral to the midline prior to incision at the approximate cranial and caudal aspects of the anticipated incision based on external landmarks. A cross-table lateral x-ray prior to incision is obtained and the actual incision is adjusted based on the location of the spinal needles. Once dissection is carried down to the facet capsules, spinal needles are then placed in adjacent facets and a second cross-table lateral film is obtained to confirm appropriate levels. A retrospective review of all posterior lumbar cases was performed to determine the incidence of unintended-level exposure and wrong-level surgery using this technique.

RESULTS: There were no wrong-level surgeries during this time period. There were 6 (0.30%) cases of unintended-level exposure.

CONCLUSIONS: The technique described provides surgeons with a reliable, accurate, and easily reproducible method for localizing surgical levels during posterior lumbar spine surgery while minimizing exposure of uninvolved areas. This technique offers distinct advantages over previously proposed protocols and may lead to a widely accepted system for intraoperative spinal level identification.

KEY WORDS: Wrong-level surgery, incorrect-site surgery, posterior lumbar spine surgery, localization, novel technique, complication, exposure

INTRODUCTION: Current spine literature reflects a heterogeneous grouping of intraoperative protocols to identify the correct surgical level in posterior lumbar spine surgery.1-5 In addition, Mody et al has shown that there is variable use of these protocols within the spine surgery community.6 These variable and potentially unreliable techniques
can result in incorrect spinal level localization which puts surgeons at risk of two main complications: exposure of an unintended spinal level during dissection and wrong-level decompression or instrumentation.

A recent systematic review by Devine et al listed the incidence of wrong-level spine surgeries in the literature ranging from 0.09 to 4.5 per 10,000 surgeries. Such an error can have a social and emotional impact on the patient-doctor relationship as well as serious medicolegal implications. More importantly, wrong-level surgery may fail to address the patient’s symptoms for which they pursued operative treatment in the first place.

Unintended-level exposure, in which a surgeon dissects down to a spinal level that was not part of the original surgical plan, has been reported to occur in anywhere from 1.3 to 15% of cases. Though exposing an unintended level can be corrected intraoperatively and is distinct from wrong-level surgery, unintended-level exposure in itself carries potential morbidity including increased length of incision, increased operative time, and greater soft tissue dissection. Additionally, exposing or dissecting the wrong facet capsule could potentially lead to additional levels requiring fusion or earlier onset of adjacent level degeneration.

The continued incidence of wrong-level surgeries makes the lack of a nationally recognized standard for proper level identification among spine surgeons concerning. We present a detailed description of an efficient localization technique and its results when used in posterior lumbar spine surgery (both decompressions and fusions). Our goal is to devise a reliable standard for proper level identification and thereby minimize unintended-level lumbar spine exposure and eliminate wrong-level surgery.

MATERIALS AND METHODS:
Localization Technique
A standard method for localization was used for all patients that underwent a posterior lumbar spine surgery (both decompressions and fusions) since the method was initiated in January 2010. Patients are positioned prone on the operating room table. Preoperative imaging is printed, hung in the rooms, and visible to all staff. The correct levels for the consented surgery are clearly identified and marked by the attending surgeon on anterior-posterior and lateral radiographs as well as sagittal magnetic resonance imaging (MRI) cuts. The planned skin incision is also marked on the preoperative lateral radiograph. In accordance with World Health Organization (WHO) procedures, the circulating nurse initiates a time-out procedure prior to incision which allows all providers in the room to introduce themselves and confirms the patient’s name, medical record number, procedure, and surgical site, including spinal level and side that is indicated on the patient’s consent form.

The patient’s lumbar skin is then disinfected and prepped with DuraPrep™ surgical solution (3M™, St Paul, MN) in the standard fashion. Based on external anatomic landmarks such as the top of the iliac crest, two spinal needles are then inserted using sterile gloves through the skin into the paraspinal muscles (Figure 1). These needles are directed exactly perpendicular to the floor - approximately 3 cm lateral to the spinous processes to avoid inadvertent dural puncture – and placed at the levels corresponding to the estimated proximal and distal extents of the skin incision desired for the given operation. A cross-table lateral radiograph is then taken with the two needles in place prior to draping (Figure 2). The image is reviewed and printed for the room, confirming both spinal needles, sacrum, and indicated surgical levels are visible in the image. The estimated cranial and caudal aspects for an appropriate skin incision are then marked on the lateral radiograph image prior to draping (Figure 3). The patient is then draped in standard sterile fashion. The location of the needles is marked with a line perpendicular to the spine (Figure 4) prior to removing the needles and covering the surgical site with Ioban™ (3M™, St. Paul, MN). Based on the location of the needles on the cross-table image, we then determine or adjust the exact skin incision that corresponds to the proposed incision that was marked on the lateral radiograph preoperatively (Figure 5). The skin is incised and dissection is then carried down through fascia to the facets of interest, leaving the facet capsule completely intact. On one side (i.e., either left or right),
a spinal needle is then placed superficially in one or two facet joints. One needle is sufficient for a one level decompressive procedure; two consecutive needles are placed for multilevel decompressions or when performing one or more level fusions. This time, the needles are ideally placed parallel to the corresponding disc space, so that on imaging the needles will “point” to the operative level(s) of interest. A second cross-table lateral radiograph is then taken to include both needles in the facet joints, the sacrum, and the indicated surgical spinal levels. The correct level in the lumbar spine is then confirmed by identifying the facet joints in which the spinal needles are placed. The facet joints are then clearly marked with a surgical pen, the spinal needles are removed, and the case proceeds for exposure, decompression and/or instrumentation.

Methods
After obtaining approval from the institutional review board all patients who underwent posterior lumbar or thoracolumbar decompression or instrumentation by a single surgeon at an academic institution between January 1, 2010 and January 1, 2017 were identified by ICD-9-CM and CPT codes. We excluded patients who did not have a cross-table lateral radiograph of the spinal needles in the facet capsule available for review in the medical record, likely due to errors in saving the images. Medical charts were reviewed for patient demographics (age, gender) and operative plan.

The intraoperative cross-table lateral radiographs were reviewed to determine the incidence of unintended-level exposure. A correct level exposure was defined by at least one needle being in an appropriate facet capsule given the intended operative plan (Figure 6). An unintended-level exposure was defined by no spinal needles placed into appropriate facet capsules for the operative plan (Figure 7).

Routine postoperative upright anterior-posterior and lateral radiographs of the lumbar spine were obtained on all instrumented patients after mobilization with physical therapy and prior to discharge in order to verify treatment of the correct spinal level. Patients who underwent decompression without instrumentation had postoperative radiographs at the 6-week follow up while fusion procedures had a minimum of 6-month radiographs. The respective postoperative imaging for every patient was reviewed and compared to the original procedure description in the operative report in order to determine the incidence of wrong-level surgery. A wrong-level surgery was defined as decompression, instrumentation, or fusion at a level not designated in the procedure description section of the operative report.

RESULTS:
2,073 posterior lumbar or thoracolumbar operations using the technique described qualified for inclusion in this study. Of these, 87 cases did not have a cross-table lateral radiograph saved into the online viewing system and were excluded from the study. There were 1,986 cases included in the final analysis.

The surgically treated levels were as follows: T2 in 1 procedure, T3 in 4 procedures, T4 in 9 procedures, T5 in 9 procedures, T6 in 10 procedures, T7 in 10 procedures, T8 in 11 procedures, T9 in 14 procedures, T10 in 50 procedures, T11 in 64 procedures, T12 in 76 procedures, L1 in 137 procedures, L2 in 447 procedures, L3 in 914 procedures, L4 in 1620 procedures, L5 in 1789 procedures, and S1 in 735 procedures (Figure 8).

There were 6 (0.30%) cases in which no facet-level spinal needle was at the intended operative level, indicating unintended-level exposure. There were zero wrong-level decompressions or instrumentations during this time period as determined by the postoperative radiographs. All 1,986 patients had postoperative radiographs that confirmed the correct levels – none were lost to follow up in that regard.

DISCUSSION:
Wrong-level spine surgery is a relatively rare occurrence but can be more difficult to prevent than wrong-site surgeries in other surgical fields. Especially in the setting of increased body mass, transitional lumbar vertebral segments, severe spondylosis or deformity, and revision lumbar operations, identifying the appropriate surgical
level is seemingly straightforward but in actual practice can at times be very challenging. Our goal is for the proposed protocol to serve as a reliable and easily reproducible method of level localization that will improve upon the protocols described below, namely in its ability to minimize unintended-level exposure and wrong-level surgery. Using this technique, the occurrence of unintended-level surgery was 0.3% and that of wrong-level surgery was 0%.

Comparison to Other Protocols

There have been several previously proposed protocols to address the issue of wrong-level and wrong-side spine surgeries; however, we believe that our novel technique offers distinct advantages. Mitchell et al proposed the “knife check strategy,” where the scrub nurse verifies the surgical site with the surgeon just prior to incision.4 Jhawar et al suggested the use of the “ABCD pause” method, which involves a pre-incision review of the operative schedule and diagnostic imaging by the entire surgical team.3 Notably, this time-out does not address the issue of wrong-level error. The Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) instituted a universal surgical protocol consisting of a three-step process where the operative plan is verified with the patient preoperatively, the operative site is marked, and a surgical time-out is executed prior to starting the procedure.2 While these protocols have been effective in outlining the importance of preoperative site verification, none of them incorporate the use of intraoperative radiography, which is obviously essential in the setting of spine surgery in order to verify not only the correct region (i.e. the posterior lumbar spine), but also the correct level(s) (eg. L4-L5).

Ebraheim et al demonstrated that reliance solely on palpation of anatomic landmarks is an unreliable method for level identification in posterior lumbar spine surgeries.14 The use of anatomic landmarks is only further complicated when operating on obese patients. The importance of incorporating intraoperative imaging for localization of the correct level in spine surgery has been recognized by several studies.9, 15-17 Ammerman et al found a 15% incidence of wrong-level exposure in the lumbar spine without the use of confirmatory radiograph.8

Some protocols exist that integrate the use of intraoperative imaging. Wong et al established the “Sign, Mark, and X-ray” program, shortened to SMaX. This protocol consists of signing the surgical site preoperatively, marking the level with a radiopaque marker, and confirming the correct level with a radiograph of the spine with the marker in place. A comprehensive surgical time-out is also included.1 In 2010, Irace et al proposed the IRACE method, which incorporates components of both the SMaX program and the “knife check strategy.” In this method, a wire is placed in the cranial spinous process of the appropriate spinal level and lateral fluoroscopy is used to confirm the correct level. Following confirmation, the superficial aspect of the wire is cut and a surgical time-out process is employed in which the level and side of the procedure are verified. Additional fluoroscopic confirmation is only utilized in cases of challenging anatomy or when a subtotal arthrectomy is planned.5

When comparing the technique proposed in this paper with the aforementioned protocols, we believe that our technique offers several advantages. First, we recognize the importance of the detailed surgical time-out process and encourage the use of a refined method similar to the WHO Surgical Safety Checklist or the one proposed by Irace et al.5, 13 Our technique focuses upon improvement of intraoperative spinal level confirmation via the use of intraoperative imaging. Our technique utilizes lateral radiographic confirmation using spinal needles as radiopaque markers at both the level of the skin and the facet joints, as opposed to the IRACE method, which only uses routine fluoroscopic imaging at the level of the skin. Our protocol serves as a second line of defense against wrong-level error. It also avoids the potential complications involved in using a buried wire as a guide for dissection as described in the IRACE method, which include mobilization of the wire during dissection and unintentional retention of the wire postoperatively. The 0% incidence of wrong-level surgeries across the 1,986 posterior lumbar spine cases performed in this study demonstrates the efficacy and reliability of this technique for spinal level localization. Additionally, this technique does not add to intraoperative time. The spinal needles can be inserted in a few seconds and the cross-table lateral radiograph
can be obtained while the surgeons are scrubbing. The use of cross-table radiographs rather than C-arm fluoroscopy allows for more detailed evaluation of bony structures for a clearer interpretation of levels and comparison to preoperative radiographs. In fact, although beyond the scope of this study, we believe that this method may actually save operative time, because the first radiograph guides the skin incision and therefore time is not wasted exposing unnecessary levels.

Our method specifically avoids marking or considering the spinous processes, which we believe is a major cause of improper interpretation of level. For lumbar surgery, we believe that a marker on the facet is preferable to the spinous process for the following reasons. First, the facet complex represents the motion segment being operated upon and is co-linear with the disc, making it easy to verify the surgical level on a lateral x-ray. In addition, because the facet is immediately adjacent to the pedicle, marking the facet makes it easy to identify the pedicle being instrumented. In contrast, because the spinous process extends distally from its origin to overlap the lamina caudal to it, it is generally not co-linear with the motion segment being operated upon and has no reliable relationship to the pedicle, facet, or disc on a lateral x-ray. This variability in the relationship between the spinous process with the disc, facets, and pedicles can lead to confusion in interpreting intraoperative lateral x-rays, especially in the setting of severe degenerative changes or scoliosis. Second, the spinous process is often not well visualized on portable intraoperative x-rays, especially in larger patients, whereas the facets and discs are almost always radiographically visible.

An additional potential benefit to the proposed technique is the preoperative determination of approximate proximal and distal extent of the skin incision. The routine employment of two spinal needles to define these boundaries helps to guide dissection down to the desired levels, thereby decreasing the incidence of unintended-level exposure. The current study reports a 0.30% incidence of unintended-level exposure compared to the reported values ranging from 1.3 to 15% in other studies.

When analyzing the 6 cases of unintended-level exposure, we found that only one facet-level needle was used in 4 of the cases. Inherently, using only one needle to localize the operative levels will be less accurate than using two. If these cases in which only one facet-level needle was used are excluded, the incidence of wrong-level exposure decreases to 0.1%. Therefore, we recommend the use of two facet-level spinal needles in every case with the exception of single-level decompression procedures in which only one level needs to be exposed. In another case of unintended-level exposure, the patient was obese with a BMI of 38 kg/m2, making the interpretation of imaging considerably more difficult. In all of these cases, the protocol allowed the surgeon to identify and correct the unintended-level exposure before going on to decompress or instrument the intended spinal levels.

The reproducibility of any proposed protocol is a necessary consideration. This series was carried out at an academic center, and the localizations were performed by a combination of junior residents, senior residents, fellows, and the single attending. We feel that the low wrong-level surgery and unintended-level exposure rates demonstrate the efficacy of this localization protocol when utilized by surgeons at any level of experience.

In a survey by Groff et al, to all of the members of the Joint Section on Disorders of the Spine and Peripheral Nerves, 88.6% of surgeons answered that they had exposed the wrong level at some point in their career. Even if correctable intraoperatively, exposure of the wrong site can lead to increased operative time, incision length, and soft tissue injury. The proper determination of the proximal and distal extent of the skin incision prior to any deep dissection decreases the size of the skin incision and also soft tissue injury. By establishing a reliable, reproducible, and efficient technique for spinal intraoperative level identification, we have been able to avoid unintended-level dissections and minimize the incidence of associated complications.

CONCLUSIONS:
Unintended-level exposure and wrong-level surgery continue to occur despite adherence to current national guidelines. This study shows that our technique of localization is associated with a very low rate of unintended-level exposure and no wrong-level surgeries in a large series of posterior thoraco-lumbar operations.
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Figure 1. Two spinal needles are then inserted using sterile gloves through the skin into the paraspinal muscles.
Figure 2. Cross-table lateral radiograph is then taken with the two needles in place prior to draping.
Figure 3. Image is reviewed and printed for the room, confirming both spinal needles, sacrum, and indicated surgical levels are visible in the image for a L4-5 fusion for spondylolisthesis
Figure 4. Location of the needles is marked with a line perpendicular to the spine prior to removing the needles and covering the surgical site with loban™.
**Figure 5.** Example of superficial localization cross-table lateral radiograph in a patient undergoing posterior lumbar fusion with instrumentation of L2-L3, allowing the surgeon to adjust their planned incision for the intended operative levels.
Figure 6. Example of correct deep localization cross-table lateral radiograph with spinal needles inserted into the L2/L3 and L3/L4 facet capsules in a patient undergoing lumbar decompression of L3-S1, since the L3-4 facet is at the level of the caudal needle.
Figure 7. Example of a unintended-level exposure with spinal needle inserted into the facet capsule of L2/L3 in a patient undergoing lumbar decompression of L4-L5, since the needle does not mark an area that is within the intended surgical field
Figure 8. Graphical representation of the number of procedures per spinal level included in the case series.
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Senior Editor with Aaron Morgenstein, MD. Publication in December 2017. Fifty-chapter textbook outlining
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Frailty Predicts Mortality and Complications in Chronologically Young Patients with Traumatic Orthopaedic Injuries; Mara Schenker, MD
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Ossification of the Posterior Longitudinal Ligament Causing Severe Progressive Cervical Myelopathy: A Case Presentation; John G. Heller, MD
Utilization Patterns, Efficacy, and Complications of Venous Thromboembolism Prophylaxis Regimens in Primary Hip and Knee Arthroplasty as Reported by American Board of Orthopaedic Surgery Part II Candidates

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Background:
Many strategies for venous thromboembolism (VTE) prophylaxis following hip and knee arthroplasty exist, with extensive controversy regarding the optimum strategy to minimize risk of VTE and bleeding complications. Data from the American Board of Orthopaedic Surgery (ABOS) Part II (oral) Examination case list database was analyzed to determine efficacy, complication rates and prescribing patterns for different prophylactic regimens.

Methods:
The ABOS case database was queried utilizing Current Procedural Terminology (CPT) codes 27447 and 27130 for primary total knee and hip arthroplasty, respectively. Geographic region, patient age, gender, DVT prophylaxis regimen and complications were obtained. Minimal prophylaxis patterns were considered if only sequential compression devises (SCDs), aspirin or no prophylaxis strategy was utilized. Aggressive VTE prophylaxis patterns were considered if any of low molecular weight heparin (enoxaparin), warfarin, rivaroxaban, fondaparinux or other strategies were used.

Results:
14,089 cases of primary joint arthroplasty were identified from 2014-2015. Average age was 64.5 years; 57.7% were female. The national rate of minimal VTE prophylaxis regimens was 37.2% while aggressive regimens were used in 62.8% of patients. Significant regional differences in prophylactic regimen patterns exist between the 6 regions. Use of minimal intensity prophylaxis strategy was significantly associated with patients having no complications (94.7% vs 91.8%). Use of aggressive prophylaxis patterns was associated with higher likelihood of a moderate thrombotic event (1.98% vs 0.62%), moderate bleeding event (4.48% vs 3.17%), severe bleeding event (1.80% vs 1.41%) and death within 90 days (0.65% vs 0.36%). There was no significant difference in the rate of fatal pulmonary embolism between minimal or aggressive prophylactic regimens.

Conclusions:
It was not possible to ascertain the individual rationale for use of more aggressive VTE prophylaxis regimens; however, more aggressive regimens were associated with higher rates of bleeding and thrombotic complications. Less aggressive regimens were not associated with a higher rate of thrombosis. This analysis indicates that a less aggressive VTE prophylaxis regimen is safe and effective in appropriate patients when compared to more aggressive regimens.

Level of Evidence: Therapeutic Level III.

Disclaimer: All views expressed in the study are the sole views of the authors and do not represent the views of the American Board of Orthopaedic Surgery.
INTRODUCTION
Joint arthroplasty is expected to exponentially increase in the coming years with up to 527,000 annual primary total hip arthroplasty (THA) and 3.48 million annual primary total knee arthroplasty (TKA) procedures by 2030. A major controversial issue with arthroplasty care is how best to manage post-operative venous thromboembolism (VTE) prophylaxis. Multiple regimens exist and the selection is often made subjectively based on local or regional practice patterns and medicolegal environment.

It is important to note that there is a spectrum of VTE among patients. Non-clinically significant deep vein thrombosis (DVT) rates can be as high as 12.6% - 31.1% following primary arthroplasty. Clinically significant DVT rates are significantly lower at 0.75% - 2.1%. The more significant VTE complication of a pulmonary embolism (PE) ranges from 0.41% to 1.93%. However, even when matched cohort of patients with non-fatal VTE were compared to those who did not have a VTE after TKA, there were no differences in patient reported clinical outcomes at 2 years.

Several studies have evaluated the catastrophic complication of fatal pulmonary embolism and found it to be extremely rare following primary joint arthroplasty: 0.07%, 0.10%, 0.01%, 0.024%, 0.02%, 0.034%. Death from any cause in the early postoperative period following primary joint arthroplasty is slightly higher ranging between 0.31% and 0.51%. Anticoagulants used to prevent these thrombotic complications have inherent risks themselves with major bleeding events ranging from 0.12% - 2.3%. The optimum strategy minimizes the risk of VTE while not placing the patient at increased risk for bleeding complications associated with anticoagulation. Cost is also a significant factor.

To evaluate trends in VTE prophylaxis prescribing patterns, data from the American Board of Orthopaedic Surgery (ABOS) Part II (oral) examination case list database was analyzed to determine frequency of utilization, regional practice patterns, effectiveness of thrombosis prevention and bleeding complications of different prophylactic regimens.

The null hypothesis is that there are no differences in bleeding or thrombotic events based on the type of VTE prophylaxis used. Additionally, we hypothesize that there are no regional differences in VTE prophylaxis prescribing patterns amongst the 6 national regions.

Materials and Methods:
Institutional review board approval was not required as this was deidentified data from a database. The ABOS provided data from its proprietary database (Scribe). The ABOS case list database is a collection of surgical cases that are self-reported by orthopaedic candidates approved for admission to the ABOS Part II examination. Orthopaedic candidates must have completed an accredited orthopaedic residency, passed the ABOS Part I examination, actively practiced orthopaedic surgery for at least 20 months in the same location, and undergone peer review. Candidates report their cases during a 6-month period (April through September) prior to their application for certification. As candidates must certify their case log (with notarized confirmation
by their hospital medical records department) by the end of October, a maximum of a 7-month follow-up (range, 1 to 7 months) is available in the database. Each surgical case was de-identified for research purposes. The data set is verified via sampling during the examination, as any of the cases input into the Scribe database may be chosen for review.14

The Scribe data entry system was modified to begin collecting VTE prophylaxis regimens, bleeding and thrombotic complications beginning in 2014. The data from 2014 and 2015 was queried for Current Procedural Terminology (CPT) codes 27447 and 27130 for primary total knee and hip arthroplasty, respectively. Geographic region (Midwest, Northeast, Northwest, South, Southeast, Southwest), year of surgery, diagnosis code, age, sex of the patient and surgeon-reported complications were analyzed. Complications are reported on a per-case basis with no limit for the number of complications for each case. The patients were separated into two groups based on VTE prophylaxis strategy (Table 1). Minimal prophylaxis patterns were considered if only sequential compression devises (SCDs), aspirin or no prophylaxis strategy was utilized. Aggressive VTE prophylaxis patterns were considered if any of low molecular weight heparin (enoxaparin), warfarin, rivaroxaban, fondaparinux or other strategies were used. Complications were grouped into none, moderate thrombotic, moderate hemorrhagic, severe thrombotic, severe hemorrhagic and catastrophic (Table 1). A patient was considered to have no complications if no venous thromboembolism occurred and there was uneventful wound healing. Moderate thrombotic complications included: non-fatal PE, DVT proximal to the knee, DVT distal to the knee, and superficial venous thrombosis. Moderate hemorrhagic events included: wound infection not requiring surgery, hematoma not requiring surgery, upper or lower gastrointestinal (GI) bleed, retroperitoneal hematoma, hematuria, or other bleeding event. Severe thrombotic event was a fatal PE. Severe hemorrhagic events were: deep infection requiring return to the operating room (OR), hematoma requiring return to the OR, or hemorrhagic stroke. The catastrophic event of death within 90 days was also analyzed.

Statistical analysis was performed using JMP Pro Software (version 10; SAS Institute). A p value of <0.05 was considered significant. Comparisons of categorical variables between the 2 cohorts used the chi-square test if the sample size was ≥10 or the Fisher exact test if the sample size was <10. Comparisons of continuous variables with a normal distribution used the Student t test. To control for certain variables, a multivariate logistic regression was performed and odds ratios (ORs) were calculated. As this study utilized a proprietary database, a sample size of convenience was used.

**Source of funding:** There were no sources of funding for this study.
Results:

14,089 cases of primary joint arthroplasty were identified from 2014 - 2015. The average age was 64.5 years; 57.7% were female. Table 2 illustrates the caseload distribution of TKA and THA by gender. 7,236 (51.4%) primary arthroplasty procedures were performed in 2014, the remaining 6,853 (48.6%) in 2015. 7,467 cases (53.0%) were primary TKA, 6,622 (47.0%) were primary THA. The overall national rate of minimal VTE prophylaxis regimens in primary arthroplasty patients was 37.2% while aggressive regimens were used in 62.8% of patients. In the minimal intensity group, there were only 9 patients (0.064%) who received no VTE prophylaxis postoperatively; the remainder had aspirin, SCDs, or both. Significant regional differences in prophylactic regimen patterns existed between the 6 regions (p<0.0001).

Table 3 illustrates the significant differences in complications for all arthroplasty patients receiving aggressive vs minimal prophylaxis strategies. The use of minimal intensity prophylaxis strategy was associated with patients having no complications (94.7% vs 91.8%, p<0.0001). Use of aggressive prophylaxis patterns was associated with higher likelihood of a moderate thrombotic event (1.98% vs 0.62%, p<0.0001), moderate bleeding event (4.48% vs 3.17%, p<0.0001), severe bleeding event (1.80% vs 1.41%, p=0.0404) and death within 90 days (p=0.0122). Fatal PE occurred in 4 (0.046%) patients treated with aggressive VTE prophylaxis and no patients with minimal VTE prophylaxis. The overall rate of fatal PE was 0.028%. There was no significant difference in the rate of fatal pulmonary embolism between minimal or aggressive prophylactic regimens (p=0.1490). 19 patients (0.36%) in the minimal prophylaxis and 57 patients (0.65%) in the aggressive prophylaxis group died within 90 days of surgery. The overall rate of death within 90 days for the cohort was 0.54%.

A subgroup analysis was performed on patients undergoing TKA (Table 4). In patients undergoing TKA, the use of minimal intensity prophylaxis strategy was significantly associated with patients having no complications (94.9% vs 91.1%, p<0.0001). Use of aggressive prophylaxis patterns in TKA was associated with higher likelihood of a moderate thrombotic event (2.42% vs 0.42%, p<0.0001), moderate bleeding event (4.99% vs 3.52%, p=0.0018), severe bleeding event (1.74% vs 1.21%, p=0.0462) and death within 90 days (0.60% vs 0.19%, p=0.0068). Fatal PE occurred in 4 (0.08%) patients treated with aggressive VTE prophylaxis and no patients with minimal VTE prophylaxis (p=0.1747).

Similar subgroup analysis of patient undergoing THA (Table 5) revealed that use of minimal intensity prophylaxis strategy was significantly associated with patients having no complications (94.4% vs 92.6%, p=0.0015). Use of aggressive prophylaxis patterns was associated with higher likelihood of a moderate thrombotic event (1.43% vs 0.82%, p=0.0146), moderate bleeding event (3.85% vs 2.82%, p=0.0137). Severe bleeding events and catastrophic death within 90 days were not significantly associated with specific prophylaxis patterns in THA. No fatal pulmonary embolisms occurred in patients undergoing THA thus statistical comparison between the groups was unable to be performed.
The distribution of caseload among the regions is outlined in Figure 1. The Southwest (1760), Midwest (1609) and Northeast (1476) had the highest volumes of TKA while the Northeast (1452), Midwest (1350) and Southwest (1256) had the highest volumes of THA. The breakdown of prophylaxis strategies by region is illustrated in Figure 2. Only the Southeast region had a higher proportion (68.5%) for aggressive VTE prophylaxis strategies than the national average (62.8%). All other regions used a lower frequency of aggressive prophylactic strategies: Northwest (55.8%); Southwest (59.7%); South (61.7%); Northeast (62.0%); Midwest (62.8%). Thus, all regions except the Southeast, use minimal intensity VTE prophylaxis strategies more frequently than the national average, and these differences were significant (p<0.0001).

Discussion:

The perfect VTE prophylaxis strategy would prevent all thromboembolic events and cause no harm to patients; however, this perfect regimen does not exist. A review of 21 studies from 1995-2015 of 34,764 patients using a variety of prophylaxis strategies calls into question the notion of pulmonary embolus as a “never event” and suggests that even healthy patients receiving aggressive anticoagulation regimens are still at risk for VTE and that some thrombotic events may never be avoided. Thus, providers seek to determine optimum regimens that are safe, effective with minimal harm to the patient and reduce the risk of clinically significant VTE. Over the past decades there have been several iterations of appropriate guidelines between the American Academy of Orthopaedic Surgeons (AAOS) and the American College of Chest Physicians (ACCP) with a push for appropriately powered randomized controlled trials to compare regimens. Recent systematic review and meta-analysis showed significant heterogeneity in dosing regimens among the prior literature which agrees with our results showing significant differences in prescribing patterns across the nation.

One argument for these differences in post-operative VTE prophylaxis patterns relates to the diversity of patients treated with arthroplasty and the need for individualized risk stratification. Parvizi et. al. identified several patient factors that independently increase pulmonary embolism risk including: obesity, surgeries on the knee, elevated Charlson Comorbidity index, chronic obstructive pulmonary disease, atrial fibrillation, anemia, depression, and post-operative DVT. However, it is not clear that more aggressive VTE prophylaxis regimens decrease the likelihood of a thrombotic event in these patients.

To try to mitigate risk and cost, institutions transitioned to risk stratification protocols for low risk and high risk patients and showed success with some showing reduction of 70-75% of aggressive strategies while maintaining low incidences of symptomatic VTE. But do we need to treat these supposed “higher risk” patients any differently? Even when the “higher” risk patients were isolated and compared for the use of aspirin and warfarin, the incidence of VTE, prosthetic joint infection, and mortality were higher for those who received warfarin, showing that aspirin was safer. These findings agree with our results showing that
aggressive VTE prophylaxis strategies are associated with increased risk for moderate thrombotic, moderate bleeding, severe bleeding, and catastrophic events. While minimal strategies were associated with fewer complications. In our sample, there were only 9 patients (0.064%) who received no VTE prophylaxis postoperatively. Thus, the superior results for the minimal prophylaxis strategies are essentially for aspirin, SCDs or both. We cannot conclude that no DVT prophylaxis is appropriate in arthroplasty patients; though, the use of aspirin, SCDs or a combination of the two has improved results compared to the more aggressive strategies in our sample.

More aggressive prophylaxis strategies come with their own set of risks. When warfarin is compared to aspirin for VTE prophylaxis following arthroplasty, the more aggressive strategy of warfarin was associated with higher rates of prosthetic joint infection (1.5% vs 0.4%). Comparison of aspirin and warfarin shows a lower direct cost of index hospitalization and total episode of care charges for patients who received aspirin for VTE prophylaxis. Markov theoretical modeling analysis comparing low-molecular-weight heparin to aspirin also shows that aspirin is more cost-effective.

More recent literature indicates that even low dose aspirin regimens are superior to high dose. In a study of 4,651 primary joint arthroplasty from 2013-2015, low dose aspirin of 81mg twice daily was shown to be not inferior to the 325mg twice daily dosing with respect to incidence of VTE, prosthetic joint infection and 90-day mortality. The use of higher dose aspirin is associated with more gastrointestinal side effects than lower 81mg dose.

A study from Singapore in 2012 showed that out of 531 patients undergoing primary TKA, only 0.75% had a clinically significant VTE. Similar to the Asian study, in a larger sample of 4037 patients, patients were risk-stratified pre-operatively where only high risk patients received chemoprophylaxis and the rest received mechanical prophylaxis alone. Only 1 patient (.024%) had a fatal pulmonary embolism and there were only 5 (0.124%) bleeding events. Even in low energy fracture patients the incidence of clinically significant VTE is low at 1.4% with 0.012% having a fatal PE. Thus, proper risk stratification of patients can lead to appropriate and more frequent use of minimal VTE prophylaxis strategies. Cusick and Beverland even go as far as to say the elective hip and knee replacement should no longer be considered high-risk procedures for VTE.

As detailed in Figure 2, there are significant regional variations in VTE prophylaxis strategies across the nation. The national trend was that nearly two-thirds of providers prescribe more aggressive VTE prophylaxis regimens of enoxaparin, warfarin, rivaroxaban, fondaparinux or other strategies. The Southeast has significantly more aggressive VTE prophylaxis prescribing patterns at 68.5% compared to the national average of 62.8%. The Northwest and Southwest were the fewest prescribers of aggressive VTE prophylaxis regimens at 55.8% and 59.7%, respectively. Whether these differences are from inherent differences in the patient populations treated or variations in the medicolegal atmosphere in these geographic regions is unknown.
Strengths and Weaknesses of the Study

Strengths:

One of the major strengths of this study is the large cohort of patients (14,089) and the power to detect differences in rare events between the groups. Additionally, the quality of data and accuracy of reporting for VTE and bleeding complications is high as each case had the potential to be selected for full review during the Part II (oral) examination.

Another strength was the ability to report recent observed incidences of patient complications. This up to date reporting will aid providers in counseling patients for informed consent. The overall death rate within the follow-up case collection period for patients having primary hip or knee arthroplasty was 0.54%. The overall rate of fatal pulmonary embolism was 0.028%. No fatal PE occurred in the THA cohort within the 1-7 month follow-up period.

Limitations:

One limitation of this database in addition to inherent limitations of self-reported data is that individual patient comorbidities are not captured. Thus, risk stratification for patients for higher risk VTE cannot be calculated and causation cannot be proven. It is likely that perceived higher risk patients received more aggressive VTE prophylaxis regimens as the specific regimen prescribed was up to surgeon discretion. Surgeon clinical judgment and regional preferences are likely strong influences on prescribing patterns. In a retrospective review of 26,391 primary and revision arthroplasty cases from 2000-2011, Parvezi et. al. identified several independent risk factors for symptomatic pulmonary embolism.\(^9\) Further variables that have been associated with higher incidences of PE are age, American Society of Anesthesiologist score of 3 or higher and the use of general anesthesia.\(^7\) Other data showed through regression models that there was no association between the type of VTE prophylaxis or type of anesthesia for increased odd of pulmonary embolism when adjusting for age, sex, and ASA score.\(^8\)

One of the inherent issues with the ABOS Part II operative database is that the follow up ranges from 1 month to 7 months maximum. Although we are unable to collect 2-year outcome data for all patients, the nature of these bleeding and thrombotic complications are likely to occur within the immediate post-operative period and would be captured by the 1-7 month follow-ups for this group. Additionally, the surgeons performing these arthroplasty cases are typically early in practice and decisions are likely strongly influenced by residency and fellowship training patterns rather than their own experience. The database is also unable to distinguish from arthroplasty cases performed by arthroplasty fellowship trained candidates, generalists or other subspecialty fellowship candidates.
Conclusions and Implications of the Study

Although we were not able to ascertain the individualized medical rationale for the use of aggressive VTE prophylactic regimens, more aggressive regimens were associated with higher rates of bleeding and thrombotic complications. Less aggressive regimens were not associated with a higher rate of thrombosis. This analysis indicates that a less aggressive VTE prophylaxis regimen is safe and effective in appropriate patients when compared to more aggressive regimens.

References

### TABLE 1. Definitions

<table>
<thead>
<tr>
<th>Prophylaxis Strategy</th>
<th>Interventions</th>
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</thead>
<tbody>
<tr>
<td>Minimal</td>
<td>No Prophylaxis</td>
</tr>
<tr>
<td></td>
<td>Sequential Compression Devices (SCDs)</td>
</tr>
<tr>
<td></td>
<td>Aspirin</td>
</tr>
<tr>
<td>Aggressive</td>
<td>Heparin/Enoxaparin</td>
</tr>
<tr>
<td></td>
<td>Warfarin</td>
</tr>
<tr>
<td></td>
<td>Rivaroxaban</td>
</tr>
<tr>
<td></td>
<td>Fondaparinux</td>
</tr>
<tr>
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<td>All other prophylactic strategies</td>
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<table>
<thead>
<tr>
<th>Complication Groupings</th>
<th>Possible Complications</th>
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<tr>
<td>No complications</td>
<td>No venous thromboembolism</td>
</tr>
<tr>
<td></td>
<td>Uneventful wound healing</td>
</tr>
<tr>
<td>Moderate Thrombotic</td>
<td>Non-fatal PE</td>
</tr>
<tr>
<td></td>
<td>DVT Proximal to Knee</td>
</tr>
<tr>
<td></td>
<td>DVT Distal to Knee</td>
</tr>
<tr>
<td></td>
<td>Superficial VTE</td>
</tr>
<tr>
<td>Moderate Bleeding</td>
<td>Wound Infection Not Requiring Surgery</td>
</tr>
<tr>
<td></td>
<td>Hematoma Not Requiring Surgery</td>
</tr>
<tr>
<td></td>
<td>Upper or Lower GI Bleeding</td>
</tr>
<tr>
<td></td>
<td>Retroperitoneal Hematoma</td>
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<tr>
<td></td>
<td>Hematuria</td>
</tr>
<tr>
<td></td>
<td>Other (soft tissue hematoma, hemarthrosis in other joints)</td>
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<tr>
<td>Severe Thrombotic</td>
<td>Fatal PE</td>
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<tr>
<td>Severe Bleeding</td>
<td>Deep Infection Requiring Return to OR</td>
</tr>
<tr>
<td></td>
<td>Hematoma Requiring Return to OR</td>
</tr>
<tr>
<td></td>
<td>Hemorrhagic Stroke</td>
</tr>
<tr>
<td>Catastrophic</td>
<td>Death Within 90 Days</td>
</tr>
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</table>
### TABLE 2. Demographic Data

<table>
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<tr>
<th></th>
<th>Age (years)</th>
<th>Gender</th>
<th>p-value</th>
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<tbody>
<tr>
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<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>THA</td>
<td>63.7 ± 11.9</td>
<td>3,047 (46.0%)</td>
<td>3,575 (54.0%)</td>
</tr>
<tr>
<td>TKA</td>
<td>65.3 ± 9.9</td>
<td>2,919 (39.1%)</td>
<td>4,548 (60.9%)</td>
</tr>
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</table>

### TABLE 3. Total Joint Complications Based on Prophylaxis Strategy

<table>
<thead>
<tr>
<th>Complication Event</th>
<th>Prophylaxis Strategy</th>
<th>p-value</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Minimal</td>
<td>Aggressive</td>
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<tr>
<td>None</td>
<td>5,050 (94.7%)</td>
<td>8,032 (91.8%)</td>
</tr>
<tr>
<td>Moderate Thrombotic</td>
<td>33 (0.62%)</td>
<td>173 (1.98%)</td>
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<tr>
<td>Severe Thrombotic</td>
<td>0 (0%)</td>
<td>4 (0.05%)</td>
</tr>
<tr>
<td>Moderate Bleeding</td>
<td>169 (3.17%)</td>
<td>392 (4.48%)</td>
</tr>
<tr>
<td>Severe Bleeding</td>
<td>75 (1.41%)</td>
<td>158 (1.80%)</td>
</tr>
<tr>
<td>Catastrophic</td>
<td>19 (0.36%)</td>
<td>57 (0.65%)</td>
</tr>
</tbody>
</table>
### TABLE 4. TKA Complications Based on Prophylaxis Strategy

<table>
<thead>
<tr>
<th>Complication Event</th>
<th>Prophylaxis Strategy</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimal</td>
<td>Aggressive</td>
</tr>
<tr>
<td>None</td>
<td>2,503 (94.9%)</td>
<td>4,396 (91.1%)</td>
</tr>
<tr>
<td>Moderate Thrombotic</td>
<td>11 (0.42%)</td>
<td>117 (2.42%)</td>
</tr>
<tr>
<td>Severe Thrombotic</td>
<td>0 (0%)</td>
<td>4 (0.08%)</td>
</tr>
<tr>
<td>Moderate Bleeding</td>
<td>93 (3.52%)</td>
<td>241 (4.99%)</td>
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<tr>
<td>Severe Bleeding</td>
<td>32 (1.21%)</td>
<td>84 (1.74%)</td>
</tr>
<tr>
<td>Catastrophic</td>
<td>5 (0.19%)</td>
<td>29 (0.60%)</td>
</tr>
</tbody>
</table>

### TABLE 5. THA Complications Based on Prophylaxis Strategy

<table>
<thead>
<tr>
<th>Complication Event</th>
<th>Prophylaxis Strategy</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimal</td>
<td>Aggressive</td>
</tr>
<tr>
<td>None</td>
<td>2,547 (94.4%)</td>
<td>3,636 (92.6%)</td>
</tr>
<tr>
<td>Moderate Thrombotic</td>
<td>22 (0.82%)</td>
<td>56 (1.43%)</td>
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<tr>
<td>Severe Thrombotic</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Moderate Bleeding</td>
<td>76 (2.82%)</td>
<td>151 (3.85%)</td>
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<tr>
<td>Severe Bleeding</td>
<td>43 (1.59%)</td>
<td>74 (1.88%)</td>
</tr>
<tr>
<td>Catastrophic</td>
<td>14 (0.52%)</td>
<td>28 (0.71%)</td>
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</table>
FIGURE 1. Geographic Variation of Surgical Cases

FIGURE 2. Geographic Variation of Prophylaxis Strategy
Figure Legends

Table 1. Definitions of post-operative VTE prophylaxis for the minimal and aggressive prophylaxis strategies. Groupings of complications considered moderate and severe for bleeding and thrombotic complications. PE = pulmonary embolism. DVT = deep vein thrombosis. VTE = venous thromboembolism. GI = gastrointestinal. OR = operating room.

Table 2. Demographic data for each group. Average age is represented in years ± standard deviation. Gender distribution within the groups are presented with more females than males for total knee arthroplasty (TKA) and total hip arthroplasty (THA) groups.

Table 3. The distribution of total joint arthroplasty complications (combining hip and knee arthroplasty) based on prophylaxis strategy presented as total cases and (percentage of total cases). Fisher’s Exact test.

Table 4. The distribution of total knee arthroplasty (TKA) complications based on prophylaxis strategy presented as total cases and (percentage of total cases). Fisher’s Exact test.

Table 5. The distribution of total hip arthroplasty (THA) complications based on prophylaxis strategy presented as total cases and (percentage of total cases). Fisher’s Exact test.

Figure 1. Caseload distribution in each region for joint arthroplasty separating total hip arthroplasty (THA) and total knee arthroplasty (TKA).

Figure 2. Regional variations and minimal and aggressive prophylactic strategies. Aggressive DVT prophylaxis strategies were significantly more common in every region (p<0.0001).
Adam Boissonneault, M.B.Ch.B., PGY-3

EDUCATION
Emory University School Of Medicine, Department Of Orthopaedics
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• Constructed geriatric hip fracture and also acetabular / pelvic fracture database for Level I trauma center

PUBLICATIONS AND PRESENTATIONS
Peer-reviewed publications:

Boden A, Staley C, Boissonneault A, Boden S, Schenker M. Emotional Intelligence in Medical Students is Inversely Correlated with USMLE Step 1 Score: Is there a Better Way to Screen Applicants? Journal of Medical Education. Accepted February 2018.


Podium presentations:


**Poster presentations:**


Impact Of Closed Suction Drainage After Surgical Fixation Of Acetabular Fractures

Adam R. Boissonneault, M.B.Ch.B., Michael Maceroli, MD, Madeline Roobach, BA, Amalie A Erwood, BS, Zachary J. Grabel MD, Christopher Staley, BS, Thomas Moore Jr, MD, William Reisman, MD, Mara Schenker, MD

Abstract

Introduction. The purpose of the present study was to evaluate the prevalence of closed suction drainage after a Kocher-Langenbeck (K-L) approach for surgical fixation of acetabular fractures and to determine the impact of use of drains on outcomes.

Methods. This retrospective study reports on 171 consecutive patients that presented to a single Level I trauma center for treatment of an acetabular fracture between January 1, 2013 and December 31, 2016. Medical records were reviewed to evaluate the use of closed suction drains. The primary outcomes measures were rate of packed red blood cell (PRBC) transfusion and length of hospital stay (LOS). Secondary outcome measures were 30-day post-operative superficial wound complication and 1-year deep infection rates.

Results. Of the 171 patients included in this study, 140 (82%) patients were treated with drains. There was a significant association between the use of closed suction drainage and post-operative blood transfusion rate (p=0.002). Thirty-five patients (25%) treated with drains required a post-operative blood transfusion compared to 0% in the no drain cohort. For every additional drain that was placed, the odds of receiving a blood transfusion doubled (p=0.002). Use of closed suction drainage was associated with a significantly longer LOS (p=0.015), and no difference in wound complication or deep infection rates.

Conclusion. The use of closed suction drains for treatment of acetabular fractures using a K-L approach is associated with increased rates of blood transfusion and increased length of hospital stay, with no impact on surgical site infection rates. The results of this study suggest against routine drain usage in acetabular surgery.

Introduction

Surgical exposure for open reduction and internal fixation of acetabular fractures is dictated by fracture morphology. The Kocher-Langenbeck (K-L) approach is ideal for surgical fixation of the majority of acetabular fractures, specifically those involving the posterior wall, posterior column, and transverse patterns with predominately posterior displacement. Closed suction drainage is commonly utilized for post-operative wound management with the K-L approach to prevent hematoma formation. However, despite the theoretical advantages of closed suction drainage, there is minimal published evidence to support its routine use. The rationale for closed suction drainage is to eliminate dead space and decrease the rate of post-operative wound complications including hematoma and infection. Despite these proposed advantages, the use of closed suction drainage has been extensively examined in posterior surgical approaches for adult reconstruction patients with no proven benefit. Similar results have been reported in the orthopaedic spine and trauma literature. Furthermore, there is suggestion that the use of drains may be detrimental, as illustrated by significantly increased blood transfusion rates in arthroplasty patients managed with drains. No clinical studies have evaluated the association of closed suction drainage with blood transfusion in operative acetabulum fractures and it is unclear if the results from elective arthroplasty would translate to trauma patients.
Although there are no published data on current rates of drain usage in the trauma population, anecdotally, such practice continues to be routine amongst orthopaedic traumatologists, including at our own institution. The purpose of the present study was to evaluate the prevalence of closed suction drainage after a K-L approach for surgical fixation of acetabular fractures and to determine whether such use was related to postoperative allogeneic blood transfusion rates and length of hospital stay (LOS). Secondary outcome measures included 30-day superficial wound complication and 1-year deep infection rates. We hypothesized that the use of closed suction drains would be associated with increased rates of blood transfusion and an increased length of hospital stay, with no difference in short-term wound complications.

Materials and Methods

Patient selection. This retrospective observational study reports on patients that presented to a single American College of Surgeons – verified Level I trauma center for treatment of an acetabular fracture between January 1, 2013 and December 31, 2016. After institutional review board approval was obtained, medical records were queried for the 275 consecutive patients that were identified as available for inclusion in this study. Patients were excluded if they had combined acetabular and pelvic ring injuries (n=40), were treated percutaneously or with anterior or extensile surgical exposure (n=56), presented with a Morell-Lavalée lesion (n=5), or underwent simultaneous acute total hip arthroplasty (n=3). The final patient population consisted of 171 consecutive patients that underwent a K-L approach for surgical fixation of an acetabular fracture.

Data inclusion. Medical records including operative reports and inpatient progress notes were reviewed to evaluate the use of closed suction drains. Use of a drain, total number of drains utilized, and daily drain output was recorded. The primary outcomes measures were rate of packed red blood cell (PRBC) transfusion and LOS. The rate and total number PRBC units transfused was recorded. Our secondary outcome measures were 30-day post-operative superficial wound complication with or without unanticipated return to the operating room and 1-year rate of deep infection requiring operative debridement. Admission laboratory information was also collected, including hemoglobin (Hb), international normalized ratio (INR), and injury severity score (ISS). Acetabular fractures were classified based on the AO/OTA system after review of anterior-posterior (AP) and Judet radiographs as well as preoperative computed tomography (CT) imaging.

Surgical protocol. All operations were performed using a standard K-L approach by an orthopaedic traumatologist (WR, TMJ, MS). The use of closed suction drainage at our institution is largely based on surgeon preference. Two author surgeons (WR, MS) routinely use multiple (2-3) closed suction drains placed in deep and superficial tissue planes. One author surgeon (TMJ) routinely uses no drains or one placed deep to the iliotibial band. Drain output was recorded every nursing shift (every 8 hours). Standard drain removal protocol was drain output less than 30 milliliters over an 8-hour time period.

Statistical analysis. The distribution of continuous numerical data including demographic and laboratory data was examined in descriptive histograms and box plots, and a Kolmogorov Smirnov test was used to confirm a normal distribution. A chi-squared test was used for nominal data to compare post-operative transfusion and wound complication to drain utilization. An independent samples t-test was used to compare laboratory and surgical data between patients who received drains and those who did not. An analysis of variance was used to compare differences in number of drains used by surgeon, and mean EBL by number of drains used; a post-hoc Bonferroni analysis was performed to explore pair-wise differences. Multi-variate logistic regression was performed to evaluate the odds of receiving a post-operative blood transfusion whether closed suction drainage was used. Co-variates included in the regression model included Hb, EBL, and ISS. All statistical analyses were performed with Stata statistical software (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP.).
Results

Prevalence of drain use. Of the 171 patients included in this study, 140 (82%) patients were treated with drains. There was a significant difference in number of drains used between surgeons (p<0.001) (Table 1). The mean number of drains used by surgeon 1 was 0.6 compared to 2.2 and 2.0 drains for surgeons 2 and 3, respectively (p<0.001). There was no significant difference in patient factors between those treated with drains and those without. The mean age for patients treated with drains was 36 (standard deviation (SD) 10) years compared to 34 (SD 10) years for those without drains (p=0.324). The mean BMI for those treated with drains was 31 (SD 18) kg/m$^2$ compared to 28 (5) kg/m$^2$ for those without drains (p=0.291).

Drain usage by fracture type. Of the 171 patients, there were 73 posterior wall (62-A1), 53 transverse posterior wall (62-B1a2), 22 posterior column posterior wall (62-A2.3), 12 T-type (62-B2), 7 transverse (62-B1a1), 2 posterior column (62-A2), and 2 anterior column posterior hemitransverse fractures (62-B3). The two anterior column posterior hemitransverse fractures were patterns with a stable anterior column segment and predominant posterior displacement of the transverse segment. There was no significant association between number of drains used and fracture morphology (p=0.085) (Table 2). For simple posterior wall fractures, 34 patients had 0 or 1 drain placed versus 39 patients that had 2 or 3 drains placed.

Drain usage versus EBL. The mean (SD) reported EBL was 254 (129) mL, 308 (164) mL, and 519 (297) mL for surgeons 1-3 respectively. There was a significant difference in reported EBL between surgeon 3 and surgeons 1 and 2 (p<0.001) (Table 3). For surgeon 1, there was a significant association between number of drains used and EBL (p=0.026), with an average of 84mL additional blood loss in patients treated with 1 drain compared to no drains. For surgeon 2 and 3, there was no significant association between number of drains used and EBL.

Prevalence of blood transfusion. Of the 171 patients in this study, 35 (20%) received a post-operative allogeneic blood transfusion. Patients that received a blood transfusion had a significantly lower mean Hb on admission (p<0.001) (Table 4). Patient that received a blood transfusion also had a significantly higher EBL (p=0.002) and ISS (p<0.001) (Table 4). There was no difference in admission INR between patient that received a blood transfusion and those that did not. The mean hemoglobin at time of blood transfusion was 7.5 (SD 1.4) g/dL. The threshold for transfusion in this study was uniform in the study population such that there was no significant difference in post-operative Hb before transfusion between surgeons (p=0.110).

Association between drain usage and blood transfusion. There was a significant association between the use of closed suction drainage and post-operative blood transfusion rate (p=0.002). Thirty-five patients (25%) treated with drains required a post-operative blood transfusion compared to 0% in the no drain cohort. After controlling for admission Hb, ISS, and EBL, patients treated with drains were 22 times more likely to receive a blood transfusion (OR 22.2, 95% confidence interval (CI) 1.0-498.7; p=0.049). For every additional drain that was placed, the odds of receiving a blood transfusion increased (OR 2.0, 95%CI 1.3-3.1; p=0.002). Amongst simple posterior wall fractures only, the odds of receiving a blood transfusion nearly tripled for every additional drain that was used (OR 2.7, 95%CI 1.3-5.8; p=0.008).

Drain utilization and length of hospital stay. The mean LOS for patients treated with drains was 11 (SD 7) days compared to 8 (SD 4) days for those that were not (p=0.015). The mean LOS for patients that received a blood transfusion was 15 (SD 8) days compared to 9 (5) days for those were not (p<0.001).

Drain utilization and surgical site infection rates. The total number of 30-day superficial wound complications in the entire cohort was 3 (1%). All wound complications occurred in patients that were treated with closed suction drains. The difference between groups was not statistically significant (p=0.411). All three patients were placed on a short course of oral antibiotics. Only one patient in the entire cohort was found to have a deep hardware associated infection that required operative management. The single patient with deep infection was treated with 3 drains at his index procedure.
Discussion and Conclusions

The present study examined the prevalence and associated impact of closed suction drainage after acetabular surgery at a high-volume level 1 trauma center. The use of drains was associated with an increased prevalence of post-operative blood transfusion and longer length of hospital stay. Furthermore, there were no differences in wound complications or deep infection rates between patients treated with or without drains. As demonstrated in our study population, the use of drains after a K-L approach is often based on surgeon preference and routine protocols and not specifically related to surgical blood loss or fracture morphology.

The increased transfusion rates in orthopaedic patients treated with drains in our study are consistent with previous reports in the arthroplasty and spine literature.15-16,18 Our study also confirms previous works in the trauma and arthroplasty literature that illustrate the association between increased EBL and ISS with increased blood transfusion rates, and also decreased admission Hb with increased blood transfusion rates.23-29 Notably, the multivariate logistic regression model in the present study revealed that independent of these previously identified risk factors for blood transfusion, the odds of receiving a blood transfusion was still over twenty times higher in patients treated with drains.

The current study revealed that omission of closed suction drainage had no association with early (30-day) or late (1-year) infection rates. This finding is supported by Hsu et al.30, who also reported drain use had no impact on infection rates in patients who underwent acetabular surgery using the K-L approach. Although the theoretical benefit of closed suction drainage is to prevent hematoma formation and potential wound breakdown, multiple studies have shown no difference in clinically significant hematoma formation irrespective of drain use.19,21 These findings suggest that judicious omission of closed suction drains in posterior approach acetabular surgery is safe when done in appropriate patients.

Current trauma and arthroplasty literature has identified closed suction drainage as a risk factor for increased length of hospital stay.23-24,29,31-33 This finding is supported in the present study with a significant association between presence of drains and longer LOS. Due to the retrospective nature of the study, we cannot confirm causation but would suggest that the increased length of stay is likely sequela from the higher blood transfusion rates in these patients. In addition, patients with multiple drains may be more hesitant to mobilize, and it is possible that the presence of multiple drains may delay discharge by impeding physical therapy.

To our knowledge, our study is the first to describe the association between the number of closed suction drains utilized and prevalence of post-operative blood transfusion. Our results demonstrated that for every additional drain that is placed, the odds of requiring a blood transfusion doubles. For simple posterior wall fractures, the odds of blood transfusion for every additional drain that was used nearly tripled. Extrapolation of this data illustrates that compared to patients that receive only 1 drain, the odds of receiving a blood transfusion is 9 times higher in those that receive 3 drains. One potential explanation for this finding may be that the increased suction pressure creates a higher flow state and prevents stable clot formation. As a result, the duration and amount of effective total blood loss is increased, as well as the risk of blood transfusion. Should one decide to use closed suction drainage after fixation of acetabular fractures, these results would support a ‘less is more’ approach to drain utilization in an effort to reduce risk of blood transfusion and decrease LOS.

There are several potential limitations to this study. Most notably, due to the retrospective nature of the study, there was no strict criteria for the decision to omit or place a closed suction drain. However, our data clearly demonstrates that drain use was related to surgeon preference and not necessarily surgical blood loss or fracture morphology. In fact, we specifically analyzed these variables and noted that there was no significant association between drain placement and intra-operative blood loss, patient BMI, or fracture morphology. Furthermore, patients with associated soft tissue injuries that would be treated with closed suction drainage (n=5) as a standard of care were omitted from our analysis to create as homogenous a population as possible.
Additionally, this investigation was conducted at a single institution and indications for transfusion may differ from other centers. However, transfusion criteria amongst the cohort evaluated in this study was uniform and did not vary significantly between surgeons.

**Conclusion**

The use of closed suction drains for treatment of acetabular fractures using a K-L approach is associated with increased rates of blood transfusion and increased length of hospital stay, with no impact on surgical site infection rates. The results of this study suggest against routine drain usage in acetabular surgery. Notably, we are not recommending against drain utilization in all patients, but when drain placement is indicated for specific at-risk wounds, a more judicious approach should be taken. Continued prospective investigation is warranted to further validate this recommendation.

**TABLES**

**Table 1. Drain utilization by surgeon**

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<th>Surgeon</th>
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**Table 2. Drain utilization by fracture morphology**

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<td>22</td>
<td>14</td>
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<td></td>
</tr>
<tr>
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<tr>
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<td>0</td>
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<td>0</td>
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<tr>
<td>AC PHT</td>
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</table>

PW – posterior wall; Trans + PW – transverse posterior wall; PC + PW – posterior column posterior wall; PC – posterior column; AC PHT – anterior column posterior hemitransverse
Table 3. Association between drain utilization and EBL by surgeon

<table>
<thead>
<tr>
<th>Surgeon</th>
<th>Number of drains (mean EBL(mL))</th>
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* Analysis of variance (ANOVA) test

Table 4. Risk factors for blood transfusion

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<td>Hb</td>
<td>13.8</td>
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<td>9.8</td>
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<td>282.6</td>
<td>388.7</td>
<td>p=0.002</td>
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Hb – hemoglobin; INR – international normalized ratio; ISS – injury severity score; EBL – estimated blood loss

References:
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PODIUM PRESENTATIONS


The Impact Of Prophylactic Intraoperative Vancomycin Powder On Microbial Profile, Antibiotic Regimen, Length Of Stay, And Reoperation Rate In Elective Spine Surgery

Zachary J. Grabel, MD; Allison Boden, BA; Dale N. Segal, MD; Stephanie Boden, BA; Andrew H Milby, MD; John G. Heller, MD

ABSTRACT

Background context: There is growing concern that the microbial profile of surgical site infection (SSI) in the setting of prophylactic vancomycin powder may favor more resistant and uncommon organisms.

Purpose: To demonstrate the impact of prophylactic intraoperative vancomycin powder on microbial profile, antibiotic regimen, length of stay, and reoperation rate in spine surgical site infection.

Study Design/Setting: Retrospective cohort study.

Patient Sample: The study included 115 post-operative spine patients who were required to return to the operating room for surgical site infection.

Outcome Measures: The outcome measures were microbial profile, reoperation rate, antibiotic regimen, and length of stay (LOS) for patients with postoperative spine infection who either did (treated) or did not (untreated) receive prophylactic vancomycin powder during their index procedure.

Methods: A retrospective review of patients who underwent posterior thoracic and/or lumbar spine surgery between 2010 and 2017 was conducted. Those undergoing surgical treatment of SSI were identified, and patients were divided into two groups - those who were treated with intra-operative vancomycin (treated) and those who were not (untreated). The organism profile for each group was compared. The average length of stay, reoperation rate, and number of patients requiring more than one antibiotic were calculated for each patient in both groups.

Results: There were 5,909 procedures performed. 115 SSIs were identified, resulting in a 1.9% infection rate. Prophylactic vancomycin powder was used in the index procedure for 42 of those cases. 23.8% of cultures in the vancomycin group were polymicrobial and 16.7% were gram negative compared to 9.6% (p=0.039) and 4.1% (p=0.021) in the untreated group, respectively. In the vancomycin-treated group, 26.1% of patients underwent repeat irrigation and debridement (I&D) compared to 38.4% in the untreated group (p=0.184). The percentage of patients in the treatment and untreated group who required more than one antibiotic was 26.0% and 26.1%, respectively (p=0.984). Mean LOS in the treatment group was 8.0 versus 7.9 for the untreated group (p=0.945)

Conclusions: In this series, vancomycin powder was associated with a higher prevalence of gram negative and polymicrobial organisms in patients that ultimately developed post-operative SSI. However, this did not adversely affect the need for multiple reoperations, antibiotic regimen, or length of stay for these patients.
Introduction

Surgical site infection (SSI) following spine surgery is a clinically devastating and resource-intensive complication. The incidence of postoperative spine SSI ranges from 0.7 to 12%. Prior literature has demonstrated an additional cost of $33,705 associated with each spine SSI. The prophylactic use of intraoperative vancomycin powder has been shown in several series to be effective in decreasing the rate of post-operative infection in spine surgery.

While the use of intraoperative vancomycin may result in a lower incidence of SSI, there is growing concern that when an SSI does occur in this setting, the microbial profile of these SSIs may favor more resistant and uncommon organisms. A recent study examined positive cultures in postoperative SSI after spine deformity surgery in which intraoperative vancomycin was used in all cases. This investigation revealed the majority of cultures were gram negative and polymicrobial. Another single institution study similarly examined the microbial trends in patients with post-operative spine SSI (all regions and indications) who were treated with prophylactic local vancomycin and suggested an increase in gram negative and polymicrobial cultures.

The purpose of this study was two-fold. First, we sought to compare the microbial profile of SSI in treated patients (intraoperative local vancomycin used) versus untreated patients (no local vancomycin) who underwent elective thoracic and/or lumbar decompression with or without fusion. Second, it examined the effects of local vancomycin powder on the extent of required treatment, including number of reoperations, complexity of antibiotic regimen, and length of stay (LOS). To our knowledge, this has not been documented in the literature.

Methods

Patient Selection

Institutional review board approval was obtained prior to initiation of this study. A retrospective review of patients who underwent posterior thoracic and/or lumbar spine surgery with or without fusion between 2010 and 2017 was conducted. Exclusion criteria included cervical spine procedures, procedures performed through a lateral or anterior approach, and infection as an indication for surgery.

Amongst this group, a query was performed to identify patients with surgical site infection. We defined a clinically-significant SSI by the need to return to the operating room for an irrigation and debridement procedure. The decision to proceed was made at the discretion of the attending surgeon based on a combination of clinical criteria. Criteria included: wound drainage, wound dehiscence, fevers, evidence of infection on imaging, and elevated infectious laboratory values such as erythrocyte sedimentation rate, C-reactive protein, and white blood cell count. Amongst this cohort of patients with SSI, patient demographics, comorbidities, previous spine surgery, the use of intraoperative vancomycin, complications, and the onset of SSI after index procedure were recorded.

Surgical Details

At our institution, it is standard practice for all patients to receive pre-operative and post-operative prophylactic antibiotics. Typically, this consists of weight based intravenous (IV) cefazolin within 1 hour of incision and every 8 hours for 24 hours after surgery. Patients with penicillin allergies receive either IV clindamycin or vancomycin. Subfascial drains are used in most cases but this is based on surgeon preference. Distribution and dosing of vancomycin powder was variable amongst surgeons, but typical use included wide dispersal of one gram of vancomycin powder throughout the wound immediately prior to fascial closure.
**Outcome Measures and Statistical Analysis**

Patients were divided into two groups – those who were treated with local intraoperative vancomycin (treated) and those who were untreated (non-vancomycin cohort). The organism profile for each group was compared. The average length of stay, reoperation rate, and number of patients requiring more than one antibiotic were calculated for each patient in both groups. Patients in the treated and untreated group were then further categorized by culture result (gram positive, gram negative, polymicrobial, fungal, no growth). The average length of stay, reoperation rate and number of patients requiring more than one antibiotic were compared by culture type between the treated and untreated group. Chi square analysis and 2-tailed t test were used. Multivariable logistic regression analysis was performed to control for discrepancies in patient characteristics amongst the vancomycin-treated group and the untreated group. Statistical significance was defined as a P value less than 0.05.

**Results**

There were 5,909 thoracic and/or lumbar decompression with or without fusion procedures performed between 2010 and 2017. 115 SSIs were identified, resulting in a 1.9% infection rate. Amongst the SSI cohort, 42 patients had received intraoperative vancomycin. Smoking history, history of diabetes, number of comorbidities, number of post-operative complications, and onset of SSI were not statistically different between the two groups. Mean BMI of patients in the vancomycin group was 32.1 compared to 29.1 in the untreated cohort (p=0.046). The majority of patients in the treatment group underwent fusion procedures (78.6%) as opposed to the untreated group (38.4%)(p=0.0003). Only 26.2% of the patients in the vancomycin-treated group had a history of prior spine surgery compared with 46.6% in the untreated group (p=0.031) (Table 1). Multivariable logistic regression analysis results are illustrated in Table 2.

Overall, the most common organism cultured was methicillin-sensitive staphylococcus (Staph) aureus (MSSA) (36.5%). Polymicrobial and gram negative organisms represented 14.8% and 8.7% of cultures, respectively. There were 28 cases with no growth from intraoperative cultures (24.3%). Coagulase-negative staphylococcus represented 6.1% of organisms. Escherichia coli was the most common gram negative culture (Table 3).

26.1% of culture-positive infections in the vancomycin group were gram positive organisms, all of which were Staph species. In the untreated group, 64.4% of positive cultures were gram positive and Staph infections represented 57.5% of infections (p=0.001). 23.8% of cultures in the vancomycin group were polymicrobial and 16.7% were gram negative compared to 9.6% (p=0.039) and 4.1% (p=0.021) in the untreated group, respectively. There were two cultures positive for fungus in the non-vancomycin group and none in the treatment group. Approximately one third (33.3%) of the cultures in the treatment group revealed no-growth compared to 19.1% in the non-vancomycin group (p=0.089)(Table 4).

In the vancomycin-treated group, 26.1% of patients required an additional irrigation and debridement (I&D) compared to 38.4% in the untreated group (p=0.184). The percentage of patients in the treatment group and non-vancomycin group who required more than one antibiotic was similar (26.0% vs. 26.1%, respectively; p=0.984). Mean length of stay for the vancomycin treatment group was 8.0 versus 7.9 for the untreated group (p=0.945) (Table 5).

When broken down by culture type, 18.2% of gram positive infections in the vancomycin group required repeat I&D and more than one antibiotic compared to 44.7% (p=0.106) and 21.3% (p=0.819) of gram positive infections in the untreated group, respectively (Table 6A, 6B). Three of the gram negative infections in the vancomycin treatment group required additional reoperations versus zero in the untreated group. Polymicrobial infections in the vancomycin group required repeat I&D and treatment with more than on antibiotic 60% of the time, respectively, compared with repeat I&D rate of 85.7% (p=0.252) and treatment with multiple antibiotics in 100% (p=0.628) of patients in the untreated group with polymicrobial infection (Table 6A, 6B). Polymicrobial
infection resulted in the greatest mean length of stay in both the vancomycin-treated and untreated group: 10.3 and 15.1 days, respectively (p=0.108) (Table 6C).

Discussion

The application of intraoperative vancomycin powder in spine surgery has been reported by many studies to decrease the rate of surgical site infection.5-11 O’Neil et al7 evaluated the infection rate of patients who underwent spine arthrodesis for traumatic spine injuries. The cohort who received intraoperative vancomycin had a 0% rate of infection and the control group had a 13% rate of SSI. Sweet et al5 demonstrated a 10-fold decrease in infection rate with intra-operative vancomycin in patients who underwent posterior thoracolumbar fusions. Furthermore, Strom et al6 demonstrated a similar decrease rate in infection with use of intraoperative vancomycin in patients who underwent posterior cervical fusions. Chiang et al9 through meta-analysis, and Heller10 et al, through retrospective investigation, specifically reported a decreased rate of Staph aureus associated SSIs when intraoperative vancomycin was used. We sought to determine whether SSI in patients who received intraoperative vancomycin may favor more virulent organisms. In addition, this study examined the impact that intraoperative vancomycin has on reoperation rate, antibiotic regimen and length of stay.

The overall infection rate in the present study was 1.9%, which is consistent with prior studies.4,5,14-16 Staph aureus was the most common organism isolated amongst all SSIs in our study. This is consistent with the results of Amir Abdul-Jabbar et al’s14 investigation, which examined the pathogen profile amongst 239 spine infections (all spine regions). Interestingly, MSSA was significantly more prevalent in the untreated cohort but there was no difference in prevalence of Coagulase-negative Staph and methicillin-resistant Staph aureus (MRSA) amongst the two cohorts. This may be attributed to the relatively small number of Coagulase-negative Staph (7) and MRSA (3) SSIs compared to MSSA (42).

This investigation revealed that gram negative infections and polymicrobial infections were significantly more prevalent in patients who received intraoperative local vancomycin compared to those who did not. Adogwa et al12 and Ghobrial et al13 suggested gram negative infections were more common amongst patients who received prophylactic vancomycin powder. However, neither of these studies included a control or untreated cohort. In addition, we demonstrated that there was a significantly higher proportion of isolated gram positive cultures in the untreated cohort compared to those who received vancomycin. We believe this phenomenon is secondary to vancomycin’s prophylactic effect against gram positive organisms. However, it must be noted that more patients in the vancomycin-treated cohort underwent a fusion procedure (Table 1) and multivariable analysis demonstrated that a fusion procedure is independently associated with a lower odds of gram positive culture in a SSI (Table 2), although there is no clear explanation for this. Furthermore, more patients in the untreated group had a history of prior spine surgery, which was found to be an independent risk factor for gram positive culture in those with SSI (Table 2). Therefore, patients with a history of previous spine surgery who are not treated with vancomycin powder may be especially susceptible to a gram positive organism should they develop an SSI.

The overall no-growth rate in our study (24.2%) is consistent with prior studies.12,13 In contrast to the vancomycin arm in our study, which demonstrated a 33.3% no growth rate, Amir Abdul-Jabbar et al14 revealed a negative culture rate of 2.9% and none of their patients received vancomycin powder. One possibility for a relatively high no growth rate in the vancomycin arm of our study is that high concentrations of local vancomycin suppressed culture growth. On the contrary, it is possible that we have a cultural bias that favors returning to the operating room in the case of a persistently draining wound, whether infected or otherwise. The notion is that a draining wound not only allows entry to bacteria but the existing hematoma/seroma is a fertile culture medium. This may also explain the relatively large percent of cultures without growth in our investigation and aforementioned studies.
Interestingly, there was no significant difference in the need for multiple antibiotics or mean length of stay between the vancomycin-treated group and the untreated cohort. There was a pattern towards increased reoperation rate for those who did not receive intraoperative vancomycin, however this was not statistically significant. It is possible that, with a larger sample size, this phenomenon becomes significant in which case another benefit of local application of vancomycin would be that it lowers reoperation rate in those who develop SSI. The reoperation rate, antibiotic regimen, and average LOS were compared by culture type between vancomycin-treated patients and the untreated group to determine if intraoperative vancomycin had an effect on the virulence of the individual organisms (i.e. are the gram negative organisms in the vancomycin treatment group causing a higher reoperation rate than those in the untreated group?) (Table 5A-C). However, the virulence of each pathogen type appeared to be no different between the treated and untreated groups. These findings should be comforting to surgeons who use intraoperative vancomycin. That is, when SSI does develop in these patients, the outcomes are not adversely affected in terms reoperation rate, need for multiple antibiotics, and mean LOS.

There are several potential limitations to this study. This was a retrospective study which employed existing documentation in the electronic medical record. In addition, this investigation was conducted at a single institution which serves as a referral center. As a result, the patients in the study may have more comorbidities and may have undergone more complex surgery than patients at other centers. As such, the microbial profile of our patients may not be generalizable. However, the aim of the study was to compare the microbial profile between the treatment and untreated arms, and there was no difference in comorbidities amongst these groups (Table 1). Another potential limitation is that there were not enough gram negative or polymicrobial SSIs to accurately perform multivariable logistic regression analysis to control for differences in patient characteristics (i.e. BMI, fusion procedure, history of previous surgery) amongst the two cohorts. Future studies with a larger sample size of gram negative and polymicrobial cultures are warranted for further investigation. Further investigation is also needed to determine whether the 24% of patients that were culture negative represented cases that were not actually SSIs versus SSIs with undetectable culture growth.

**Conclusion**

This study demonstrates an association between the use of vancomycin powder and a relative increase in prevalence of gram negative and polymicrobial organisms in patients ultimately developing SSI following thoracolumbar spine surgery. However, this did not adversely affect the type of care required by the SSI patients, such as the need for multiple reoperations, complexity of antibiotic regimen, or length of stay in this series. Continued investigation is needed to evaluate whether the addition of local prophylactic antibiotics with gram negative coverage coupled with intraoperative vancomycin powder may further affect this microbial profile and serve as a safe and cost-effective means of further reducing the SSI rate in spine surgery.

**References**


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Doctor of Medicine, Alpha Omega Alpha Honor Society  Spring 2014
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PUBLICATIONS, PRESENTATIONS & POSTERS


Surgical Videos Produced with Dr. Mark Miller and Published to Orthobullets.com, Summer 2012:
- “ACL Reconstruction with Hamstring Autograft”
- “ACL Reconstruction with Patellar Tendon Autograft”
- “Arthroscopic Biceps Tenodesis”
- “Arthroscopic Meniscus Repair with All-Inside Technique”
- “Arthroscopic Rotator Cuff Repair”
- “Femoral Physeal Sparing ACL Reconstruction”
- “MPFL Reconstruction with Free Soft Tissue Graft”
- “Multiple Knee Ligament Injury Repair”
- “Open Subpectoral Biceps Tenodesis”
- “Revision ACL Reconstruction with Hamstring Autograft”
- “Fulkerson Osteotomy”
Ultra Sound Guided Aspiration Of Wrist Ganglion Cysts Does Not Reduce Recurrence

Gregory Kurkis MD, Albert Anastasio BS, Marijke DeVos MD, Michael Gottschalk MD

INTRODUCTION

Ganglion cysts are a common upper extremity pathology encountered by hand surgeons. In fact, they are the most frequent soft tissue tumor encountered in the upper extremity, with the wrist being the most common location (1). Ganglion cysts of the wrist may arise from either an inflamed tendon sheath or from a degenerative and arthritic underlying joint. 60-70% occur on the dorsal aspect of the wrist, most commonly in the scapholunate region. Approximately 20% of wrist ganglions are volar, most commonly found between the flexor carpi radialis tendon and the first extensor compartment (2).

Controversy remains as to the most effective treatment for this pathology. Observation, percutaneous aspiration, and open versus arthroscopic surgical excision are all options. Open surgical excision has a significantly lower chance of recurrence compared to aspiration, with a recurrence rate of 21% versus 59% shown in a recent systematic review and meta-analysis (3). However, surgical excision of wrist ganglions may be associated with an increased risk of complications such as wound infection or damage to surrounding anatomical structures. Also, surgical excision likely carries a more prolonged postoperative recovery and an increased cost of care. Despite the inferior recurrence rate, given the ease of performing in-office aspiration of a wrist ganglion and the potential complications and increased morbidity associated with surgical excision, aspiration still remains a valid treatment option.

Ultrasound is becoming a widely used modality within orthopedics both for its role in assisting and improving bedside procedures as well as for its diagnostic utility. There is relatively little literature examining the role of ultrasound-guided aspiration of wrist ganglions. Zeidenberg et al. published a study in the radiology literature on a series of 39 patients at 9-month minimum follow up that had been treated with ultrasound-guided aspiration. They found a 20% recurrence rate in this group (4). Ultrasound provides the benefit of localizing the needle tip with visual confirmation within a ganglion prior to aspiration. Additional benefits might include minimizing the risk of damage to surrounding soft tissues and neighboring anatomical structures (5,6). At the time of our literature review, no studies were found comparing ultrasound-guided versus blind aspiration of wrist ganglion cysts. We hypothesize that ultrasound-guided aspiration will lead to improved recurrence rates and better patient outcomes compared to blind aspiration of ganglion cysts of the wrist.

MATERIALS AND METHODS

A chart review was conducted of all ganglion cysts of the wrist joint treated at our institution over 6 years (2009-2015). 186 patients were identified from this chart review. Of these 186 subjects, 114 patients were treated with attempted aspiration of the ganglion cyst; 27 of these 114 individuals underwent ultrasound-guided aspiration. Phone calls were placed to all 114 patients who had undergone attempted aspiration of their wrist ganglion cyst. Of these 114 patients, 52 could be reached by telephone and agreed to participate in the study. The information collected from these phone calls included confirmation of prior aspiration, other treatment history, obtaining up-to-date ganglion presence (e.g. recurrence status), any additional treatments undergone, and patient-reported Quick-DASH scores of upper extremity function from the afflicted wrist. Among those 52 patients who were successfully contacted by telephone, recurrence rates were compared between those whose cyst was treated with ultrasound-guided (13 patients) versus blind aspiration (39 patients). Additionally, patient reported Quick-DASH scores were compared between patients who experienced a recurrence after aspiration versus those who did not suffer a recurrence.
Statistical analysis was performed using JMP Pro 12 (Cary, North Carolina). For continuous variables a T-test analysis was used to obtain p-values. For categorical or dichotomous variables, contingency tables were created and three analyses were carried out: Fisher exact test, a Z-score test for two population proportions, and N-1 Chi-squared testing. There was no difference in statistical significance for any variables among these three tests. Given the relatively small sample sizes involved with this study, Fisher exact test was utilized and reported.

RESULTS

Recurrence rates were 69% (9 patients) and 74% (29 patients) for the ultrasound-guided and blind aspiration groups respectively (p-value 0.73), showing no significant difference in recurrences of wrist ganglion between the two groups. The average follow-up time was 2.9 years to the time of phone follow-up from the time of aspiration.

The average age at time of aspiration was 40 years for the ‘blind’ group versus 44 years for the ultrasound group. The ‘blind’ group was 74% female and the ultrasound group was 85% female, with only two male patients in the ultrasound-guided aspiration group. The ‘blind’ group was 47% African American and 42% Caucasian whereas the ultrasound-guided group was 75% Caucasian and 25% African American. In the ‘blind’ aspiration group, 74% of the cysts were dorsal and 18% were located on the volar aspect of the wrist; comparatively, in the ultrasound-guided aspiration group, 54% of the cysts were located dorsally versus 39% volarly. Steroid was injected at the time of aspiration in 82% of the ‘blind’ aspiration group and in all (100%) of the patients who received ultrasound-guided aspiration. 39% of the cysts in the ultrasound group were fenestrated with a needle at the time of aspiration compared 18% fenestration in the ‘blind’ aspiration group. Quick-DASH scores in the ‘blind’ aspiration group were higher (14.3) compared to the ultrasound-guided group (10.1). Of the above variables, none showed a statistically significant difference between the two groups, with all calculated p-values greater than 0.05.

The average time to phone follow up from initial aspiration for the ‘blind’ aspiration group was 2.7 years versus 3.5 years for the ultrasound-guided aspiration group. For the recurrences encountered in the ultrasound group, the average reported time to recurrence after aspiration was 275 days, compared to 226 days to recurrence for the ‘blind’ aspiration group. Neither of these time variables were statistically significantly different between the two groups.

| Table 1. Recurrence Rates and Demographic Data for ‘Blind’ and Ultrasound-Guided Aspiration Groups |
|---------------------------------------------------------------|-----------------------------------|-------------------------------|-----------------|
| Ganglion recurrence rate                                       | Ultrasound-Guided Aspiration   | ‘Blind’ Aspiration      | P-value        |
| Avg Age (years)                                                | 69%                             | 74%                        | 0.73           |
| % Female                                                      | 44                              | 40                          | 0.39           |
| % African American                                            | 85%                             | 74%                        | 0.71           |
| % Caucasian                                                   | 25%                             | 47%                        | 0.31           |
| % Volar Location                                              | 75%                             | 18%                        | 0.15           |
| % Steroid Injected                                             | 39%                             | 82%                        | 0.17           |
| % Fenestrated by Needle                                       | 100%                            | 14%                        | 0.15           |
| Avg Quick-DASH Score                                          | 10.1                            | 14.3                       | 0.49           |
| Avg Follow-up (yrs)                                           | 3.5                             | 2.7                        | 0.26           |
Additionally, for those patients that experienced a ganglion recurrence after aspiration (either ‘blind’ or ultrasound-guided) Quick-DASH scores at the time of phone follow-up were greater (17.4) compared to the Quick-DASH scores of those patients that did not experience a recurrence (2.11); this was a statistically significant difference (p-value 0.008).

DISCUSSION

This study shows worse functional outcomes (higher Quick-DASH scores) in patients who experience a recurrence of wrist ganglion cysts after initial attempted aspiration. Thus, it is important to attempt to improve the efficacy of our aspiration techniques in an effort to improve patient outcomes and satisfaction. However, this research demonstrates no significant improvement in recurrence rates with the use of ultrasound-guided aspiration of ganglion cysts of the wrist.

The intuitive benefits of using ultrasound to guide aspiration attempts are numerous, notably visual confirmation of accurate needle placement to ensure optimal and sufficient aspiration of the ganglion cyst. Additional benefits include minimization of damage to surrounding soft tissues and neighboring anatomical structures as well as potentially fewer needle sticks leading to decreased procedural-related discomfort for the patient. These benefits, combined with the relatively low risk of harm that comes with the addition of the use of ultrasound make for a compelling argument in the use of the management of ganglion cyst aspiration. Despite the results of this study showing no improvement in recurrence rates with the use of ultrasound guidance, there may be particular situations where use of ultrasound guidance for aspiration is warranted. Volar ganglion cysts as well as ganglion cysts that are in the vicinity of neurovascular structures may certainly benefit from the use of ultrasound-guided aspiration to ensure avoidance of damage to surrounding nerves, vessels, and soft tissues. For clinical settings that already have an ultrasound available on-site, there is little down-side in using ultrasound to guide aspiration attempts. Additionally, it should also be considered that use of ultrasound-guidance for needle placement may constitute an additional billable procedure for physicians in certain practice settings.

Despite a thorough review of the literature, we found no prior studies comparing ultrasound-guided versus blind aspiration of ganglion cysts. The 69% recurrence rate with ultrasound-guided aspiration that we found in our analysis is higher than that seen in other studies. Zeidenberg et al. showed, in a series of 39 patients followed for 9 months, a 20% recurrence rate with ultrasound-guided aspiration (4). Although this recurrence rate is significantly less than that demonstrated in our study, the average follow-up time was 15 months, shorter than the 42-month mean follow up time in our group. Breidahl and Adler conducted a case series of 10 patients that underwent ultrasound-guided treatment of ganglion cysts (6). 7 of these were located at the wrist. Of those 7 ganglia, 2 resolved completely, 1 recurred 1 year after attempted aspiration, 3 experienced a reduction in size of the ganglion with improved symptoms but persistence of the cyst, and 1 patient did not experience any noticeable relief. Other research on blind aspiration of wrist ganglion cysts showed a wide range with similar high recurrence rates as those seen in our data. The recurrence rates reported in the literature for blind aspiration of wrist ganglions range from 27% to 89% (7,8). Regardless of aspiration technique and the use of ultrasound, recurrence rates of ganglion cysts of the wrist are high, as demonstrated both in our study as well as throughout the literature. This should be discussed with patients, and they should be counseled on the risks, benefits, and likelihood of success of aspiration versus excision. While a less-invasive option is always a preferred initial treatment, given the overall poor efficacy of aspiration, proceeding straight to surgical excision may provide patients with a more reliable solution with a quicker return to symptom-free function.

Limitations of this study include its small sample size and relatively low rate of successful phone follow-up. This study would benefit from addition of more study participants to increase sample sizes and improve power. Additionally, given the retrospective design of our study and the lack of randomization of subjects to blind or ultrasound-guided aspiration groups, there could have been additional factors not identified in our study that led the treating physician to pursue ultrasound-guided versus blind aspiration based on certain patient
presentations, cyst locations, or other factors. Future studies should look toward a randomized, prospective controlled trial to further investigate the possible benefit of ultrasound-guided aspiration of ganglion cysts of the wrist. Additionally, this study could be expanded to investigate the role of ultrasound in the management of ganglion cysts in other anatomical locations beyond the wrist. More research would also be useful in assessing any morbidity associated with ultrasound-guided aspiration. Although, it can be assumed that procedure-related morbidity and complications would likely be less with aspiration in comparison to open resection, it would be useful to investigate if ultrasound-guidance led to an improvement in treatment-associated morbidity compared to morbidity and complications associated with blind aspiration.

REFERENCES


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Dual Degree Program with Emory
Emory University  Aug 2006 – May 2009
    B.S. in Biology, Dual Degree Program with Georgia Tech

PATENTS
“Access Device for Surgery” – Co-inventor
Patent number US8771173 B2  Issued July 8, 2014
• A surgical device that provides minimally invasive access for sterile endoscopes to organs including the
  beating heart  • Can stabilize the heart, create a working space, provide direct visualization, and deliver
therapies such as stem cells  • Other applications include delivery of therapeutics, transmyocardial
revascularization, ablation, echo-probe diagnostics, LAA isolation and procedural observation

PUBLICATIONS, PRESENTATIONS & POSTERS
Fletcher ND, Lazarus DE, Desai MJ, Patel NN, Bruce RW. Medicaid insurance is associated with larger curves in
Wise BT, Patel NN, Wier G, Labib SA. Outcomes of ACL Reconstruction With Fixed Versus Variable Loop Button
Patel NN, Labib SA. The Achilles Tendon in Healthy Subjects: An Anthropometric and Ultrasound Mapping
Patel NN, Guild GN, Erens GA. Femoral Head-Trunnion Dissociation in Metal-on-Polyethylene Total Hip
Patel NN, Bruce RW. Transcapsular Buttonholing of the Proximal Ulna as a Cause for Irreducible Pediatric
Anterior Elbow Dislocation: A Case Report. Accepted for publication Apr 2018 in Case Reports in Orthopedics.
Accepted for publication Jan 2018 in JBJS.

PRESENTATIONS
The Achilles Tendon in Healthy Subjects: An Anthropometric and Ultrasound Mapping Study  New Orleans, LA
Outcomes of ACL Reconstruction With Fixed Versus Variable Loop Button Fixation  Amelia Island, FL
Eastern Orthopedic Association: Podium Presentation Oct 22, 2014
Outcomes of ACL Reconstruction With Fixed Versus Variable Loop Button Fixation  Atlanta, GA
Annual Emory Research Symposium Apr 23, 2015
CURRENT PROJECTS

Emory University School of Medicine, Department of Orthopaedics Atlanta, GA

The Use of Intra-wound Vancomycin Powder in Hip and Knee Arthroplasty
PI: Dr. George Guild
Performing a retrospective review of >500 surgical patients to analyze the potential benefits of routine intra-wound vancomycin powder in arthroplasty surgery.

Surgeon Preferences and Perceptions Regarding the Direct Anterior Approach for Hip Arthroplasty
PI: Dr. Greg Erens
Currently in the process of surveying fellowship trained arthroplasty surgeons regarding their perceptions and preferences towards DAA for hip arthroplasty. We aim to gain insight into factors driving surgical choice as well as those providing barriers to transitioning surgical practice.

Treatment of Infection Through Thermal Heating of Implants
Currently combining my passions for orthopedics and engineering in order to investigate the ability of in-vivo electromagnetic heating to clear infection from implanted hardware. My goal is to develop a way to eradicate biofilm on implants and, therefore reduce the need for revision surgery to remove infected hardware.

Comparison of Early Outcomes of Total Elbow Arthroplasty Based on Surgical Indication
Performing an analysis of the NSQIP Database in order to identify difference in early outcomes for TEA based on surgical indication.
Intra-wound Vancomycin in Primary Hip & Knee Arthroplasty –
A Safe and Cost Effective Means to Decrease Prosthetic Joint Infection

Nick N. Patel, MD; George N. Guild III, MD; Arun Kumar, MD

Introduction

The utilization of hip and knee arthroplasty has been steadily increasing due to an active aging population. It is projected that the number of total hip and knee replacements will approach greater than 570,000 and 3.4 million respectively by 2030 [1]. Despite substantial research and robust multimodal programs to mitigate infection, periprosthetic joint infection (PJI) continues to be a devastating complication to patients and the health care system. PJI rates have continued to average between 0.5-2% [2-4], and it is estimated that by 2020, $1.62 billion will be spent on revisions for infection in the U.S. alone [5].

Many PJI prevention strategies have been developed ranging from preoperative screening, intraoperative methods, and postoperative intervention with varying levels of success. One such prevention strategy has been the use of intraoperative vancomycin powder. Although this has been well described in the spine surgery literature including its safety and effectiveness [6, 7], information regarding the use of intra-wound vancomycin in the arthroplasty setting is almost nil.

Several studies do exist supporting the use of intra-wound antibiotics for total joint arthroplasty in animal models. Separate in-vivo rat investigations performed by Edelstein et al. and Cavanaugh et al. both demonstrated the effectiveness of intra-wound antibiotics on clearing staph aureus from contaminated femoral implants [8, 9]. Johnson et al. recently published data supporting the safety of vancomycin powder placed intra-articular after arthroplasty [10]. While there is basic science and spine literature supporting the use of intra-wound vancomycin powder, there is a paucity of clinical data in its efficacy for prevention of PJI.

The most common pathogen in infected total joint arthroplasty is staphylococcal species[11], and an increasing incidence of methicillin resistant Staphylococcus aureus (MRSA) has made vancomycin a reasonable choice for intra-wound antibiotics[12]. Potential benefits of intra-wound antibiotics include maximizing local bactericidal concentrations while minimizing adverse systemic effects. Despite these potential benefits, there are numerous questions regarding this practice including safety information on seroma formation, bearing wear, nephrotoxicity and ototoxicity. Further questions exist to whether this practice truly decreases infection rates.

The objective of this study is to determine if the routine use of intra-wound vancomycin powder resulted in a decreased periprosthetic joint infection rate as the primary outcome metric in our large volume, academic, teaching hospital. Secondary outcomes include safety metrics based on 90 day all cause readmissions, mechanical complications, nephrotoxicity, ototoxicity, and cost data.

Materials and Methods

This retrospective investigation was performed in accordance with our institutional review board. Operative records for patients having undergone primary total hip or knee arthroplasty from April 2016 through October 2017 were analyzed for a single fellowship trained arthroplasty surgeon. This timeline was selected to use contemporary data with an updated PJI prevention program rather than historical data which may introduce confounding variables. Furthermore, one year of clinical practice, October 2016 to October of 2017, was chosen as the experimental consecutive cohort with intra-wound vancomycin to be able to report all infection and complications that may occur over a year of clinical practice. 112 consecutive surgeries without
vancomycin powder were used as the control consecutive cohort, followed by 348 consecutive surgeries used as the experimental intra-wound vancomycin group. All surgeries were performed at the same institution which is a large volume, urban, academic-teaching hospital. Inclusion criteria included patients undergoing primary total hip or knee arthroplasty with indication of osteoarthritis, osteonecrosis, post-traumatic arthritis, as well as inflammatory arthropathies. Patients were excluded if they were undergoing a revision surgery. With this criteria, no patient undergoing a primary total hip or knee replacement was excluded from either group for any reason over the above mentioned time period, minimizing potential for sampling bias and aiding in its generalizability to other populations. Standard patient pre-operative screening measures included BMI<40, Hemoglobin A1C<7, appropriate dentition, smoking cessation, nasal MRSA screening, and optimization of medical comorbidities such as renal failure, COPD, CHF, and anticoagulation.

Preoperatively, patients received dosed intravenous cephalosporin within one hour prior to incision; however, intravenous vancomycin was administered instead for those with a history of anaphylaxis to penicillins. Hoods and cloth gowns were utilized during surgery. After hardware implantation, a three-minute dilute betadine soak of the surgical wound was performed followed by irrigation using one liter of normal saline with 50,000 units of bacitracin on all patients. Starting in October 2016, the principle surgeon routinely applied one gram of vancomycin powder into the surgical wound prior to closure in primary hip and knee arthroplasties. The antibiotic powder was applied into the joint and surrounding muscle, fascia and subcutaneous tissues. No antibiotics were placed in bone cement in any hip or knee. Subcutaneous vicryl suture followed by subcuticular monocryl and dermabond was routinely utilized for hip closure, and staples with occlusive dressing (Aquacel Ag, ConvaTec, Bridgewater, NJ) were used for knee replacement.

Our institution participates in the Center for Disease Control and Prevention’s National Healthcare Safety Network (NHSN) for surveillance and reporting of deep and superficial surgical site infections (SSI)[13]. A review of this database located all patients who had been identified as having an SSI within the designated timeline. Additionally, operative records for all patients of the primary surgeon were reviewed to ensure that all infections were in fact captured. Subjects were grouped based on whether they did receive intra-wound vancomycin (October 2016 – October 2017) or did not (April 2016 – September 2016). Information regarding patient demographics, baseline characteristics, comorbidities and operative data was collected. Culture positive superficial wound infections and deep joint infection (subfascial intra-articular) were included. Superficial wound infections were routinely treated with irrigation, debridement, and closure, followed by a course of antibiotics, while deep infections were treated with one or two stage revision procedures depending on chronicity. Minor postoperative wound complications such as stitch abscesses or erythema that were treated with routine postoperative wound care were not considered wound infections and thus not included in the infection data. Return to the OR for hematoma or seroma that met Musculoskeletal Infection Society (MSIS) criteria for infection, or simply had a single positive culture were included in the infection data. In addition, post-operative sub-metrics including 90-day all-cause readmission, acute kidney injury (AKI) and ototoxicity were recorded. AKI was considered an increase of > 0.3mg/dL in serum creatinine post-operatively. Student t-test was utilized to compare numerical variables while Fischer exact test was used to compare categorical variables.

Results

From April 2016 through October 2017, a total of 460 primary total hip and knee arthroplasty cases were performed by the primary surgeon that satisfied inclusion and exclusion criteria (217 TKA, 243 THA) (Table 1). Patients were similar in terms of demographics, comorbidities and other operative variables for those with and without vancomycin (Table 2). The control primary arthroplasty group had an overall infection rate of 2.7%, which included 3 deep infections and 0 superficial infections. The vancomycin powder cohort had and overall infection rate of 0.57%, which included 1 superficial and 1 deep infection (Table 3). The deep infection rate in the vancomycin group was 0.29%. The decrease in overall infection rate from 2.7% to 0.57% (p = 0.031) and deep infection rate from 2.7% to 0.29 (p=0.009 ) with the addition of vancomycin powder were both statistically significant. There was no significant difference in incidence of post-operative AKI or ototoxicity. The control
group had a 5.4% 90-day all-cause hospital readmission rate while the vancomycin group had a rate of 3.2% (p = 0.14). When analyzing various factors for readmission, there was no statistical difference in readmission rate for non-infectious wound issues, mechanical complications, or medical issues unrelated to the index procedure (p > 0.05, Table 4). As expected, the control group had a statistically higher 90-day readmission rate due to infection compared to the vancomycin subset (2.7% vs. 0.57%, p = 0.031). Table 5 demonstrates detailed information regarding the cases of infections in both subsets including bacteria cultured, time to repeat surgery, risk factors, and clinical outcome. One TKA patient in the control group had multiple recurrences of infection and required an eventual above knee amputation. The remaining four infections cleared clinically after surgical intervention.

Table 1

<table>
<thead>
<tr>
<th>Primary Surgical Case Breakdown</th>
<th>Control</th>
<th>With Vanc</th>
</tr>
</thead>
<tbody>
<tr>
<td>TKA</td>
<td>56</td>
<td>161</td>
</tr>
<tr>
<td>THA</td>
<td>56</td>
<td>187</td>
</tr>
<tr>
<td>Total</td>
<td>112</td>
<td>348</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Primary Arthroplasty Demographics</th>
<th>Control</th>
<th>With Vanc</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>42.9% (48)</td>
<td>39.7% (138)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>57.1% (64)</td>
<td>60.3% (210)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>64.9</td>
<td>63.6</td>
<td>0.334</td>
</tr>
<tr>
<td>BMI (kg/m2)</td>
<td>31.1</td>
<td>30.6</td>
<td>0.526</td>
</tr>
<tr>
<td>Smoker</td>
<td>12.5% (14)</td>
<td>10.9% (38)</td>
<td>0.646</td>
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<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>12.5% (14)</td>
<td>9.8% (34)</td>
<td>0.412</td>
</tr>
<tr>
<td>CAD</td>
<td>9.8% (12)</td>
<td>6.3% (22)</td>
<td>0.121</td>
</tr>
<tr>
<td>PAD</td>
<td>0.9% (1)</td>
<td>1.4% (5)</td>
<td>0.660</td>
</tr>
<tr>
<td>Renal insufficiency</td>
<td>1.8% (2)</td>
<td>3.7% (13)</td>
<td>0.313</td>
</tr>
<tr>
<td>Anticoagulated</td>
<td>8.0% (9)</td>
<td>4.6% (16)</td>
<td>0.162</td>
</tr>
<tr>
<td>Albumin ≤ 3.5</td>
<td>6.3% (7)</td>
<td>4.0% (14)</td>
<td>0.327</td>
</tr>
</tbody>
</table>

Table 3

<table>
<thead>
<tr>
<th>Primary Arthroplasty Post Operative Outcomes</th>
<th>Control (n=112)</th>
<th>With Vanc (n=348)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superficial</td>
<td>0% (0)</td>
<td>0.29% (1)</td>
<td>0.28</td>
</tr>
<tr>
<td>Deep</td>
<td>2.7% (3)</td>
<td>0.29% (1)</td>
<td>0.009</td>
</tr>
<tr>
<td>Total</td>
<td>2.7% (3)</td>
<td>0.57% (2)</td>
<td>0.031</td>
</tr>
<tr>
<td>Post-op AKI</td>
<td>0% (0)</td>
<td>0.29% (1)</td>
<td>0.28</td>
</tr>
<tr>
<td>Ototoxicity</td>
<td>0% (0)</td>
<td>0% (0)</td>
<td></td>
</tr>
</tbody>
</table>
The use of intra-wound vancomycin powder has been well described in the spine surgery literature with regards to safety and efficacy in reducing surgical site infection[6, 7, 14]. With regard to total joints, Otte et al. demonstrated a reduced infection rate for hip and knee arthroplasty with the addition of vancomycin powder but only in the revision setting[15]. Dial et al. recently showed a decreased infection rate in a series of primary hip arthroplasties but did find an increased incidence of associated sterile seroma[16]. Results of our investigation demonstrate a significantly decreased overall infection rate from 2.7% to 0.57% for primary total hip and knee arthroplasty with the addition of intra-wound vancomycin. More notably, the most significant reduction observed was in deep PJI with an infection rate of 0.29% (p = 0.009).

<table>
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<th>Table 4</th>
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<tr>
<td>Primary Arthroplasty 90-Day All-Cause Readmission</td>
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Discussion

The use of intra-wound vancomycin powder has been well described in the spine surgery literature with regards to safety and efficacy in reducing surgical site infection[6, 7, 14]. With regard to total joints, Otte et al. demonstrated a reduced infection rate for hip and knee arthroplasty with the addition of vancomycin powder but only in the revision setting[15]. Dial et al. recently showed a decreased infection rate in a series of primary hip arthroplasties but did find an increased incidence of associated sterile seroma[16]. Results of our investigation demonstrate a significantly decreased overall infection rate from 2.7% to 0.57% for primary total hip and knee arthroplasty with the addition of intra-wound vancomycin. More notably, the most significant reduction observed was in deep PJI with an infection rate of 0.29% (p = 0.009).
The PJI rate for control primary cases in our series was found to be 2.7% which is slightly higher than the reported 0.5%- 2.0% described in the literature [2-4]. This increased infection rate is thought to be partly attributable to the patient population seen at our institution which is a high volume tertiary referral center. Patients in our cohort had an average BMI > 30, 11.3% rate of active smokers, and 10.4% rate of diabetes mellitus, all of which are known PJI risk factors after arthroplasty surgery [17-19]. Additionally, patients of lower socioeconomic status have been shown to have a higher incidence of PJI, and our institution is one of the sole providers for Medicaid patients in the area[20]. Although smoking cessation as a standard practice was implemented during the study period, subsequently a negative urine nicotine has been required at pre-anesthesia testing. The increased infection rate in the control group was the impetus to evaluate a new strategy to prevent PJI: intra-wound vancomycin powder. 

Concerns have been raised regarding the safety of intra-wound vancomycin. Studies have demonstrated low morbidity associated with intra-wound vancomycin in surgical spine cases [21]. Similarly, an investigation by Johnson et al. attested to the safety of 2g of intra-articular vancomycin powder in arthroplasty surgery[10]. They found highly therapeutic vancomycin concentrations in the local tissue yet low systemic levels. Our results are in agreement with the previous published data on safety, as there was no significant difference in post-operative acute kidney injury or ototoxicity between the control and vancomycin groups. There was a low threshold in this study to include AKI as a complication with increase in creatinine of 0.3 mg/dl. The one patient in the vancomycin group who experienced AKI had a correction of creatinine to baseline after 24 hours of fluid hydration with no long-term nephrotoxic sequelae. There was also no statistical significant difference in seroma formation in the vancomycin group. There was one seroma in the vancomycin group that required an irrigation and debridement in the postoperative period who had five negative cultures and was not treated with antibiotics. That patient did heal uneventfully and no further surgical intervention was required. The authors suggest that this work contributes to the existing literature on safety regarding the use of intra-wound vancomycin powder.

The efficacy of intra-wound vancomycin powder has been debated in the spine literature. Strom et al. showed that the implementation of intra-wound vancomycin powder is particularly beneficial in decreasing infection rates in posterior cervical fusion surgery when current high rates exist[22]. In their study, the infection rate decreased from 10% to 2.5%. Other studies from the spine literature show that if the existing infection rate is low, then the routine use of vancomycin powder is of little benefit [23]. The authors of this manuscript cannot comment on what infection rate should trigger a root cause analysis in total joint arthroplasty, but just a general guideline that if the exiting infection rate is >2% [4] then an investigation with tracked solutions should be performed locally. This is the scenario that prompted the investigation and potential solution to the increased infection rate at the authors’ institution (2.7%). Since the single change to protocol in October of
2016, only one patient had a deep infection in that year with an infection rate of 0.29%. The single infection occurred in a patient with rheumatoid arthritis who unknowingly used recreational amphetamines which may have contributed to his delayed wound healing and subsequent deep infection. Despite routine drug use, the patient was included in the study in an effort to be generalizable to other surgeon’s practices and for full transparency. The authors attribute the lower infection rate in this study to the use of intra-wound vancomycin, as other confounders such as surgeon technique, implants, facility, and multimodal PJI prevention strategies were identical between groups. The authors have continued to routinely use intra-wound vancomycin powder on all primary and revision total joint arthroplasties.

The introduction of a crystalline substance into a prosthetic joint provokes thought about premature third-body implant wear; however, Qadir et al. demonstrated no appreciable implant wear with the addition of intra-articular vancomycin in a biomechanical study [24]. High concentrations of certain antibiotics have been shown to be cytotoxic towards osteoblasts[25]. Vancomycin exhibited one of the weakest effects on osteoblast growth and osteogenic activity, thus making it suitable for local delivery[25, 26]. This concept is particularly important in the arthroplasty setting with regards to implant fixation and bony ongrowth. With the follow-up period in our investigation, we did not note any issues with aseptic loosening; however, this could be more appreciable with long-term data. Furthermore, long-term information about the osteogenic effects of intra-wound vancomycin may provide insight into potential differences in outcomes between cemented or cementless implants.

The vast financial burden on patients and healthcare system associated with PJI imparts particular importance when discussing the economics with intra-wound vancomycin. At our institution, one gram of vancomycin powder costs $17, which is on par with the rates at other facilities[27]. The addition of intra-wound vancomycin in this investigation led to a decrease in the overall infection rate from 2.7% to 0.57% suggesting an absolute risk reduction (ARR) of 2.13% or 0.21. This leads to the determination of number needed to treat (NNT) as 47.5 (NNT = 1/ARR). In other words, 48 primary total hip or knee arthroplasties need to be performed with the addition of vancomycin powder to prevent one case of prosthetic joint infection. At the rate of $17 per patient, the total cost with the addition of intra-wound vancomycin to prevent one PJI is $816. This is a relatively insignificant cost in comparison to an estimate of the 2018 average hospital cost per case of infected THA ($30,329) and TKA ($25,155)[28].

The strengths of the study are that it is a single surgeon series, at one institution, without change in infection prevention protocols over the study period. This potentially limited confounding variables which can be numerous in an infection study. The potential for sampling bias was limited by the fact that no patient was eliminated from either group unless it was a revision surgery. The consecutive nature of the surgeries
performed in each group may afford some protection from selection bias; however, the non-randomized nature of the study is a limitation. Other limitations include the low effect size with regards to number of surgical site infections. A sample size of 3,416 patients would be required to adequately detect a 50% reduction in infection rate from 2.7% to 1.35% with power of 0.80 and alpha 0.05. To obtain this number of control group patients, a historical control infection rate would have to be utilized, or information used from more than one surgeon which would introduce other confounding variables and protocol changes. Furthermore, several consecutive years of clinical practice would be required to identify enough vancomycin group patients to gain appropriate power which would delay the reporting of a potentially safe and beneficial strategy in decreasing PJI. Consideration was given to including data from other surgeons and institutions but the authors believe this would have introduced numerous confounding variables in an effort to increase sample size. Future research on increasing the sample size to allow for appropriate power without introducing confounders is a worthy endeavor. The allotted sample size of 460 was however, sufficient in detecting the significantly decreased infection rate noted in this investigation.

The authors suggest that the use of intra-wound vancomycin is safe in short term follow and was protective in preventing early postoperative complications or readmissions. Its usage shows promise in reducing the incidence of PJI, particularly if an increased rate of PJI is present or the hospital population is at risk. Furthermore, intra-wound vancomycin is a low-cost option with a low number needed to treat to show value. Future research aimed at adding sample size without the introduction of confounding variables is necessary before any formal recommendations for its routine use in total joint arthroplasty can be made.

References


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International Presentations


Regional Presentations


Total Disc Replacement Adjacent to a Multilevel Fusion in the Cervical Spine: A Biomechanical Study

Dale N. Segal, MD, Zachary J. Grabel, MD, Jacob M. Wilson, MD, Andrew H. Milby, MD, Weilong J Shi, MD, William C. Hutton, DSc, John M. Rhee, MD

Abstract

Background Context: The cervical total disc replacement (TDR) has emerged as a motion-preserving alternative to anterior cervical disectomy fusion (ACDF). Biomechanical studies have demonstrated that the TDR preserves motion at the diseased segment and minimizes motion and stress at adjacent segments compared to fusion. There has been growing interest in performing a TDR adjacent to a cervical fusion.

Purpose: The purpose of this study was to investigate the kinematics of a TDR after sequentially fusing adjacent segments.

Methods: Seven fresh-frozen human cadaveric cervical spine specimens from C1-T1 were used (average age 56.2 ± 7.3 years). The effect on cervical flexion-extension motion, by instrumenting a TDR above or below a one, two or three-level fusion, was measured. The protocol consisted of taking fluoroscopic images of each cervical specimen obtained at maximal angular displacement in flexion and extension during force application. Cobb angles were measured on the digital radiographs to determine flexion-extension range of motion.

Results: The segmental range of motion (ROM) of the C6-7 TDR in the unfused spine was 11.3 ±1.9°. After performing a three-level fusion at C3-6, the motion of the C6-7 TDR increased to 12.9 ±1.3°(p=0.33). The ROM of the C2-3 TDR in the unfused spine was 5.0 ±1.1°. After performing a three-level fusion of C3-6, the C2-3 TDR segmental motion was 6.1 ±1.3° (p=0.09).

Conclusion: Biomechanically performing a cervical total disc replacement adjacent to a long segment fusion did not subject the implant to significantly greater motion than when the TDR was instrumented alone.

Introduction

Anterior cervical disectomy and fusion (ACDF) is a well-established procedure with favorable outcomes and high levels of patient satisfaction(1, 2). Despite its widespread utilization, adjacent segment disease after ACDF remains a clinical concern. Prior studies have demonstrated that spine mechanics are altered at segments adjacent to fusion, potentially leading to hypermobility and accelerated degenerative changes(3-7). Biomechanical studies have demonstrated that a cervical total disc replacement (TDR) may preserve motion at the diseased segment while minimizing motion and stress at adjacent segments(8-10). Cervical TDR has emerged as an alternative to ACDF with favorable outcomes(10-13). In addition, cervical TDR has shown promise as a potential option for treatment of degeneration adjacent to prior ACDF constructs. The kinematics of the cervical spine with a TDR adjacent to a long fusion construct (>2 levels) has not been documented.

Early clinical results of a cervical disc replacement adjacent to a single level ACDF are encouraging(12-14). In a biomechanical study, Lee et al(15) demonstrated cervical disc replacement adjacent to a single level fusion improves overall spine motion and reduces compensatory adjacent segment spine motion...
compared with a two-level cervical fusion. A similar cadaveric study revealed cervical replacement adjacent to a two-level fusion is not associated with hypermobility at the level of the disc replacement(16). The purpose of this study was to measure the segmental cervical spine motion of a TDR adjacent to a long fusion construct (≥2 levels). In this investigation we evaluated the flexion-extension segmental motion of the cervical spine with a TDR adjacent to a single, two and three level fusion. We also compared the implant motion to a control native disc with adjacent fusions at corresponding levels. We hypothesized that there would be no significant increase in the degree of flexion-extension motion in the TDR instrumented alone or adjacent to a one, two or three level fusion.

Materials and Methods

Materials

Seven fresh-frozen human cadaveric cervical spine specimens from C1-T1 were used (5 men, 2 women; average age 56.2 ± 7.3 years). The seven specimens were selected after screening in order to exclude any with prior cervical surgery, metastatic disease, auto-fusion, or congenital anomalies. The specimens were thawed at room temperature for 24 hours prior to the experimental protocol. Paravertebral muscles were dissected taking care to preserve osseous, ligamentous and disc material. Fluoroscopy was employed to confirm appropriate levels. Three screws were inserted radially into the body of T1 to aid in cement fixation and the specimens were potted in dental cement up to the caudal endplate of C7.

An external fixator construct was applied to each of the seven cadaver specimens for the purpose of simulating a fusion construct in a non-destructive fashion. The construct was composed of 3 mm diameter Schanz pins inserted from anterior to posterior into the bodies of C3-C6 with care not to damage the adjacent soft tissue structures. Carbon fiber rods were used to rigidly fix each Schanz pin to the adjacent pins using pin-to-bar clamps, thus allowing for simulation of fusion at different spinal segments within the same specimen.

Experimental Procedure

A 4.0-mm diameter threaded screw was inserted from cephalad to caudad into the body of C2. A tensioning cable was secured to this screw. The cable was used to apply a flexion force or an extension force to the cervical spine. The force in each case was applied in a direction parallel to the cephalad endplate of C2 as described by Horton et al(17). We applied a constant 40 N. A force of this magnitude achieved maximal angular displacement (in flexion and in extension) and allowed the spine to return to its neutral position within its elastic region, as defined during pilot studies. Each specimen was preconditioned by subjecting it to 5 cycles of flexion-extension at 40N prior to testing. The protocol consisted of fluoroscopic images of the specimen obtained at maximal angular displacement in flexion during force application (Figure 1). The procedure was then repeated with the specimen at maximal angular displacement in extension during force application.

Two experiments were performed on each cervical specimen:

Experiment 1: We tested spine motion when a TDR was instrumented below a multilevel fusion by placing the implant at C6-7 in the C2-7 specimen (Figure 2). After completing experiment 1, the TDR at C6-7 was removed and the specimen was potted up to the C6 caudal endplate. We then moved to experiment 2.

Experiment 2: We tested the spine motion when a TDR was instrumented above a multilevel fusion by inserting the implant at C2-3 (figure 2). The C2-6 cervical spine was used for this experiment.

The stepwise protocol for each experiment is described below.
Disc replacement below fusion: Experiment 1

Step 1: Lateral fluoroscopic images were obtained for the native cervical spine at flexion and extension end points under the 40 N force described above.

Step 2: A single level fusion was simulated at C5-6 using the pin-bar construct described and fluoroscopic images were obtained at both flexion and extension end points.

Step 3-4: This process was repeated for a two-level fusion of C4-6 and a three-level fusion of C3-6.

Step 5: Next, the fusion construct was disassembled and a C6-7 discectomy was performed. A NuVasive PCM cervical disc was inserted into the C6-7 disc space as described in the technique guide (NuVasive, Inc. 7475 Lusk Blvd., San Diego, CA 92121 USA). The prosthesis was appropriately sized so as to not over tension the stabilizing soft tissue structures. Placement was confirmed under image intensification.

Step 6: With the prosthetic disc in place, the cervical spine was again tested in flexion and extension and fluoroscopic images were obtained.

Step 7-9: With the C6-7 TDR adjacent to a one-level fusion (C5-6) a two-level fusion (C4-6) and a three-level fusion (C3-6); the cervical spine was again tested in flexion and extension and fluoroscopic images were obtained.

Step 10: The fusion construct was removed and the cervical spine was tested in flexion and extension and fluoroscopic images were obtained. The purpose of this step was to confirm that baseline motion, as observed in step 1, was preserved.

The above 10-step protocol was carried out for all seven specimens.

Disc replacement above fusion: Experiment 2

After completion of experiment 1, the implant was removed from the C6-7 disc space and the specimen was re-potted in dental cement up to the C6 inferior endplate. Thus, a C2-6 specimen was used for this portion of the experiment.

Step 1: First, lateral fluoroscopic images were obtained for the native cervical spine at the flexion end point and then at the extension end point under the 40 N force described above.

Step 2: A single level fusion was simulated at C3-4 using the pin bar construct and radiographs were taken at both flexion and extension end points.

Step 3-4: This process was repeated for a two-level fusion of C3-5 and a three-level fusion of C3-6.

Step 5: Next, the rod-to-rod connectors were removed and a C2-3 discectomy was performed. A NuVasive PCM cervical disc was inserted into the C2-3 disc space as described above.

Step 6: With the prosthetic disc in place, the cervical spine was again tested in flexion and extension and lateral fluoroscopic images were obtained.

Step 7-9: This process was repeated with the C2-3 TDR adjacent to a one-level fusion (C3-4), a two-level fusion (C3-5) and a three-level fusion (C3-6); the cervical spine was tested in flexion and extension and fluoroscopic images were obtained after each step.
Step 10: The fusion construct was removed and the cervical spine was again tested in flexion and extension and fluoroscopic images were obtained. The purpose of this step was to confirm that baseline motion was preserved as measured in step 1.

The above 10-step protocol was carried out for all seven specimens.

After the biomechanical testing was complete, the digital fluoroscopic images were analyzed on the PACS system (GE Centricity PACS Radiology 1000 workstation). The C2-7 Cobb angles were measured in flexion and in extension as described by Park et al(18) to quantify the overall range of motion (ROM). The segmental motion was assessed by measuring the flexion and extension Cobb angles of C2-3, C3-4, C4-5, C5-6 and C6-7. Cobb angles were measured three times to determine intra-observer agreement. Three independent blinded observers repeated the measurements in order to determine inter-observer reliability. The ROM was obtained by summation of the flexion and extension values. The average flexion-extension ROM values for the seven specimens at each segment were used for the final analysis.

Data Analysis:

In order to validate the fusion model, the segmental ROM in the native cervical spine was compared to that in the fused spine. To demonstrate the integrity of the spine after removal of the external fixator fusion construct, we compared the segmental motion of the specimen prior to external fixator placement to the segmental motion after external fixator removal. C2-3 and C6-7 were not considered in this comparison as the prosthetic disc had been placed in these segments.

We compared the segmental motion at the level of the TDR implant when instrumented as a stand-alone device and when placed adjacent to a one, two and three level fusion. These comparisons were made for both the TDR above and below a multi-level fusion. We also compared the segmental motion of the TDR to that of the native disc at the corresponding level. These comparisons were made for the unfused specimen, and for the one, two and three level fusions above and below the TDR. We assessed the overall motion of the cervical specimen instrumented with a stand-alone TDR implant and compared it to the overall motion of the control native specimen. Finally, we compared the overall cervical motion with the TDR adjacent to a one, two and three level fusion construct to that of the control spine with corresponding levels fused.

Repeated-measures analyses were used to analyze segmental motion using a means model via the SAS MIXED Procedure (version 9.4; SAS Institute, Cary, NC), providing separate estimates of the means by TDR group, fusion level and cervical location. A compound-symmetric variance-covariance form in repeated measurements was assumed for each outcome, and robust estimates of the standard errors of parameters were used to perform statistical tests and construct 95% confidence intervals(19). Predictors included in each model were TDR group, fusion level, cervical location and the interaction between TDR group, fusion level and cervical location. All specific statistical tests were done within the framework of the mixed effects linear model, using t tests to compare differences between the model-based means. The results were summarized with model-based means and 95% confidence intervals by TDR group, fusion level and cervical location. Statistical tests were two-sided and unadjusted for multiple comparisons. A p value < .05 was considered statistically significant.

Results

Effect of Simulated Fusion

As expected, the external fixator fusion construct reduced flexion-extension motion. We measured the segmental ROM on the flexion-extension radiographs of the C2-7 cadaver specimen and compared it
to the segmental motion after performing the C3-6 fusion. The C3-6 ROM in flexion-extension was reduced from 29.3 \( \pm 5.3 \) in the native spine to 2.9 \( \pm 1.1 \) after a C6 fusion (p<0.0001) (Table 1).

Reversibility of Fusion Construct

Removal of the fusion construct allowed the spine to return to its native state. This was demonstrated by comparing the total flexion-extension ROM of the native spine at C3-6 prior to fusion to the motion at C3-6 after fusion construct was removed; 29.3 \( \pm 5.3 \) versus 35.3 \( \pm 8.0 \), respectively (p=0.11).

Motion with a C6-7 TDR below a three-level fusion in the C2-7 cervical spine

The segmental ROM of the C6-7 TDR in the unfused spine was 11.3 \( \pm 1.9 \). After performing a three level fusion (C3-6), the segmental motion of the C6-7 TDR increased to 12.9 \( \pm 1.3 \). This difference was not statistically significant (p=0.33) (Table 1). In the native spine, the flexion-extension ROM at C6-7 of the native segment was 9.2 \( \pm 2.0 \) whereas, the ROM of C67 after performing a C3-6 fusion was 11.3 \( \pm 1.9 \) (p=0.18). The difference between the motion of the C67 TDR segment below a three-level fusion (12.9 \( \pm 1.3 \)) and the C67 native disc below a three-level fusion (11.3 \( \pm 1.9 \)) was not statistically significant (p=0.30) (Figure 3). The overall C2-7 motion in the native specimen compared to specimen with a C6-7 TDR was 39.3 \( \pm 5.4 \) vs 42.1 \( \pm 7.6 \), respectively (p=0.38). After performing a C3-6 fusion, the C2-7 overall motion between the specimen with the native C6-7 segment and the one with a C6-7 TDR were similar; 24.3 \( \pm 5.6 \) vs 27.3 \( \pm 5.1 \) (p=0.27) (Figure 4).

Motion of a TDR at C2-3 above a three-level fusion in the C2-6 cervical spine

The segmental ROM of the C2-3 TDR in the unfused spine was 5.0 \( \pm 1.1 \). After performing a three level fusion (C3-6), the C2-3 TDR segmental motion was 6.1 \( \pm 1.3 \). This difference was not statistically significant (p=0.09) (Table 2). In the native spine, there was a significant difference in the flexion and extension ROM at the C2-3 native segment (4.4 \( \pm 0.9 \)) compared with the ROM after performing a C3-6 fusion (6.4 \( \pm 0.8 \) (p=0.001). The difference in motion of the TDR above a three-level fusion and the native disc above a three-level fusion was not statistically significant; 6.1 \( \pm 1.3 \) vs 6.4 \( \pm 0.8 \) respectively (p=0.15) (Figure 5). The overall C2-6 motion in the native specimen compared to specimen with a C2-3 TDR was 32.1 \( \pm 5.9 \) vs 32.8 \( \pm 4.8 \), respectively (p=0.77). After performing a C3-6 fusion the C2-6 overall motion between the specimen with the native C2-3 segment and the one with a C2-3 TDR were similar; 10.3 \( \pm 1.9 \) vs 9.3 \( \pm 1.3 \) (p=0.33) (Figure 6).

Inter-observer reliability

The overall inter-observer agreement was 0.91. The intra-observer agreement was 0.95.

Discussion

The primary result demonstrated by this study is that there was no significant difference in cervical TDR motion when instrumented alone or adjacent to a one, two or three level fusion. Furthermore, there was no significant difference in segmental motion at the level of the TDR implant compared to the corresponding native segment when instrumented above or below a fusion construct. This held true irrespective of its placement adjacent to a one, two or three-level fusion. In our study there was a small trend towards increased motion in the TDR as the number of levels fused adjacent to this segment increased however the magnitude of the observed difference was small and therefore unlikely to be clinically relevant.

Our results are consistent with previous kinematic studies. Lee et al. concluded that the motion of the PCM cervical total disc replacement adjacent to a fused level is comparable with that of a stand-alone prosthesis(15). Their study did not find a significant difference in the motion of the prosthesis when
the fused level was below or above to the TDR. Martin et al assessed motion of a C3-4 disc arthroplasty implanted as a standalone and above a 2 level fusion and found that there was no increase in compensatory motion when subjected to a constant load(16).

There are several limitations to this study. First, this investigation did not employ a compressive load on the cervical spine to simulate the force of the head, known as the follower load technique, but rather used pure bending moments(15, 16, 20, 21). Theoretically, pure bending moments are more likely to subject the spine to shearing forces which may lead to structural damage. Additionally, we used a load control rather than a displacement control method for applying the flexion and extension force to the spine; displacement control poses an increased risk of damaging the specimens through overload. Despite using pure bending moments and a load control method, the specimens in our study remained intact, which was demonstrated by verifying segmental motion after testing was complete. No assessment of rotational motion was performed. Our experimental protocol did not include destructive testing of specimens. As such, we extrapolated from individual trials performed within the elastic region of the flexion-extension arc to assess whether a segment may experience additional range of motion within physiologic activity, as this may contribute to accelerated adjacent segment degeneration. No

conclusions can be drawn regarding the propensity of TDR adjacent to long fusion toward prosthesis loosening or catastrophic failure with supra-physiologic loading. Cobb angles from lateral fluoroscopic imaging were used to measure flexion-extension angles. These measurements demonstrated satisfactory intra-observer predictability and inter-observer reliability scores. Our fusion model did not completely eliminate segmental motion which may have been due to the biomechanical nature of the construct or Cobb-angle measurement error. These values were consistent with previous studies and are unlikely to be clinically significant. Our study failed to reject the null hypothesis which could have been due to our sample size of seven specimens and the study being underpowered. However, a post-hoc power analysis demonstrated that four specimens would have been sufficient to find a 10° difference in segmental motion (a value that we would have considered clinically significant). Lastly, the implant utilized for the study (Nuvasive PCM) is not FDA approved for instrumentation at C2-3. The purpose of utilizing this level was to maximize adjacent caudal fusion segments in order to illustrate its effect on motion.

In conclusion, in this biomechanical experiment we observed no significant difference in cervical TDR motion when instrumented alone, or above or below, a one, two or three-level fusion.

Furthermore, there was no significant difference in segmental motion at the level of the TDR implant compared to the corresponding native segment when instrumented above or below a one, two, or three-level fusion. These results suggest that performing a TDR adjacent to a long anterior cervical fusion preserves native flexion-extension at that level and is not subjected to excessive compensatory motion.
## Table 1. Flexion Extension Motion of a TDR below a Fusion

<table>
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<tr>
<th></th>
<th>Overall motion</th>
<th>C2-3 motion</th>
<th>C3-4 motion</th>
<th>C4-5 motion</th>
<th>C5-6 motion</th>
<th>C6-7 motion</th>
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<td><strong>Native (C2-7)</strong></td>
<td>39.3°±5.4 (4.0)</td>
<td>4.3°±1.6 (1.3)</td>
<td>8.9°±1.6 (1.2)</td>
<td>9.9°±1.8 (1.4)</td>
<td>10.5°±3.6 (2.7)</td>
<td>9.2°±2.8 (2.0)</td>
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<td><strong>C5-6 Fusion</strong></td>
<td>34.5°±6.4 (4.8)</td>
<td>5.4°±3.5 (2.6)</td>
<td>10.7°±1.4 (1.0)</td>
<td>10.3°±4.2 (3.1)</td>
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<td><strong>C4-6 Fusion</strong></td>
<td>29.9°±10.2 (7.6)</td>
<td>5.5°±1.5 (1.1)</td>
<td>10.4°±2.9 (2.2)</td>
<td>1.4°±0.9 (0.7)</td>
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<td>24.3°±5.6 (4.1)</td>
<td>5.7°±1.8 (1.4)</td>
<td>1.3°±0.7 (0.5)</td>
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<td><strong>C6-7 TDR</strong></td>
<td>42.1°±7.6 (5.7)</td>
<td>5.3°±2.0 (1.5)</td>
<td>9.6°±1.7 (1.2)</td>
<td>10.4°±1.6 (1.3)</td>
<td>10.8°±2.6 (1.9)</td>
<td>11.3°±2.6 (1.9)</td>
</tr>
<tr>
<td><strong>C5-6 Fusion/C6-7 TDR</strong></td>
<td>39.3°±3.9 (2.9)</td>
<td>5.3°±1.0 (0.7)</td>
<td>10.7°±2.5 (1.9)</td>
<td>11.2°±3.3 (2.5)</td>
<td>1.0°±0.7 (0.5)</td>
<td>11.7°±1.3 (1.0)</td>
</tr>
<tr>
<td><strong>C4-6 Fusion/C6-7 TDR</strong></td>
<td>33.3°±4.4 (3.2)</td>
<td>5.9°±1.7 (1.3)</td>
<td>12.0°±1.7 (1.3)</td>
<td>1.5°±0.8 (0.6)</td>
<td>0.9°±0.5 (0.4)</td>
<td>13.6°±2.8 (2.1)</td>
</tr>
<tr>
<td><strong>C3-6 Fusion/C6-7 TDR</strong></td>
<td>27.3°±5.1 (4.0)</td>
<td>5.9°±1.5 (1.1)</td>
<td>1.2°±0.5 (0.4)</td>
<td>1.9°±1.1 (0.8)</td>
<td>1.5°±1.0 (0.8)</td>
<td>12.2°±2.2 (1.7)</td>
</tr>
</tbody>
</table>

## Table 2. Flexion Extension Motion of a TDR above a Fusion

<table>
<thead>
<tr>
<th></th>
<th>Overall motion</th>
<th>C2-3 motion</th>
<th>C3-4 motion</th>
<th>C4-5 motion</th>
<th>C6-7 motion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Native (C2-6)</strong></td>
<td>32.1°±5.9 (4.4)</td>
<td>4.4°±0.9 (0.7)</td>
<td>9.2°±1.6 (1.2)</td>
<td>9.7°±1.4 (1.1)</td>
<td>9.9°±3.9 (2.9)</td>
</tr>
<tr>
<td><strong>C3-4 Fusion</strong></td>
<td>28.1°±4.9 (3.6)</td>
<td>5.1°±0.8 (0.6)</td>
<td>1.0°±0.7 (0.5)</td>
<td>10.9°±1.7 (1.3)</td>
<td>10.2°±3.1 (2.3)</td>
</tr>
<tr>
<td><strong>C3-5 Fusion</strong></td>
<td>22.0°±3.0 (2.2)</td>
<td>5.9°±1.0 (0.8)</td>
<td>0.9°±0.8 (0.6)</td>
<td>1.5°±0.7 (0.5)</td>
<td>11.0°±3.1 (2.3)</td>
</tr>
<tr>
<td><strong>C3-6 Fusion</strong></td>
<td>10.3°±1.9 (1.4)</td>
<td>6.4°±0.8 (0.6)</td>
<td>0.9°±0.5 (0.4)</td>
<td>1.1°±0.5 (0.4)</td>
<td>1.0°±0.6 (0.4)</td>
</tr>
<tr>
<td><strong>C2-3 TDR</strong></td>
<td>32.8°±4.8 (3.6)</td>
<td>5.0°±1.5 (1.1)</td>
<td>9.8°±1.3 (1.0)</td>
<td>10.6°±2.6 (2.0)</td>
<td>10.2°±2.8 (2.1)</td>
</tr>
<tr>
<td><strong>C3-4 Fusion/C2-3 TDR</strong></td>
<td>28.1°±3.6 (2.7)</td>
<td>4.8°±1.6 (1.2)</td>
<td>1.0°±0.5 (0.4)</td>
<td>10.3°±2.2 (1.6)</td>
<td>9.3°±3.0 (2.2)</td>
</tr>
<tr>
<td><strong>C3-5 Fusion/C2-3 TDR</strong></td>
<td>19.2°±3.2 (2.4)</td>
<td>4.8°±1.7 (1.2)</td>
<td>1.5°±0.5 (0.4)</td>
<td>1.1°±0.5 (0.4)</td>
<td>9.7°±4.3 (3.1)</td>
</tr>
<tr>
<td><strong>C3-6 Fusion/C2-3 TDR</strong></td>
<td>9.3°±1.3 (1.0)</td>
<td>6.1°±1.3 (1.1)</td>
<td>1.2°±0.9 (0.7)</td>
<td>1.0°±0.5 (0.4)</td>
<td>1.2°±0.8 (0.6)</td>
</tr>
</tbody>
</table>
Figure 1.
Flexion (left) and extension (right) fluoroscopic images of a cervical total disc replacement instrumented at C6-7. Cobb angles were measured to determine the segmental range of motion.

Figure 2.
Examples of fluoroscopic images used to assess motion. a) C6-7 TDR with no fused segments b) C6-7 TDR adjacent to a simulated C5-6 fusion c) C2-3 TDR above a C3-5 simulated fusion and d) C2-3 TDR above a C3-6 simulated fusion.
Figure 3.
Motion of the C6-7 native segment and the C6-7 TDR below a multilevel fusion. Error bars represent 95% confidence interval.

Figure 4.
Overall C2-7 cervical spine motion with a C6-7 TDR below a multilevel fusion compared to the native segment. Error bars represent 95% confidence interval.
Figure 5.
Motion of the C2-3 native segment and the C2-3 TDR above a multilevel fusion. Error bars represent 95% confidence interval.

Figure 6.
Overall C2-6 cervical spine motion with a C2-3 TDR above a multilevel fusion compared to the native segment. Error bars represent 95% confidence interval.
REFERENCES:


David Shau, MD, MBA  PGY-3

EDUCATION

Emory University, Atlanta, GA                                    July 2015 - Present
  Orthopaedic Surgery Resident Physician
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  Doctor of Medicine
Vanderbilt University Owen School of Business                     May 2015
  Master of Business Administration
University of Texas at Austin                                    May 2010

HONORS AND AWARDS

Eastern Orthopaedic Association Travel Grant: Eastern Orthopaedic Society
  • Awarded $1000 for abstract titled: Increased Resource Utilization in Medicaid Patients following Primary Hip Arthroplasty. This grant was given to a resident with one of the top abstracts accepted for presentation at EOA’s Annual Meeting. Invited to present at annual conference hosted in Miami, FL in October 2017.

Georgia Orthopaedic Society Paper Competition – 2nd Place: Georgia Orthopaedic Society
  • Second place and $1000 award for abstract titled: Increased Resource Utilization in Medicaid Patients following Primary Hip Arthroplasty. Invited to present at annual conference hosted in Cloister Island, GA in October 2017.

PUBLICATIONS

Shau DN, Shenvi N, Easley K, Smith M, Guild G. Medicaid Payer Status is Associated with Increased 90-day Morbidity and Resource Utilization following Primary Total Knee Arthroplasty: a Propensity Score Matched Analysis. Submitted to JOA. [In progress]


**PRESENTATIONS**


Increased Resource Utilization in Medicaid Patients following Primary Total Hip Arthroplasty

Shau DN, Shenvi N, Easley K, Smith M, Bradbury T, Guild G.

ABSTRACT

Background:
Medicaid payer status has been shown to affect risk-adjusted outcomes and resource utilization across multiple medical specialties. The purpose of this study is to examine resource utilization via readmission rates, length-of-stay, and total cost specific to Medicaid payer status following primary total hip arthroplasty (THA).

Methods:
The Nationwide Readmissions Database (NRD) was utilized to identify patients who underwent THA in 2013 as well as corresponding “Medicaid” or “non-Medicaid” payer statuses. Demographics, fourteen individual comorbidities, readmission rates, length-of-stay, and direct cost were evaluated. A propensity-score-based matching model was utilized to control for baseline confounding variables between payer groups. Following propensity-score matching, chi-square test was used to compare readmission rates between the two payer groups. The relative risk (RR) with 95% confidence-intervals (CI) was estimated to quantify readmission risk. Length-of-stay and total cost comparisons were evaluated using the Wilcoxon signed rank test.

Results:
A total of 5,311 Medicaid and 144,814 non-Medicaid THA patients were identified from the 2013 NRD. A propensity score was estimated for each patient based on the available baseline demographics, and 5,311 non-Medicaid patients were propensity-score matched to the 5,311 Medicaid patients. Medicaid vs. non-Medicaid payer status yielded statistically significant differences in overall readmission rates of 28.8% vs. 21.0% (p<0.001, RR=1.37, 95% CI [1.28-1.46]) and 90 day hip-specific readmission rates of 2.5% vs. 1.8% (p=0.01, RR=1.38, 95% CI [1.07-1.78]). Mean length-of-stay was greater in Medicaid group compared to non-Medicaid group at 4.5 days vs. 3.3 days (p<0.0001) as well as mean total cost of $71,110 vs. $65,309 (p<0.0001).

Conclusions:
This study demonstrates that Medicaid payer status is independently associated with increased resource utilization, including readmission rates, length-of-stay, and total cost following primary THA.
Providers may have a disincentive to treat patient populations who require increased resource utilization following surgery. Risk adjustment models accounting for Medicaid payer status are necessary to avoid decreased access to care for this patient population and to avoid financial penalty for physicians and hospitals alike.

**Level of Evidence:**

Prognostic Level III.

**INTRODUCTION**

Over the last six decades, the Medicaid program has grown from a healthcare coverage program for welfare recipients into a large public health insurance program for low income and disabled Americans. Medicaid now provides coverage for over 72 million patients and is the single largest health insurance plan in the United States. The Affordable Care Act expanded the Medicaid program by creating a national Medicaid minimum eligibility level of 133% of the federal poverty level beginning in 2014, which has been estimated to increase the number of individuals younger than 65 years of age by approximately 12 million. Total hip arthroplasty is among the largest and fastest growing healthcare expenditures accounting for nearly $3 billion in Medicare reimbursement in 2013 alone. Recent healthcare reform has tasked hospitals, surgeons, and policymakers to reduce cost while maintaining quality in total hip arthroplasty. Medicare programs such as the Medicare Bundled Payment for Care Improvement Initiative and the Comprehensive Care for Joint Replacement Model aim to align incentives to contain costs through bundling payments for an episode of care from time of surgery through 90 days post discharge. While the early results of these alternative payment models (APM’s) seem promising, concern remains regarding patient selection and access to care.

Medicaid insurance status and lower socioeconomic status have repeatedly been shown affect risk-adjusted outcomes and resource utilization across multiple medical specialties. Varying explanations for this finding have described this disparity including complex interaction between socioeconomic status, access to care, patient factors, and clinical outcomes measures. Data has been limited to small retrospective studies that suggest Medicaid patients who undergo total joint arthroplasty are more likely to have a longer length-of-stay, disposition to a rehabilitation facility, and increased readmission within 90 days. Despite evidence that patients with Medicaid status require more resources at increased cost, payers have yet to provide adjustment in reimbursement based on Medicaid payer status. With the increasing prevalence of APM’s there may be a disincentive to perform THA’s on patients with Medicaid status.
The purpose of this study is to evaluate the 90 days post-operative readmission and resource utilization associated with Medicaid payer status following THA. A large, national administrative database was utilized to achieve a comprehensive analysis and allow Medicaid patients to be matched one-to-one with control patients who differed only in payer status. This publication uniquely examines Medicaid payer status as an independent risk factor for morbidity and increased resource utilization on a national level and is the largest patient sample to date. The primary hypothesis is that Medicaid payer status results in increased 90 day readmission rates specific to hip replacement, increased all cause 90 day comorbidity, longer length-of-stay with increased resource utilization and total cost compared with a matched cohort of control patients with other payer profiles.

MATERIALS AND METHODS

The Nationwide Readmissions Database (NRD) was utilized to identify patients who underwent primary THA (ICD-9 Code 8151) in 2013 as well as corresponding “Medicaid” or “non-Medicaid” payer statuses. Demographics (age, gender, severity of illness, discharge to skilled facility), fourteen individual risk factors/comorbidities (smoking, AIDS, alcohol abuse, deficiency anemia, rheumatoid arthritis, chronic blood loss anemia, congestive heart failure, chronic pulmonary disease, coagulopathy, depression, diabetes, peripheral vascular disorders, drug abuse, weight loss), readmission rates, length-of-stay, and direct cost were evaluated. A propensity-score-based matching model was then utilized to control for baseline confounding variables between payer groups\textsuperscript{17,18}. Propensity scores were estimated using binary logistic regression with type of insurance as the dependent variable or outcome variable (i.e., the exposure groups). The independent variables for the propensity score model included covariates potentially associated with type of insurance, outcome, and type of insurance. Using the resulting logistic regression equation, the propensity score was calculated as the probability of each patient being in the Medicaid group.

Using only the propensity score, Medicaid cases were matched one-to-one to other insurance types using a greedy matching strategy\textsuperscript{19}. Propensity score matching involved the formation of pairs of Medicaid and non-Medicaid THA patients with similar propensity scores. The most commonly used method for formation of the pairs is greedy matching using calipers of a specified width\textsuperscript{20}. The propensity score caliper is the standard deviation of the logit of the propensity score. Calipers of width 0.20 standard deviations of the logit of the propensity score were used for matching (calipers = 0.2*standard deviation). In this approach, a Medicaid THA patient is randomly selected and the non-Medicaid THA patient with the closest propensity score that lies within a fixed distance (the propensity score caliper) of the Medicaid
subject’s propensity score is selected for matching. If multiple non-Medicaid patients had propensity scores that were equally close to that of a Medicaid patient, then one of the non-Medicaid patients was selected at random. Standardized differences were used to assess the balance of confounders between the two exposure groups.

Standardized differences were defined as the difference in means between the two exposure groups divided by a measure of the standard deviation of the variable and were computed for both continuous (i.e., age) and binary covariates. A standardized difference less than 0.1 suggests negligible difference in the mean or prevalence of a covariate between the two insurance groups in the propensity-score-matched sample. Evaluation of common support using distributions of propensity scores by types of insurance. The degree to which the propensity score has been appropriately specified was ascertained through evaluation of common support. Common support is defined by overlapping distributions of propensity scores between insurance groups. Overlap in the propensity score distributions indicates the potential for a patient in the Medicaid group to be in the non-Medicaid insurance group, and that patients with each level of covariates may have either exposure status (i.e., supporting the assumptions of exchangeability and positivity). A lack of common support, or a complete separation of propensity scores without any overlap between the two exposure groups (i.e., Medicaid patients and patients with non-Medicaid types of insurance) indicates severe differences between the two exposure groups and the possibility that confounding cannot be reduced using propensity methods. Figures 1-6 (Appendix) demonstrate the details on assessing the balance produced by the propensity model. The final step involved estimating the effect of exposure on readmission (overall readmission and hip-related readmission data were obtained) after THA. Multivariable regression is not necessary since matching on the propensity scores addressed confounding. The relative risk and its 95% confidence interval for readmission were calculated based on the two by two table for matched pairs where the outcome is readmission and the predictor is type of insurance. A relative risk estimate above 1.0 suggests Medicaid patients were at higher risk of readmission after THA than patients with other types of insurance. Length-of-stay and total cost comparisons were evaluated using the Wilcoxon signed rank test.

**SOURCE OF FUNDING**

There was no external funding source for this investigation.
RESULTS

A total of 5,311 Medicaid and 144,814 non-Medicaid THA patients were identified from the 2013 NRD. A propensity score was estimated from the logistic regression model for each patient. Non-Medicaid patients (5,311) were propensity-score matched to the 5,311 Medicaid patients. A summary of patient baseline characteristics and risk factors/comorbidities is provided in Table 1.

The propensity score is a balancing score. The key assessment of the success of the propensity score adjustment is to demonstrate that the propensity score produced covariate balance between the exposure groups (Medicaid versus non-Medicaid THA patients). Three approaches were used to assess covariate balance and propensity score performance. First, the degree to which the propensity score has been appropriately specified was ascertained through evaluation of common support. Common support is defined by overlapping distributions of propensity scores by exposure group (see Figure 1). Second, the boxplots of the propensity scores by quintiles and exposure groups provide additional support of balance between covariates produced by propensity score matching (Figure 2). Third, balance was examined using the standardized difference of each covariate between the two exposure groups. All standardized differences were less than 0.1, suggesting negligible differences in the mean or prevalence of all patient characteristics and comorbidities between the Medicaid and non-Medicaid groups. Although there is no universally agreed upon criterion as to what threshold of the standardized difference can be used to indicate important imbalance, a standard difference in the mean or prevalence that is less than 0.10 has often been used in other studies. All of the standardized differences reported in Table 1 meet the 0.1 threshold indicating an improvement in balance after propensity matching compared to the standardized differences before matching.

Medicaid vs. non-Medicaid payer status yielded statistically significant differences in overall readmission rates of 28.8% vs. 21.0% (p<0.001, RR=1.37, 95% CI [1.28-1.46]), 90 day readmission for any reason rates of 14.0% vs. 9.7% (p<0.001, RR=1.45, 95% CI [1.31-1.60]), hip-related reasons for readmission rates of 6.4% vs. 5.1% (p=0.006, RR=1.25, 95% CI [1.06-1.45]), and 90 day hip-related readmission rates of 2.5% vs. 1.8% (p=0.01, RR=1.38, 95% CI [1.07-1.78]). A relative risk estimate above 1.0 suggests Medicaid patients were at higher risk of readmission after THA than patients with other types of insurance, which suggest that the risk of readmission for any reason is 37% higher for Medicaid THA patients compared to THA patients with other types of insurance; the risk of readmission for any reason is 45% higher for Medicaid THA patients compared to THA patients with other types of insurance; the risk of hip-related readmission at any time is 24% higher for Medicaid THA patients compared to THA patients with other types of insurance; and the risk of hip-related readmission by 90 days is 38% higher for Medicaid THA
patients compared to THA patients with other types of insurance. Table 2 summarizes the readmission outcomes in propensity-matched Medicaid versus non-Medicaid patients. Mean length-of-stay was greater in Medicaid group compared to non-Medicaid group at 4.53 days vs. 3.28 days (p<0.0001) as well as mean total cost of $71,110 vs. $65,309 (p<0.0001). Tables 3 and 4, respectively, summarizes these findings. The database 90-day hip readmission rate is 1.3% for all 150,126 patients. Table 5 summarizes readmission rates for all patients, non-Medicaid patients, and Medicaid patients at 90 days and overall.

DISCUSSION

With continued healthcare reform and the Affordable Care Act (ACA), it is expected that Medicaid will expand to millions of uninsured Americans\textsuperscript{21}. With this growth, it is expected that the states will be required to fund approximately 10% of the expansion by 2020. In an effort to decrease cost, APM’s, such as bundled payments, may become more prevalent. Although the ACA has allowed APM’s for Medicaid patients in some states, these models have not been readily adopted for arthroplasty patients as cost data for Medicaid patients is sparse. This study demonstrates that Medicaid payer status is independently associated with increased morbidity and resource utilization for 90 days following total hip arthroplasty after adjusting for comorbidities and potential confounders. In addition, Medicaid payer status is associated with increased length-of-stay, general readmission, and hip-related readmission within 90 days. These findings are consistent with previous orthopaedic literature\textsuperscript{22-25} and is the largest patient sample size evaluating Medicaid patients undergoing primary THA from a national standpoint. There are a few small retrospective cohort studies evaluating Medicaid status with increased 90 day readmission and one large national inpatient sample study looking at Medicaid inpatient reporting only\textsuperscript{1,25}. This study is the first to assess a large national database on the impact of Medicaid payer status on resource utilization via 90 day and overall readmission rates, length-of-stay, and direct cost in THA patients.

The differences in 90 day outcomes after total hip replacement persist after matching Medicaid patients to non-Medicaid patients. This study design accounts for a wide range of confounding patient demographics and comorbidities that may be encountered in patients with Medicaid payer status. Previous studies have revealed several disparities in preoperative patient characteristics that could influence outcomes. For example, Medicaid patients who undergo total hip replacement are typically younger, positive smoking history, and increased medical comorbidities. These are potential confounders that were accounted for in this analysis. Previous studies on this population have been underpowered and lacked confounding variable control.
With the increased prevalence of bundled payment programs, health care stakeholders have a financial incentive to provide high quality care to patients at the lowest cost. With post-discharge care accounting for a significant portion overall cost, patients who are at increased risk to be discharged to rehabilitation center or be readmitted within 90 days will significantly increase cost per episode of care\(^9\). Because of increased cost per episode of care in patients with Medicaid status, providers may be hesitant to take on financial risks associated with Medicaid insurance, thus potentially increasing disparities in patient access to care. This study justifies further investigation into adjusting reimbursement models for THA patients based on Medicaid payer status.

The strength of the study is the ability to analyze a large number of patient records and control for confounding variables through matching. This is a nationwide sample and is representative of clinical practice. This is the first study to include administrative data on payer status, for 90 days, with sufficient sample size to avoid beta error. The limitations are those inherent in the analysis of large administrative databases, such as incomplete data collection, inaccurate diagnostic and procedural coding, and lack of detailed clinical information. There are also limitations inherent to propensity score matching analysis. Specifically, propensity score methods only provide the expectation that measured baseline covariates will be balanced between Medicaid and non-Medicaid groups but make no claim to balance unmeasured covariates. Psychosocial factors such as income, education level, employment status, and race are not available in the NRD and thus not available for propensity score matching. Similarly, factors such as surgeon experience, surgical technique, specific implants, and hospital type were not assessed in this study. Medicaid patients may also have greater challenge in obtaining care at higher quality hospitals, but the data is fully de-identified and individual hospital ratings were not available for assessment. Lastly, the insufficient clinical detail prevents conclusions based on preoperative functional status or the severity of joint disease that can vary inside of ICD9 Code 8151.

Although this study shows that Medicaid status is an independent risk factor for complications, readmission, and increased resource utilization, it does not explain why the association exits, nor does it suggest causation. In the author’s experience, Medicaid patients often have complex social environments that may lend themselves to complication and readmission. Specifically, patients may only have access to public transportation and compliance with pre-operative and post-operative appointments can be difficult and costly. The patient’s housing environment maybe unstable or non-existent and may present with advanced or neglected hip disease. In some cases, the patient’s post-operative functional status and/or lack of a care partner may be optimally addressed with post-operative inpatient rehabilitation. As the Medicaid program does not fund such support, these patients may be prone to an inferior outcome.
These potential challenges have led to the authors to implement a robust pre-operative social/medical screening protocol as well as a pre-operative social worker consultation to minimize post-operative issues with at-risk patients.

The influence of socioeconomic factors on 90 day readmissions and complications is complex and all potential factor cannot be captured in a study of administrative data. It is important to note that there are Medicaid patients who are educated, have insight, adequate home support, and may be low-risk candidates for total hip arthroplasty. However, these socioeconomical factors were not available in the database and should be considered along with medical comorbidities in reimbursement models. Further studies are needed to identify other possible psychosocial variables that may impact readmission and cost of care. These factors should be considered along with medical comorbidities in reimbursement models, and these models need to be critically evaluated at a continuum to allow policymakers and providers to implement strategies that will improve care and access for a spectrum of patients. With the continued growth of APM’s including bundled payments, access to care for individuals with increased risk of complications, readmission, and discharge to facility will continue to be an issue. Physicians and hospitals may potentially have a disincentive on patient populations who require increased resource utilization. Medicaid status in this study was predictive of increased overall and 90 day readmission, length-of-stay, and direct cost after THA. Risk adjustment models accounting for Medicaid status are necessary to avoid decreased access to care for this patient population and avoid financial penalty for physician and hospital alike.
REFERENCES:


### Table 1. Characteristics of the total hip arthroplasty (ICD 9 code 8151) patients from the 2013 Nationwide Readmissions Database (NRD)

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Before Propensity Matching</th>
<th>Other Insurance n=144,814</th>
<th>P</th>
<th>Standardized difference</th>
<th>After Propensity Matching</th>
<th>Other Insurance n=5,311</th>
<th>P†</th>
<th>Standardized difference‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years (mean ± SD)</td>
<td>52.0 ± 10</td>
<td>66.0 ± 12</td>
<td>&lt;.0001</td>
<td>1.279</td>
<td>52.0 ± 10</td>
<td>52.8 ± 11</td>
<td>&lt;.0001</td>
<td>0.023</td>
</tr>
<tr>
<td>Female sex</td>
<td>2,798 (52.7%)</td>
<td>81,259 (56.1%)</td>
<td>&lt;.0001</td>
<td>0.069</td>
<td>2,798 (52.7%)</td>
<td>2,776 (52.3%)</td>
<td>0.3271</td>
<td>0.008</td>
</tr>
<tr>
<td>Severity of Illness (major/other)</td>
<td>453 (8.5%)</td>
<td>8,687 (6.0%)</td>
<td>&lt;.0001</td>
<td>0.098</td>
<td>453 (8.5%)</td>
<td>420 (7.9%)</td>
<td>0.1036</td>
<td>0.023</td>
</tr>
<tr>
<td>Discharged to skilled facility</td>
<td>1,152 (21.7%)</td>
<td>38,898 (26.9%)</td>
<td>&lt;.0001</td>
<td>0.121</td>
<td>1,152 (21.7%)</td>
<td>1,145 (21.6%)</td>
<td>0.7554</td>
<td>0.003</td>
</tr>
<tr>
<td>Smoking</td>
<td>2,243 (42.2%)</td>
<td>36,447 (25.2%)</td>
<td>&lt;.0001</td>
<td>0.367</td>
<td>2,242 (42.2%)</td>
<td>2,235 (42.1%)</td>
<td>0.7634</td>
<td>0.003</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIDS</td>
<td>30 (0.6%)</td>
<td>149 (0.1%)</td>
<td>&lt;.0001</td>
<td>0.080</td>
<td>30 (0.6%)</td>
<td>20 (0.4%)</td>
<td>0.1317</td>
<td>0.028</td>
</tr>
<tr>
<td>Alcohol abuse</td>
<td>326 (6.1%)</td>
<td>2,504 (1.7%)</td>
<td>&lt;.0001</td>
<td>0.228</td>
<td>326 (6.1%)</td>
<td>291 (5.5%)</td>
<td>0.0348</td>
<td>0.028</td>
</tr>
<tr>
<td>Deficiency anemia</td>
<td>705 (13.3%)</td>
<td>16,550 (11.4%)</td>
<td>&lt;.0001</td>
<td>0.056</td>
<td>705 (13.3%)</td>
<td>693 (13.0%)</td>
<td>0.5582</td>
<td>0.007</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>269 (5.1%)</td>
<td>5,778 (4.0%)</td>
<td>&lt;.0001</td>
<td>0.052</td>
<td>269 (5.1%)</td>
<td>242 (4.6%)</td>
<td>0.0668</td>
<td>0.024</td>
</tr>
<tr>
<td>Chronic blood loss anemia</td>
<td>62 (1.2%)</td>
<td>1,881 (1.3%)</td>
<td>0.4041</td>
<td>0.012</td>
<td>62 (1.2%)</td>
<td>42 (0.8%)</td>
<td>0.0098</td>
<td>0.038</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>115 (2.2%)</td>
<td>3,866 (2.7%)</td>
<td>0.0245</td>
<td>0.033</td>
<td>115 (2.2%)</td>
<td>89 (1.7%)</td>
<td>0.0291</td>
<td>0.036</td>
</tr>
<tr>
<td>Chronic pulmonary disease</td>
<td>1,222 (23.0%)</td>
<td>20,400 (14.1%)</td>
<td>&lt;.0001</td>
<td>0.231</td>
<td>1,222 (23.0%)</td>
<td>1,204 (22.7%)</td>
<td>0.4227</td>
<td>0.008</td>
</tr>
<tr>
<td>Coagulopathy</td>
<td>137 (2.6%)</td>
<td>3,511 (2.4%)</td>
<td>0.4724</td>
<td>0.010</td>
<td>137 (2.6%)</td>
<td>124 (2.3%)</td>
<td>0.3285</td>
<td>0.016</td>
</tr>
<tr>
<td>Depression</td>
<td>915 (17.2%)</td>
<td>16,964 (11.7%)</td>
<td>&lt;.0001</td>
<td>0.157</td>
<td>914 (17.2%)</td>
<td>962 (17.0%)</td>
<td>0.5619</td>
<td>0.006</td>
</tr>
<tr>
<td>Diabetes</td>
<td>776 (14.6%)</td>
<td>21,316 (14.7%)</td>
<td>0.8223</td>
<td>0.003</td>
<td>776 (14.6%)</td>
<td>780 (14.7%)</td>
<td>0.8415</td>
<td>0.002</td>
</tr>
<tr>
<td>Peripheral vascular disorders</td>
<td>62 (1.2%)</td>
<td>4,217 (2.9%)</td>
<td>&lt;.0001</td>
<td>0.124</td>
<td>62 (1.2%)</td>
<td>39 (0.7%)</td>
<td>0.0032</td>
<td>0.045</td>
</tr>
<tr>
<td>Drug abuse</td>
<td>290 (5.5%)</td>
<td>1,140 (0.8%)</td>
<td>&lt;.0001</td>
<td>0.271</td>
<td>289 (5.4%)</td>
<td>226 (4.3%)</td>
<td>0.0002</td>
<td>0.055</td>
</tr>
<tr>
<td>Weight Loss</td>
<td>68 (1.3%)</td>
<td>1,120 (0.8%)</td>
<td>&lt;.0001</td>
<td>0.050</td>
<td>68 (1.3%)</td>
<td>53 (1.0%)</td>
<td>0.1508</td>
<td>0.027</td>
</tr>
</tbody>
</table>

†McNemar’s test (a chi-square test for paired proportions). The difference in paired proportions is small for all covariates but statistically significant for several covariates due to the large sample size.

‡A standardized difference less than 0.10 suggests negligible difference in the mean or prevalence of a covariate between the two insurance groups.
Table 2: Readmission outcomes in propensity-matched Medicaid versus other types of insurance patients

A. Readmission for any reason

<table>
<thead>
<tr>
<th>Other insurance types</th>
<th>Readmitted</th>
<th>Not Readmitted</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readmitted</td>
<td>363&lt;sup&gt;a&lt;/sup&gt;</td>
<td>758&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1,121</td>
</tr>
<tr>
<td>Not Readmitted</td>
<td>1169&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3021&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4,190</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,532</td>
<td>3,779</td>
<td>5,311</td>
</tr>
</tbody>
</table>

Paired proportion Medicaid, P<sub>m</sub>: a+c/n = 1532/5311 (0.288)
Paired proportion Other, P<sub>0</sub>: a+b/n = 1121/5311 (0.211)
Relative Risk = (a+c)/(a+b)
(95% Confidence interval) = 1.37 (1.28, 1.46), P<0.001

B. 90 day readmission for any reason

<table>
<thead>
<tr>
<th>Other insurance types</th>
<th>Readmitted</th>
<th>Not Readmitted</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readmitted</td>
<td>101&lt;sup&gt;a&lt;/sup&gt;</td>
<td>414&lt;sup&gt;b&lt;/sup&gt;</td>
<td>515</td>
</tr>
<tr>
<td>Not Readmitted</td>
<td>646&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4150&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4,796</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>747</td>
<td>4,564</td>
<td>5,311</td>
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</tbody>
</table>

Paired proportion Medicaid, P<sub>m</sub>: a+c/n = 747/5311 (0.140)
Paired proportion Other, P<sub>0</sub>: a+b/n = 515/5311 (0.097)
Relative Risk (95% Confidence interval) = 1.45 (1.31, 1.60), P <0.001

C. Hip readmission

<table>
<thead>
<tr>
<th>Other insurance types</th>
<th>Readmitted</th>
<th>Not Readmitted</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readmitted</td>
<td>21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>252&lt;sup&gt;b&lt;/sup&gt;</td>
<td>273</td>
</tr>
<tr>
<td>Not Readmitted</td>
<td>316&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4720&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5,038</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>339</td>
<td>4,972</td>
<td>5,311</td>
</tr>
</tbody>
</table>

Paired proportion Medicaid, P<sub>m</sub>: a+c/n = 339/5311 (0.0638)
Paired proportion Other, P<sub>0</sub>: a+b/n = 273/5311 (0.0514)
Relative Risk (95% Confidence interval) = 1.24 (1.06, 1.45), P=0.006

D. 90 day hip readmission

<table>
<thead>
<tr>
<th>Other insurance types</th>
<th>Readmitted</th>
<th>Not Readmitted</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readmitted</td>
<td>4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94&lt;sup&gt;b&lt;/sup&gt;</td>
<td>98</td>
</tr>
<tr>
<td>Not Readmitted</td>
<td>131&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5082&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5,213</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>135</td>
<td>5,176</td>
<td>5,311</td>
</tr>
</tbody>
</table>

Paired proportion Medicaid, P<sub>m</sub>: a+c/n = 135/5311 (0.025)
Paired proportion Other, P<sub>0</sub>: a+b/n = 98/5311 (0.018)
Relative Risk (95% Confidence interval) = 1.38 (1.07, 1.78) p=0.01
E. Summary of readmission outcomes in propensity matched Medicaid vs other types of insurance patients

<table>
<thead>
<tr>
<th></th>
<th>Medicaid† n=5,311</th>
<th>Other insurance† n=5,311</th>
<th>P value</th>
<th>Relative Risk (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readmission for any reason</td>
<td>28.8%</td>
<td>21.0%</td>
<td>&lt;0.001</td>
<td>1.37 (1.28, 1.46)</td>
</tr>
<tr>
<td>90-day readmission for any reason</td>
<td>14.0%</td>
<td>9.7%</td>
<td>&lt;0.001</td>
<td>1.45 (1.31, 1.60)</td>
</tr>
<tr>
<td>Hip readmission</td>
<td>6.4%</td>
<td>5.1%</td>
<td>0.006</td>
<td>1.24 (1.06, 1.45)</td>
</tr>
<tr>
<td>90-day hip readmission</td>
<td>2.5%</td>
<td>1.8%</td>
<td>0.01</td>
<td>1.38 (1.07, 1.78)</td>
</tr>
</tbody>
</table>

†For the matched sample, the values reported are the percentages.

Table 3. Comparison of length-of-stay after THA between Medicaid and Non-Medicaid patients (n=5,311)

<table>
<thead>
<tr>
<th></th>
<th>Medicaid (95% CI)</th>
<th>Other insurance (95% CI)</th>
<th>Difference (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length-of-stay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3 (3 - 3)</td>
<td>3 (3 - 3)</td>
<td>0 (0 - 1)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Mean</td>
<td>4.53 (4.31, 4.75)</td>
<td>3.28 (3.19, 3.37)</td>
<td>1.25 (1.01, 1.49)</td>
<td>&lt;0.0001†</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>8.29</td>
<td>3.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inter quartile range</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† P-value from paired t-test   *P-value from Wilcoxon signed rank test

Table 4. Comparison of total cost after THA between Medicaid and Non-Medicaid patients (n=5,061)

<table>
<thead>
<tr>
<th></th>
<th>Medicaid (95% CI)</th>
<th>Other insurance (95% CI)</th>
<th>Difference (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>58,674 (57,609 – 59,704)</td>
<td>54,936 (54,094 – 55,939)</td>
<td>3,825 (2,303 – 5,013)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Mean</td>
<td>71,110 (69,490 – 72,730)</td>
<td>65,309 (64,150 – 66,467)</td>
<td>5,802 (3,855 – 7,748)</td>
<td>&lt;0.0001†</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>58,784</td>
<td>42,044</td>
<td>70,619</td>
<td></td>
</tr>
<tr>
<td>Inter quartile range</td>
<td>44,368</td>
<td>39,751</td>
<td>56,928</td>
<td></td>
</tr>
</tbody>
</table>

† P-value from paired t-test   *P-value from Wilcoxon signed rank test

Table 5. Readmission rates for all, non-Medicaid, and Medicaid patients at 90 days and overall.

<table>
<thead>
<tr>
<th></th>
<th>All Patients n=150,126</th>
<th>Non-Medicaid n=144,814</th>
<th>Medicaid n=5,312</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. 90-day hip readmission</td>
<td>1,953/150,126 (1.3%)</td>
<td>1,818/144,814 (1.3%)</td>
<td>135 / 5,312 (2.5%)</td>
</tr>
<tr>
<td>B. Any hip readmission</td>
<td>5,821/150,126 (3.9%)</td>
<td>5,482/144,814 (3.8%)</td>
<td>339 / 5,312 (6.4%)</td>
</tr>
</tbody>
</table>
The degree to which the propensity score has been appropriately specified was ascertained through evaluation of common support. Common support is defined by overlapping distributions of propensity scores between insurance groups. Overlap in the propensity score distributions indicates the potential for a patient in the Medicaid group to be in the ‘Other’ insurance group, and that patients with each level of covariates may have either exposure status (i.e. supporting the assumptions of exchangeability and positivity). A lack of common support, or a complete separation of propensity scores without any overlap between the two exposure groups (i.e., Medicaid patients and patients with ‘Other’ types of insurance) indicates severe differences between the two exposure groups and the possibility that confounding cannot be reduced using propensity methods.

This boxplot demonstrates overlapping ranges of the boxplots of propensity scores between Medicaid patients and patients with ‘Other’ types of insurance, which indicates that the propensity model exhibits common support. Circles within each boxplot denote the mean score. The middle line within the box represents the median, the top line represents the 75th percentile and the bottom line represents the 25th percentile. The upper fence is defined as the third quartile (represented by the upper edge of the box) plus 1.5 times the interquartile range. The lower fence is defined as the first quartile (represented by the lower edge of the box) minus 1.5 times the interquartile range. Observations outside the fences are identified with an open circle.
References:


**Figure 2:** Distribution of propensity scores by quintiles and type of insurance in matched dataset: non-Medicaid vs Medicaid

Boxplot demonstrates distribution of propensity scores among Medicaid patients and patients with other types of insurance by quintiles of propensity scores. Circles within each boxplot denote the mean score. The middle line within the box represents the median, the top line represents the 75th percentile and the bottom line represents the 25th percentile. The upper fence is defined as the third quartile (represented by the upper edge of the box) plus 1.5 times the interquartile range. The lower fence is defined as the first quartile (represented by the lower edge of the box) minus 1.5 times the interquartile range. Observations outside the fences are identified with an open circle.
Figure 3: Propensity score distribution (density) in matched database: non-Medicaid vs Medicaid

Figure 4: Propensity score distribution (percentile) in matched dataset: non-Medicaid vs Medicaid
**Figure 5:** Distribution of propensity scores by quintiles and type of insurance in unmatched dataset: non-Medicaid vs Medicaid

**Figure 6:** Propensity score distribution in unmatched dataset: non-Medicaid vs Medicaid
2017 - 2018 Orthopaedic Surgery Residents
PGY4 – PGY1

PGY 4
Briggs Ahearn
Medical University of South Carolina
College of Medicine
Hometown: Georgetown, SC

Ian Gao
Northwestern University
The Feinberg School of Medicine
Hometown: Clemson, SC

Sandra Hobson
University of Virginia
School of Medicine
Hometown: Lynchburg, VA

Rishin Kadakia
Vanderbilt University
School of Medicine
Hometown: Nashville, TN

Jeffrey Konopka
Indiana University School of Medicine
Hometown: Greenwood, IN

Timothy McCarthy
Creighton University
School of Medicine
Hometown: W. Des Moines, IA

PGY 3
Adam Boissonneault
Trinity College
Dublin, Ireland
Hometown: Long Valley, NJ

Zach Grabel
Brown University
Alpert Medical School
Hometown: Palm Beach Gardens, FL

Greg Kurkis
University of Virginia
School of Medicine
Hometown: Roswell, GA

Nick Patel
Emory University
School of Medicine
Hometown: North East, MD

Dale Segal
Florida International University
Hometown: Queens, NY

David Shau
Vanderbilt University School of Medicine
Hometown: Flower Mound, TX

PGY 2
Russell Holzgrefe
University of Virginia
Hometown: Tucker, GA

Thomas Neustein
Emory University
Hometown: Demarest, NJ

Keith Orland
Medical University of South Carolina
Hometown: Charlotte, NC

Andrew Schwartz
Albert Einstein College of Medicine
Hometown: West Chester, OH

R. Matt Wham
University of Tennessee
Hometown: Oak Ridge, TN

Jacob Wilson
Medical College of Wisconsin
Hometown: Richmond, OH

PGY 1
William Godfrey
Emory University
Hometown: Atlanta, GA

Matthew Lunati
University of Texas Health at San Antonio
Hometown: Sandy Springs, GA

Jeremy Pflederer
University of Illinois College of Medicine
Hometown: Tremont, IL

Huai Ming Phen
Emory University
Hometown: Ilford, UK

William Runge
University of North Carolina at Chapel Hill
Hometown: Ann Arbor, Michigan

Weilong Jeff Shi
Emory University
Hometown: Atlanta, GA
Emory Orthopaedics Research & Surgical Faculty

Scott Boden  
Professor & Interim Chairman, Spine

Thomas L. Bradbury  
Assistant Professor, Adult Reconstruction

Dheera Ananthakrishnan  
Assistant Professor, Spine

Jason Bartheau  
Assistant Professor, Foot & Ankle

Robert W. Bruce, Jr.  
Associate Professor, Pediatric Orthopaedics

Hicham Drissi  
Professor & Vice Chairman, Research

Greg Erens  
Assistant Professor, Adult Reconstruction

Nicholas Fletcher  
Assistant Professor, Spine

Matthew Gary  
Assistant Professor, Spine

George Guild  
Assistant Professor, Adult Reconstruction

Michael Gottschalk  
Assistant Professor, Hand & Upper Extremity

Kyle Hammond  
Assistant Professor, Sports Medicine

John G. Heller  
Baur Professor of Orthopaedic Surgery, Spine

William Hutton, Ph.D  
Professor, Research

Edward Jackson, III  
Assistant Professor, Sports Medicine

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

Gary McGillivary  
Assistant Professor, Hand & Upper Extremity

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

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

Nick Willett, PhD  
Assistant Professor, Research

Brent Wise  
Assistant Professor, Trauma

John W. Xerogeanes  
Professor, Sports Medicine

S. Tim Yoon  
Professor, Spine
## Kelly Day Visiting Professors

<table>
<thead>
<tr>
<th>Year</th>
<th>Professor Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>William Murray MD</td>
<td>Professor &amp; Chairman of The Department of Orthopedic Surgery at UCSF.</td>
</tr>
<tr>
<td>1979</td>
<td>Robert E. Leach MD</td>
<td>Boston University</td>
</tr>
<tr>
<td>1980</td>
<td>Carl L. Nelson MD</td>
<td>Chairman of the Department of Orthopaedic Surgery at the University of Arkansas for Medical Science</td>
</tr>
<tr>
<td>1981</td>
<td>Sir John Charnley</td>
<td>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.</td>
</tr>
<tr>
<td>1982</td>
<td>Howard H. Steel MD</td>
<td>Shriner's Hospital-Philadelphia</td>
</tr>
<tr>
<td>1983</td>
<td>Robert H. Fitzgerald, Jr. MD</td>
<td>Chairman - Wayne State University</td>
</tr>
<tr>
<td>1984</td>
<td>Joseph Schatzker MD</td>
<td>Professor Emeritus of Surgery at the University of Toronto</td>
</tr>
<tr>
<td>1985</td>
<td>Larry Matthews MD</td>
<td>The University of Michigan</td>
</tr>
<tr>
<td>1986</td>
<td>John P. Kostuik MD</td>
<td>Professor Johns Hopkins University School of Medicine</td>
</tr>
<tr>
<td>1987</td>
<td>Richard H. Gelberman MD</td>
<td>Washington University, Department of Orthopaedic Surgery</td>
</tr>
<tr>
<td>1988</td>
<td>J. Leonard Goldner MD</td>
<td>Duke University</td>
</tr>
<tr>
<td>1989</td>
<td>Henry J. Mankin MD</td>
<td>Massachusetts General Hospital</td>
</tr>
<tr>
<td>1990</td>
<td>Bernard F. Morrey MD</td>
<td>Professor &amp; Chairman of Orthopaedics at the Mayo Clinic</td>
</tr>
<tr>
<td>1991</td>
<td>Gary G. Poehling MD</td>
<td>Professor of Orthopaedic Surgery at Bowman Gray School of Medicine</td>
</tr>
<tr>
<td>1992</td>
<td>Michael W. Chapman MD</td>
<td>Professor &amp; Chairman, Department of Orthopaedic Surgery University of California at Davis</td>
</tr>
<tr>
<td>1993</td>
<td>Michael F. Schafer MD</td>
<td>Professor &amp; Chairman, Department of Orthopaedic Surgery Northwestern School of Medicine</td>
</tr>
<tr>
<td>1994</td>
<td>James R. Urbaniak MD</td>
<td>Virginia Flowers Baker Professor &amp; Chief of Orthopaedic Surgery, Duke University Medical Center</td>
</tr>
<tr>
<td>1995</td>
<td>Dan M. Spangler MD</td>
<td>Professor &amp; Chairman of Orthopaedic Surgery &amp; Rehabilitation, Vanderbilt University</td>
</tr>
<tr>
<td>1996</td>
<td>James H. Herndon MD</td>
<td>David Silver Professor &amp; Chairman of Orthopaedic Surgery, University Pittsburgh’s Medical School &amp; Chief of Orthopaedics &amp; Rehabilitation at the UPMC.</td>
</tr>
<tr>
<td>1997</td>
<td>S. Terry Canale MD</td>
<td>Professor, Department of Orthopaedic Surgery, University of Tennessee College of Medicine.</td>
</tr>
<tr>
<td>1998</td>
<td>Angus M. McBryde, Jr. MD</td>
<td>Professor &amp; Chairman, Orthopaedic Surgery,The Medical University of South Carolina.</td>
</tr>
<tr>
<td>1999</td>
<td>L. Andrew Koman MD</td>
<td>Professor &amp; Chairman, Department of Orthopaedic Surgery, Duke University Medical Center</td>
</tr>
<tr>
<td>2000</td>
<td>Louis U. Bigliani MD</td>
<td>Frank E. Stinchfield Professor &amp; Chairman Department of Orthopaedic Surgery College of Physicians &amp; Surgeons</td>
</tr>
<tr>
<td>2001</td>
<td>Robert S. Adelaar MD</td>
<td>Professor &amp; Vice-Chairman, Department of Orthopaedic Surgery Medical College of Virginia</td>
</tr>
<tr>
<td>2002</td>
<td>John S. Gould MD</td>
<td>Alabama Sports Medicine</td>
</tr>
</tbody>
</table>
2003  Freddie H. Fu MD  
Professor & Chairman,  
Department of Orthopaedic Surgery  
University of Pittsburgh  
Chief of Staff, Emeritus at Texas  
Scottish Rite Professor of  
Orthopaedic Surgery University of  
Texas Southwestern Medical School  

2004  Peter Stern MD  
Professor & Chairman, University of Cincinnati  

2005  James N. Weinstein DO  
Chairman Department of Orthopaedics Dartmouth  

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 Orthopaedic Surgery  

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

2012  J.A. “Tony” Herring, MD  
at the University of Iowa Hospitals & Clinic  

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
FACULTY PUBLICATIONS

Peer-Reviewed Journals: 2016-2018


Increasing hip and knee flexion during a drop-jump task reduces tibiofemoral shear and compressive forces: implications for ACL injury prevention training. Tsai LC, Ko YA, Hammond KE, Xerogeanes JW, Warren


