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Clinical Expertise: Hand

Leslie Dunlap  MSPAS PA-C
Degree: The University of New Mexico
Clinical Expertise: General, Foot
Christopher Bankhead MD
I was born and raised in Baton Rouge, Louisiana, and earned my undergraduate and medical school degrees at Louisiana State University. Growing up in South Louisiana, I had always dreamed of seeing a mountain range and learning to ski. I never predicted that I would live in the shadows of the Sandias or that my orthopaedic residency program would allow me to pursue international education a short drive from the French Alps.

Outside residency, my favorite activities are backpacking and skiing. I will miss these outdoor opportunities that New Mexico provides. Next year, I will start a sports fellowship at the University of Virginia, and I am hoping to do some mountain biking and hiking in the nearby Blue Ridge Mountains and Shenandoah Valley.

During residency, I researched hip and knee pathology and treatment. While in my elective rotation in Lyon, France, I participated in several arthroplasty research projects, co-authoring two publications in the *Journal of Arthroplasty*. I also contributed to abstracts presented at the World Arthroplasty Congress and EFORT (European Federation of National Associations of Orthopaedics and Traumatology). Additionally, I published articles in *The University of New Mexico Orthopaedics Research Journal* and a book chapter in *Clinics in Sports Medicine*.

My path to orthopaedics led me to success in more than just academics because along the way I met my wife Rachel. She has been a part of my journey since the first day of medical school. After spending most of her life in Louisiana, too, she agreed to put down new roots in Albuquerque. She has been incredibly supportive during the last 5 years, and I cannot imagine going through residency without her. We have recently added a new member to the family, a son named Bennett born in September. I would also like to thank my parents Mike and Cheryl for years of help along the way. They instilled in me a belief that I could accomplish anything and provided me with the tools and opportunities to do it. I would not have made it this far without them there from the beginning. My sister Sarah and brother John Michael were also an integral part of the team effort it took to get me to this point. They were reliable friends and helped me keep an even keel.

Like most good siblings, they functioned as a great system of checks and balances—never letting me get too high or too low. I am excited about the new opportunities ahead, but I still hope to maintain the relationships made here. I look forward to being a part of the Lobo family for life.
J. Andy Dollahite MD
Growing up I wandered a bit like Kerouac, mostly in California. As an undergraduate at Cal Poly, San Luis Obispo, I studied computer engineering for about 6 seconds. Realizing my inner nerd loved the life sciences more, I pursued biology instead. For 5 years after college, I taught and coached at Immanuel High School, but ultimately decided to change careers. While shadowing my Uncle Andy over a Memorial Day weekend call, the Sirens of orthopaedics seduced me. I attended medical school at the University of Southern California and was ecstatic to complete residency here at The University of New Mexico (UNM). Outside of the hospital, my interests include home-roasting coffee, metaphysical poetry, backpacking, and reading with my kids. The next destination on this wild adventure will be at Keesler Air Force Base on the Mississippi Gulf Coast.

During residency, my research focused primarily on orthopaedic trauma. I published papers in The Bone & Joint Journal (formerly JBJS British) on management of segmental bone defects with titanium mesh cages, The American Journal of Surgery on radiographic imaging of critical care patients, and The University of New Mexico Orthopaedics Research Journal on foot and ankle topics. In 2016, a multicenter project I contributed to was presented as a poster at the Orthopaedic Trauma Association national meeting, and I was also the recipient of the UNM Resident Research Award.

Undoubtedly, my diploma and graduation certificate ought to have a congregation of names attached. With heartfelt gratitude I wish to acknowledge and honor . . . Christ the King: immortal, invisible, God only wise. Stephanie: joyful wife, ballast of our home, ineffable beauty, sonnet to my soul. Annaliese, Titus, Ezekiel, Carys, and Stephen: favored grace, defender, strength of God, beloved, crown; psalm 127. My parents (Bert and Dale) and in-laws (Bill and Carol): your indefatigable love towards us overflows at all times. My siblings and their families: devoted cheerleaders. Uncle Andy: inspiration and catalyst. Aunt Carolyn: effervescent encouragement. Cedar Springs Church: bearing our burdens, sharing our triumphs. Faculty mentors: you were more patient than I ever deserved. Co-residents: our shared crucible made us better orthopaedists, and more vitally, better people. I’m profoundly grateful for your friendship. Shine on!

Patrick Gilligan MD
I was born and raised in Santa Fe, New Mexico (NM). I spent most of my time playing sports and running in the arroyo behind my house. After high school, I attended Santa Clara University where I obtained a bachelor’s degree in psychology with a minor in photography. I then moved back to NM and worked in real estate with my father for a few years but decided to pursue a medical career. I traveled for 2.5 months in Southeast Asia and then attended The University of New Mexico (UNM) School of Medicine. During my fourth year, my wife and I had premature twins, Neala and Rylan, now 5 years old. After residency, I will attend West Virginia University for a fellowship in adult reconstruction and plan on returning to NM. My interests outside of work include recreational soccer, spending time with family and friends, travel (when time allows), and grilling outdoors.

During residency, I studied the effect of extensor tendon lacerations, cyclical loading, and load to failure to better evaluate when surgical intervention is required. I also joined a prospective randomized clinical trial on tibial fractures, and I started another study that reviewed the relationship between multiligament knee injuries and subsequent total knee arthroplasty constraint. My grand rounds focused on acetabular fractures in older patients and the role of combined open reduction and internal fixation and acute total hip arthroplasty.

I would like to thank my wife, Alden, for all her help and dedication during my years of education and residency and for taking the lead on raising our children. I would like to thank my parents, Sean and Gwen, and their partners, as well as my in-laws, Scotty and Kay, for their love and support during medical school and residency. I would also like to thank my fellow residents and their families for their support, camaraderie, and friendship that will last a lifetime. The attendings and support staff of UNM Orthopaedics have also been integral in my success. Lastly, I would like to thank the joints attendings for their mentorship and support throughout residency and helping me secure a fellowship position. The last 5 years have been an amazing experience, and I am very happy that I was able to spend it here at UNM.
Paul Johnson MD  
I grew up in Bountiful, Utah. I grew up waterskiing and playing basketball and soccer, and still love to do these things today. I planned on being an engineer, and went to the University of Utah to study mechanical engineering. As I became more involved in engineering research, I was drawn to the field of medical device development and sought a master’s degree with a focus on biomechanical sensor systems. This ultimately led to my interest in medicine, and I elected to attend a research focused medical school program at the University of Pittsburgh. 
I developed a natural interest in orthopaedics because of the biomechanical principles involved, and I was lucky enough to be accepted to The University of New Mexico (UNM) Orthopaedic Residency Program. Along the way, I’ve participated in research projects studying posterolateral corner ligament reconstruction as well as outcomes after complex spinal surgery. My research resulted in seven published studies during residency, featured in journals such as KSSTA (Knee Surgery, Sports Traumatology, Arthroscopy) and The University of New Mexico Orthopaedics Research Journal. I also co-authored three abstracts presented at local, regional, and international meetings such as the New Mexico Shared Knowledge Conference, Orthopaedic Research Society, and ISAKOS (International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine). 
I wouldn’t trade my training at UNM for anything. I’ve learned a great deal from fantastic mentors and teachers along the way—people that taught me to learn from my successes and from my mistakes. I wouldn’t have made it to where I am now without phenomenal parents who pushed me and supported me along the way. Also, I couldn’t have done this were it not for my amazing wife and my four awesome children. They have cheered me on endlessly and have put up with me throughout this long process. We are excited to head to Wisconsin next year to start our next adventure as I complete a fellowship training in spine surgery.

Jay Wojcik MD  
I grew up in sunny Arvada, Colorado, spending most of my childhood playing outdoors. I loved riding bikes with my friends and camping and fishing with my family. I completed my undergraduate training at the University of Colorado—20 miles down the highway to the University of Colorado in Aurora. 
I always enjoyed working with my hands, so orthopaedics was a natural attraction. Rotating at The University of New Mexico as a medical student is what drew me to Albuquerque. During residency, my research efforts focused primarily on examining transitional anatomy of the spine and reviewing modern techniques in diagnosing and treating periprosthetic joint infections. My efforts culminated in published articles in The University of New Mexico Orthopaedics Research Journal. 
Five years in this program have gone by fast, but I know that this is just the beginning. I look forward to my fellowship in adult reconstruction next year in Tampa at the Florida Orthopaedic Institute. I hope to expand on my training and gain exposure to some state-of-the-art joint replacement techniques using robotics and performing outpatient total joint arthroplasty. 
To get this far on my journey, I owe credit to so many! My friends and family have provided unyielding support. My father has always encouraged me to pursue my passion, and my mother taught me the virtues of being a good person and to show compassion. I would not be where I am today without the love, sacrifice, and support of my wife Annie. I am so excited to continue my journey with her by my side. She has an incredible heart and excels in her career as a nurse; she motivates and inspires me daily. I am so grateful to have her and her family’s support. Of course, I am so grateful to be part of this incredible orthopaedic program. The relationships I have made will last forever, and the foundation of my training will serve me well for years to come.
Residents: PGY Four

Paul Goodwyn MD
SUNY Upstate Medical University

Travis Hughes MD
University of Arizona

Aditi Majumdar MD
The University of New Mexico

Andrew Parsons MD
University of Oklahoma

Christopher Shultz MD
University of Arizona

Residents: PGY Three

Scott Plaster MD
University of Oklahoma

Jordan Polander MD
Louisiana State University-Shreveport

Amber Price MD
Creighton University

Jory Wasserburger MD
University of Washington

Matthew Wharton MD
University of Arizona
Residents: PGY Two

Benjamin Albertson MD
University of Vermont

Kathryn Helmig MD
University of Oklahoma

Nathan Huff MD
The University of New Mexico

Christopher Kurnik MD
University of Nevada - Reno

Benjamin Packard MD
Creighton University

Residents: PGY One

Aamir Ahmad MD
University of Arizona

Bryce Clinger MD
Virginia Commonwealth University

Jordan Hump MD
University of Utah

Allicia Imada MD
University of Vermont

Kate Yeager MD
Oregon Health & Science University
Orthopaedic Biomechanics & Biomaterials Laboratory

Christopher Buksa
MS in progress, Mechanical Engineering
BS, Mechanical Engineering - The University of New Mexico

Serafina Lopez
BS in progress - The University of New Mexico (senior)
Degree: Chemical Engineering (Concentration, Bioengineering)
Future Graduate: Cornell University (Biomedical Engineering)

Nafisa Elghazali
Post-Baccalaureate Research and Education Program - The University of New Mexico
BS, Public Health Sciences - University of California-Irvine
Future Graduate: Georgia Institute of Technology

Emma Garcia
Engineer at Innovative Surface Technologies
MS, Biomedical Engineering - The University of New Mexico

Lorraine Mottishaw
PhD in progress, Biomedical Engineering - The University of New Mexico
BS, Chemical Engineering and Chemistry - University of Idaho

Mystique Lamb
Amy Bleihi High School (senior)
Future Undergraduate: The University of New Mexico (Mechanical Engineering)

Marissa Pérez
BS in progress – The University of New Mexico (senior)
Degree: Chemical Engineering (Concentration, Bioengineering)
Future Graduate: Rice University (Biomedical Engineering)

Fermin Prieto
MD in progress (year 2)
BS, Biomedical Engineering - University of Arizona
Orthopaedic Biomechanics & Biomaterials Laboratory

Matthew Rush
PhD, Nanoscience and Microsystems Engineering (NSMS) - The University of New Mexico
MS, NSMS - The University of New Mexico
BS, Mechanical Engineering - New Mexico Institute of Mining and Technology

Tony Sapradit
BS in progress - The University of New Mexico (sophomore)
Degree: Mechanical Engineering

Daniel Sikora
BS in progress - The University of New Mexico (senior)
Degree: Biochemistry
Future Graduate: The University of New Mexico (Biomedical Engineering)

Ruben Trujillo
BS in progress - The University of New Mexico (senior)
Degree: Chemical Engineering (Concentration: Bioengineering)
Future Graduate: Cornell University (Biomedical Engineering)

Jacob Valdez
BS in progress – The University of New Mexico (senior)
Degree: Mechanical Engineering
Future Industry: Wall Colmonoy, Los Lunas, NM
Letter from the Chair
Robert C. Schenck Jr, MD

As chair of The University of New Mexico (UNM) Department of Orthopaedics & Rehabilitation since 2005, I am pleased to present the eighth volume of The University of New Mexico Orthopaedics Research Journal (UNMORJ). This volume marks a period of transition to our goal of becoming an external peer-reviewed orthopaedic journal with citations in PubMed. This is our third year of initiating the peer-review process as well as improving overall publication process. We are grateful to the many peer reviewers who made this happen for our previous volumes, including the following individuals:


The amazing work of the UNMORJ editorial board, with leadership from Co-Editors Christina Salas, PhD, and Deana Mercer, MD, have made the publication an established entity within the department and university. Additionally, it is fascinating to see this volume in the light of the career growth of Sahar Freedman, our managing editor brought on as part-time student intern in August 2014, and Joni Roberts who has helped bring the journal to fruition since the first volume.

We hope you enjoy this eighth volume, and my personal thanks to the many others responsible for the continued expansion of research at UNM Orthopaedics, including Sahar Freedman, Dustin Richter, MD, Christina Kurnik, MPH, our fantastic residents, our supportive faculty, and our team of engineering students led by Dr. Salas at our in-house Orthopaedic Biomechanics & Biomaterials Laboratory. We have the vision of becoming the premier research journal in the West and will continue to strive to that end.

To parallel the success of UNMORJ, the department itself has great stability thanks to our many dedicated faculty, residents, and staff. We are ever so grateful for the leadership of Gehron Treme, MD, as director of the residency program for the past 6 years and welcome Selina Silva, MD, as our new associate program director of residency. Furthermore, I would like to thank Gail Case in her management of the large enterprise of UNM Orthopaedics, finances, education, and research. My thanks to Gail Case, Joni Roberts, and Darren Krehoff for all of their work and dedication in the process of educating residents and fellows.

Lastly, I would like to thank the entire UNM Orthopaedics family in making our space of work, academics, and research such a positive experience for all.

Sincerely,

Robert C. Schenck Jr, MD
Professor and Chair
Department of Orthopaedics & Rehabilitation
Letter from the Co-Editors
Deana Mercer, MD; Christina Salas, PhD

Welcome to the eighth volume of The University of New Mexico Orthopaedics Research Journal (UNMORJ), featuring efforts of faculty, alumni, fellows, residents, and students. This is the third volume to feature a double-blinded external peer-review process for UNMORJ. We are pleased to announce the addition of at least two reviewers per submission. We continually strive to facilitate quality control for reviewers and authors alike in our goal to nationally and internationally expand UNMORJ audiences, with eventual indexing in MEDLINE and PubMed—the primary database listings for scholarly biomedical articles.

We would like to express the utmost gratitude to our reviewers who lent their expertise, efforts, and time to make our eighth volume a successful, peer-reviewed publication. We sincerely thank all the contributors to this production—as well as Gail Case, Department Administrator; Sahar Freeman, Managing Editor and Copy Editor; and Joni Roberts, Managing Editor—whose work and dedication were instrumental in bringing the journal to fruition. We are grateful for the help of our copy editors Mikhaela Smith and Angelique Tapia, as well as our layout editor Jana Fothergill.

We invite you to explore this small selection of our recent department publications outside of UNMORJ, listed below. These were selected to provide an overview of the breadth of our research efforts. We hope that the articles inspire thought, discussion, and future research ideas and contributions. Bolded names indicate current or past faculty members, residents, fellows, and graduate students of the department.


UNMORJ is proud of its past and current accomplishments in highlighting original research relevant to orthopaedic surgery and engineering. We look forward to continued spread of knowledge to help improve care for patients on local, regional, national, and international levels.

Sincerely,

Deana Mercer, MD  
Associate Professor  
Department of Orthopaedics & Rehabilitation

Christina Salas, PhD  
Assistant Professor  
Department of Orthopaedics & Rehabilitation
Letter from the Chief of the Division of Physical Therapy
Beth Moody Jones, PT, DPT, EdD, MS

The University of New Mexico (UNM) Division of Physical Therapy continues to be a steadfast group of almost 100 students within the School of Medicine and larger Health Sciences Center. We continue to be the only physical therapy program in New Mexico, proudly graduating 26 new doctors of physical therapy (DPT) in May 2018. I am honored to assume the leadership of this remarkable group of faculty, staff, and students.

My leadership journey began in August 2018 with a facilitated strategic planning meeting. The ideas, experiences, and dedication of more than 25 stakeholders, as well as another 30 who completed surveys, led to a new plan for the division. I am happy to share our new vision, mission, and goals.

Our **vision** is to prepare physical therapists as movement specialists and leaders to fulfill essential roles within interprofessional collaborative teams serving the diverse communities of New Mexico.

Our **mission** is to develop highly skilled and compassionate doctors of physical therapy who optimize the human experience of New Mexico communities by enhancing movement and function through evidence-based practice.

Our three **goals** are as follows: 1) using an efficient and effective approach, the student and faculty experience will be optimized to produce highly skilled, compassionate DPTs, 2) our community ties will be built and strengthened through the provision of quality professional development and research, and 3) the diversity of the DPT students will mirror the diversity of New Mexico.

Owing to the many objectives within each goal, we are busy working to fulfill this strategic plan. The new initiatives include the following:

**A new Student Success Committee comprised of two elected students from each cohort.** Recognizing the need for transparency and team building, the faculty began this committee of students, faculty, and administration that meets at least twice a month to review and measure the pulse of the hidden curriculum within the classroom and school. From this committee, we began a new cooperative evaluation process that examines improvement and success throughout the program.

**A new Mentorship Program with community-based physical therapists.** Recognizing a need to increase national and state-wide involvement within the American Physical Therapy Association (APTA), a committee of students, faculty, administration, and members of the New Mexico APTA (NMAPTA) gathered to begin this inaugural mentoring program. We matched clinicians from the NMAPTA with students in our second-year cohort, fostering the relationships through events each quarter. We look forward to continuing this program with future second-year cohorts at the Induction Ceremony every fall.

**Re-organization of our Research Committee.** Identifying the need to build our team of researchers, the Research Committee has been re-structured to foster more collaboration among faculty, students, and our partners throughout the campus. Our research agenda is robust, with multiple publications and presentations this past year, and the future outlook is bright.

**Improving undergraduate outreach.** To continue reaching our diverse population of undergraduates and helping them matriculate to our program, we have increased our presence on main campus. The initiatives that have grown from this effort include an increased presence at the UNM Health Professions Symposium in March 2019 (included five educational programs led by faculty and students) and improving awareness of student resources to prepare for the Graduate Record Examination.

The faculty and staff of the division are working hard on multiple fronts to improve the student experience, increase our research agenda, and build strong ties to our profession and the community. We are excited to oversee this strategic plan and build on an already historically excellent program.

Respectfully,

Beth Moody Jones, PT, DPT, EdD, MS

Board-Certified Orthopaedic Clinical Specialist
Certified in Dry Needling
Associate Professor
Division Chief, Physical Therapy
Letter from the Residency Director
Gehron P. Treme, MD

Congratulations to our graduating chief residents in the class of 2019. It has been a true honor to participate in the orthopaedic surgical training of Drs. Christopher Bankhead, J. Andy Dollahite, Patrick Gilligan, Paul Johnson, and Jay Wojcik. Even more, watching all of them grow personally and professionally illustrates the good fortune that we all enjoy as members of the The University of New Mexico Orthopaedics family. This is a time for these gentlemen to be proud of their accomplishments and for us to reflect on our time with them during the past 5 years.

Recently, I was visiting with one of our junior residents about what an excellent group this chief class is. “Yes,” the resident agreed “they are.” “They are all very talented,” I said. “Thoughtful, conscientious, thorough. Lots to be proud of in that group.”

It was quiet, and then the resident continued, “But you know what? They are all really good people. I’m really going to miss them.”

This speaks so highly of this group of graduates, and I could not agree more. It also sheds some light on what is remembered of us after we spend 5 years in one place. It is true that our skill and knowledge carry weight. Our approach to patient care serves as a model for those around us. None of that should be taken lightly. But what is remembered frequently is how others see us go through our day and our interactions with those around us. People notice. I have heard friends and family members many times say about their surgeons, “They don’t have a great bedside manner, but that’s OK. As long as they do a good job, that’s all I care about.” Perhaps there is some truth to that, particularly if patients finds themselves in a situation to choose between physician character and quality of care. But it turns out, as exemplified by these five graduates, that surgical skill and clinical knowledge can be packaged with humanity, humility, and honor in such a way that their patients will not have to choose.

We are excited to welcome Chris, Andy, Pat, Paul, and Jay into our always expanding group of program graduates. We are so proud to have had them here and are prouder still of what they will accomplish as they move to their next challenge. You have all gone about this the right way and have served as role models to those around you during the past 5 years. Thank you. You will be missed.

My very best regards,

Gehron P. Treme, MD
Associate Professor and Residency Program Director
Department of Orthopaedics & Rehabilitation
Rigid Nail Fixation for Treatment of Femur Fractures in Children Aged 6 to 12 Years: A Review

Brielle Payne Plost, MD; David M. Bennett, MD; Andrew W. Parsons, MD; Matthew G. Wharton, MD; Kathryn C. Helmig, MD

Department of Orthopaedics & Rehabilitation, The University of New Mexico Health Sciences Center, Albuquerque, New Mexico

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ABSTRACT
Although femoral shaft fractures are common in children, treatment using rigid intramedullary nail fixation remains controversial owing to concerns of avascular necrosis (AVN) and disruption of growth of the proximal femur. We examined studies on AVN complications and proximal femur deformity after rigid nail fixation in children aged 6 to 12 years. Of the 13 studies included, nine had no incidents of AVN or clinically significant proximal femur deformity using a greater trochanter entry point. Four studies showed cases of AVN or proximal femoral deformity in patients treated with intramedullary nails through a starting point at or near the piriformis fossa or the tip of the greater trochanter. The findings of this review suggest that antegrade rigid intramedullary nailing may be an acceptable treatment option for femoral shaft fractures in children aged 6 to 12 years, especially when the lateral aspect of the external fixation—each with a range of risks and benefits. Results of future research are needed on age-related outcomes and complications of rigid intramedullary nailing fixation of femoral shaft fractures in children.

Keywords: Femoral Fractures, Femoral Fixation, Intramedullary, Pediatric, Femur

INTRODUCTION
Femoral shaft fractures are common injuries in children (Figure 1). Despite the frequency of occurrence, treatment remains controversial especially in younger and larger patients who are skeletally immature. Studies remain somewhat limited in this population, particularly in children between the ages of 6 to 12 years. In adults, the most common treatment of these fractures is operative fixation using rigid intramedullary nails. This type of fixation allows for early mobilization and stable fracture fixation; however, its use in skeletally immature patients remains controversial owing to concerns of avascular necrosis (AVN) and disruption of growth of the proximal femur. In children, common operative interventions include intramedullary nail fixation, submuscular plating, and external fixation—each with a range of risks and benefits. First, flexible intramedullary nailing may not provide adequate fixation in children aged 6 to 12 years if they have length-unstable fractures, rotationally unstable fractures, or are obese.5,6 Additionally, very proximal and distal fractures may not be adequately stabilized with flexible intramedullary nails.6 Next, submuscular plate fixation provides the benefit of allowing an anatomic reduction; however, it often requires a larger incision as well as removal of the implant owing to risk of stress shielding, leg length discrepancy, and screw prominence.7,8 In 2013, May et al9 found a 6% unplanned reoperation rate for children with femoral shaft fractures treated with plate fixation. External fixation is another treatment option that is minimally invasive; however, there is a high risk of complications when using an external fixator for treating femoral shaft fractures in children.9 Complications include pin infections and the risk of refracture after removal of the pins and fixator.10,11

The purpose of this review was to examine the studies that focused on the complications of AVN.
In 2000, Townsend and Hoffinger\textsuperscript{12} studied 34 patients between the ages of 10 to 17 years who underwent intramedullary nail fixation using a greater trochanter tip entry point. There were no cases of AVN or deformity. In 2002, Gordon et al\textsuperscript{13} looked at nine patients between the ages of 8 to 11 years who underwent femoral lengthening over a nail. There were no cases of AVN or proximal femur complications using a lateral greater trochanter entry point. In 2003, Gordon et al\textsuperscript{14} performed another study that found no cases of AVN. The study comprised 22 patients between the ages of 7 to 13 years who underwent intramedullary nail fixation using a trochanteric entry point. This resulted in clinically important femoral neck narrowing, valgus femur changes, or proximal femur changes. In 2004, Gordon et al\textsuperscript{15} performed a third study and found the same results in 15 patients between the ages of 8 to 17 years who were treated with intramedullary nail fixation through lateral trochanteric entry point.

In 2009, Keeler et al\textsuperscript{16} reviewed 78 children treated with intramedullary nail fixation though a lateral trochanteric entry point and reported no incidents of AVN or proximal femur deformity. In 2012, Miller et al\textsuperscript{17} reviewed 17 skeletally immature patients between the ages of 7 to 11 years, in which all patients had open physes and trochanteric apophyses at the time of operative treatment. The patients were treated with a rigid intramedullary nail using a lateral trochanteric entry point, and the authors found no incidents of AVN or proximal femur deformity. In a review of 23 children aged 9 to 15 years, Elgohary and El Adl\textsuperscript{18} found no cases of AVN or proximal femoral deformity using a greater trochanter entry point. Shahabuddin et al\textsuperscript{19} examined 18 patients aged 6 to 13 years treated with Surgical Implant Generation Network (SIGN) Pediatric nails and SIGN-Fin nails without any complications. In a 2015 retrospective review, Herrera-Soto et al\textsuperscript{20} reported findings of 10 patients aged 9 to 14 years with subtrochanteric femur fractures. The patients were treated with intramedullary nail fixation with a lateral greater trochanter entry point, and no major complications were reported.

We encountered four papers that described patients with AVN or proximal femur deformity.\textsuperscript{21-24} MacNeil et al\textsuperscript{25} found that rates of AVN varied significantly based on entry site, with rates of 2\% for the piriformis fossa (5 of 239 patients), 1.4\% for tip of the greater trochanter (2 of 139 patients), and 0\% for lateral greater trochanter entry (0 of 80 patients). The patients who were developing AVN with piriformis fossa nail entry were aged 10, 12, 13, and 13 years, with the fifth patient’s age unspecified. The patients who developed AVN after rigid nail fixation with tip of greater trochanter entry were aged 11 years and one age was unspecified. Furthermore, a study by Letts et al\textsuperscript{22} had one case of AVN in a group of children aged 11 to 17 years, with 10 of the children under the age of 13 years. The case of AVN was in a 13-year-old patient who underwent intramedullary nail fixation through the piriformis fossa.
**Table 1. Description of articles**

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Description</th>
<th>Entry point</th>
<th>AVN or PFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Townsend and Hoffinger</td>
<td>2000</td>
<td>34 aged 10-17 years</td>
<td>Tip of greater trochanter</td>
<td>None</td>
</tr>
<tr>
<td>Gordon et al</td>
<td>2002</td>
<td>Nine aged 8-11 years</td>
<td>Lateral greater trochanter</td>
<td>None</td>
</tr>
<tr>
<td>Gordon et al</td>
<td>2003</td>
<td>22 aged 7-13 years</td>
<td>Lateral greater trochanter</td>
<td>None</td>
</tr>
<tr>
<td>Gordon et al</td>
<td>2004</td>
<td>15 aged 8-17 years</td>
<td>Lateral greater trochanter</td>
<td>None</td>
</tr>
<tr>
<td>Keeler et al</td>
<td>2009</td>
<td>80 fx in patients aged 8-18 years</td>
<td>Lateral greater trochanter</td>
<td>None</td>
</tr>
<tr>
<td>Miller et al</td>
<td>2012</td>
<td>17 aged 7-11 years</td>
<td>Lateral greater trochanter</td>
<td>None</td>
</tr>
<tr>
<td>Elgohary and El Adil</td>
<td>2014</td>
<td>23 aged 9-15 years</td>
<td>Tip of greater trochanter</td>
<td>None</td>
</tr>
<tr>
<td>Shahabuddin et al</td>
<td>2015</td>
<td>18 aged 6-13 years</td>
<td>Lateral greater trochanter</td>
<td>None</td>
</tr>
<tr>
<td>Herrera-Soto et al</td>
<td>2015</td>
<td>10 aged 9-14 years</td>
<td>Lateral greater trochanter</td>
<td>None</td>
</tr>
<tr>
<td>MacNeil et al</td>
<td>2011</td>
<td>458 aged 6-18 years</td>
<td>Piriformis fossa, tip of greater trochanter, lateral greater trochanter</td>
<td>5 AVN with piriformis entry, 2 AVN with tip of greater trochanter entry</td>
</tr>
<tr>
<td>Letts et al</td>
<td>2002</td>
<td>54 aged 11-17 years</td>
<td>Piriformis fossa, greater trochanter</td>
<td>1 AVN</td>
</tr>
<tr>
<td>Buford et al</td>
<td>1998</td>
<td>50 aged 10-16 years</td>
<td>Lateral and posterior to the piriformis fossa</td>
<td>2 AVN</td>
</tr>
<tr>
<td>Beaty et al</td>
<td>1994</td>
<td>17 aged 10-13 years</td>
<td>Piriformis fossa</td>
<td>1 AVN, 1 PDF</td>
</tr>
</tbody>
</table>

AVN, avascular necrosis; fx, fractures; PFD, proximal femur deformity.
aNumbers represent number of patients unless otherwise stated.
bFemoral lengthening over intramedullary nailing.
cSurgical Implant Generation Network (SIGN) pediatric nail and SIGN-Fin nail.
dSubtrochanteric femur fractures treated with intramedullary nailing.
eSystematic review including 19 articles.
fLocation unspecified.
gMedial greater trochanter.
hNone that were clinically significant.
iAsymptomatic.

AVN sometimes developed without symptoms. In a prospective study, Buford et al described 54 children between the ages of 11 to 17 years. He found two cases of AVN treated with intramedullary nail fixation through an entry point described as more lateral and posterior than piriformis fossa. One of these cases was in a 12-year-old boy who also had evidence of AVN on the uninjured and unoperated side, raising the possibility of an idiopathic source. The other case was in a 10-year-old girl who developed signs of AVN as found on magnetic resonance imaging. The patients with AVN had no symptoms. Out of 17 children under the age of 13 years who were treated with intramedullary nail fixation through the piriformis fossa, Beaty et al also reported one patient without AVN symptoms. They also found one patient with an increase in articulotrochanteric distance that was similarly asymptomatic.

**CONCLUSION**

We reviewed the available studies on rigid nail fixation for treating skeletally immature children with femur fractures, particularly focusing on studies that included children as young as 6 years. A total of nine of thirteen papers found no incidents of AVN or clinically significant proximal femur deformity using a greater trochanter entry point (especially a lateral greater trochanter entry point). The remaining four studies described AVN or proximal femoral deformity in patients who were treated with intramedullary nails through a starting point at or near the piriformis fossa or the top of the greater trochanter. There was a lesser rate when using a starting point at the tip of the greater trochanter.

Other treatment options for femoral shaft fractures in children aged 6 to 12 years include external fixation, submuscular plating, and flexible intramedullary nail fixation. Each of these treatment options have their own risks and benefits. This findings of this review suggest that rigid nail fixation in children aged 6 to 12 years may be an acceptable operative intervention for treating femoral shaft fractures, particularly when the lateral aspect of the greater trochanter is used as the entry point.

Notably, we found no studies that solely focused on children aged 6 to 12 years; additionally, the studies...
that did include these ages also reported on older ages. Considering that most of these studies did not report data divided by age group, we were unable to separate the data regarding children aged 6 to 12 years from the data pertaining to the older children. Future studies that solely focus on patients aged 6 to 12 years would provide more information regarding the treatment outcomes of this age group.

REFERENCES

Understanding and Improving Patient Satisfaction in Orthopaedic Surgical Procedures: A Review

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Conflict of Interest The author reports no conflicts of interest.

ABSTRACT

Orthopaedic surgeons and their hospitals are being evaluated and reimbursed according to their ability to provide patient satisfaction. It behooves physicians to learn how patient satisfaction is evaluated, how patient satisfaction may be improved, and how improvements in patient satisfaction may positively influence patient outcomes both subjectively and objectively. The purpose of this review is to illuminate how evaluation works, how patient factors may affect or correlate with increased satisfaction, and how physicians can improve actions to enhance patient satisfaction. Notably, studies have found that improved care coordination, nursing follow-up, provider listening skills, providing realistic yet positive expectations, and sitting down with patients during their clinic visit can increase patient satisfaction. An improved understanding of patient satisfaction will help orthopaedic surgeons work with government agencies and hospital administrations to make sure that patients receive the best care possible.

Keywords: Patient Satisfaction, Patient Reported Outcome Measures, Hospital Consumer Assessment of Healthcare Providers and Systems, Outcome Measures

INTRODUCTION

In the past 2 decades, both patient satisfaction and patient-reported outcomes have become increasingly important components of how we assess the value of our care as orthopaedic surgeons. As providers within a surgical field, it may be appealing to solely focus on our ability to diagnose and treat orthopaedic conditions. Although these are important aspects of the care we provide, additional factors contribute to overall patient satisfaction and outcomes. Particularly, “consumer experience” is a major contributor to how patients perceive their received care. Developments with Patient Satisfaction Surveying and government reporting of patient satisfaction scores are requiring physicians to take a closer look at their patients’ overall care experience.

Regarding a wide array of elective orthopaedic surgical procedures, patient satisfaction falls within the range of 68% to 91%. This suggests that 1 of 11 patients undergoing elective surgical treatment do not rate their outcome as “good” or “excellent.” This would be considered a failure within many industries of the service sector. These studies show that orthopaedic surgeons’ perception of patient outcome does not correlate with the patients’ reported outcomes; additionally, it shows that the mismatch is due to the surgeons’ overestimation of patient satisfaction in most cases. As healthcare providers seeking to add quality to peoples’ lives, we must understand that there is much more to providing quality care than physiological, radiological, or biomechanical measurements.

It has become imperative that we, as physicians, understand how we are being evaluated and portrayed within our community, which affect not only our reputation but our reimbursement. In addition to improving the inherent value of patient and family experiences, it is suggested that improved patient satisfaction and experience has the reciprocal effect on patients’ physiological and functional outcomes.

This review aims to help orthopaedic surgeons understand the following: 1) how evaluation works and the subsequent implications, 2) how patient factors may affect or correlate with increased satisfaction, and 3) how we can modulate our actions as physicians to improve patient satisfaction while simultaneously improving patients’ and surgeons’ measurements of outcomes. Furthermore, an improved understanding will help us identify potential flaws in the governmental oversight of patient care, in which we can then advocate for positive change in specific ways.

CONCERNS WITH THE “CUSTOMER IS ALWAYS RIGHT” APPROACH

Many physicians dislike the recent phenomenon of online reviews and customer satisfaction reporting because of the pressure it may place on physicians to provide undue diagnostic tests or treatments. In a study by Jerant et al., a total of 68% of 1319 primary care
visits entailed patient requests for specific diagnostic tests, medical treatment, surgical treatment, or specialty referral. Denial of request for referrals, pain medication prescriptions, or laboratory tests correlated with lower satisfaction scores, whereas denial of requests for antibiotics or imaging studies had no correlation with satisfaction.

Zgierska et al\textsuperscript{17} surveyed 155 physicians to assess their feelings on satisfaction ratings, in which 78% of physicians reported that the recent public focus on patient satisfaction had affected their job satisfaction and 28% had subsequently considered leaving the medical profession. Additionally, 59% of physicians reported that patient satisfaction scores affected their compensations, and 50% reported a constant temptation to provide inappropriate care to improve their satisfaction ratings. Clearly, this aspect of trying to obtain patient approval could be considered concerning.

**PATIENT-REPORTED EXPERIENCE MEASURES AND PATIENT-REPORTED OUTCOME MEASURES**

Patient-reported experience measures (PREMs) are distinctly different from patient-reported outcome measures (PROMs). However, both contribute to overall patient satisfaction.

**Patient-Reported Experience Measures**

In 1985, Press-Ganey was founded by medical anthropologist Irwin Press, PhD, and sociologist and statistician Rod Ganey, PhD.\textsuperscript{1} They popularized the idea of the medical field being part of the consumer service industry, saw that the public would find value in the collection of patient-reported satisfaction scores, and that reporting these data to the public would allow patients to compare “care” across organizations. These data were largely focused on patient experience. In 2002, the Centers for Medicare and Medicaid Services (CMS) collaborated to develop and validate the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey.\textsuperscript{16} With the help of the CMS, it morphed into a standardized 27-question survey that could be administered by approved vendors, the most prominent being Press-Ganey. The 27 questions were split into 10 domains (Table 1). However, the survey was not focused on patient outcomes, but rather on the “consumer experience” during an inpatient hospital stay, or PREMs.

In 2005, hospitals began to receive a financial incentive for participation in the HCAHPS survey.\textsuperscript{1} Results from these surveys were first reported publicly in March 2008 and are now reported annually. In 2010, the results of the HCAHPS survey began to influence Medicare reimbursement. In 2017, about 1.7 billion dollars were withheld from hospitals across the United States, which was then distributed to top performers in consumer satisfaction.\textsuperscript{1} Although the results from this survey may affect reimbursement and patient perception, specific consumer experiences correlate poorly with overall patient satisfaction. Kemp et al\textsuperscript{17} found that coordination, nursing follow-up, and ability to listen were the top correlates with patient satisfaction, and even these had low correlation (Spearman’s Correlation Coefficients of 0.54, 0.46, and 0.45, respectively).

| Patient-Reported Outcome Measures | PROMs | are patients’ perception of their overall health, function, and pain experience after undergoing orthopaedic procedures. These are not focused on the “consumer experience” but rather on measuring how effectively orthopaedic care can improve the quality of life. Some of these questionnaires focus on general quality of life and disability (ie, Veterans RAND12 or PROMIS 10), whereas others focus on the patients’ perception of functional results and pain relief in a specific joint or area of the body (ie, Oswestry Disability Index; Knee Injury and Osteoarthritis Outcome Score; and Disability of the Arm, Shoulder, and Hand Score). The most commonly used assessments regarding PROMs can be found on the website of American Academy of Orthopaedic Surgeons.\textsuperscript{18} Results of PROM assessments seem more clinically relevant for surgeons. This is because they represent the ability to apply orthopaedic knowledge and skill to improve the quality of life rather than the ability to provide a luxurious consumer experience. However, these assessments do not contribute to government or agency reporting of patient satisfaction, nor do they influence government reimbursement.\textsuperscript{18} |
| EASY WAYS TO MODULATE PATIENT SATISFACTION | Several studies have shown that various factors may increase satisfaction ratings. Morris et al\textsuperscript{19} found that providing orthopaedic trauma patients with the attending surgeon’s biosketch increased the number of patients that reported their care as “excellent,” from 52% to 74%. Swayden et al\textsuperscript{20} showed that satisfaction |

**Table 1. Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey domains and question focus**

<table>
<thead>
<tr>
<th>Question focus</th>
<th>Nurse communication</th>
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<tr>
<td>Overall rating of hospital</td>
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<tr>
<td>Willingness to recommend hospital</td>
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<tr>
<td>Satisfaction</td>
<td></td>
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<tr>
<td>Pain management</td>
<td></td>
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<tr>
<td>Communication about medicines</td>
<td></td>
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<tr>
<td>Discharge information</td>
<td></td>
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<tr>
<td>Cleanliness of hospital environment</td>
<td></td>
</tr>
<tr>
<td>Quietness of hospital environment</td>
<td></td>
</tr>
<tr>
<td>Doctor communication</td>
<td></td>
</tr>
<tr>
<td>Responsiveness of hospital staff</td>
<td></td>
</tr>
<tr>
<td>Communication about medicines</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{1} Zgierska et al\textsuperscript{15} surveyed 155 physicians to assess their feelings on satisfaction ratings, in which 78% of physicians reported that the recent public focus on patient satisfaction had affected their job satisfaction and 28% had subsequently considered leaving the medical profession. Additionally, 59% of physicians reported that patient satisfaction scores affected their compensations, and 50% reported a constant temptation to provide inappropriate care to improve their satisfaction ratings. Clearly, this aspect of trying to obtain patient approval could be considered concerning.
rates increased by 34% when the surgeon sat (rather than stood) during patient visits. Additionally, patients’ perceived time spent with the physician increased nearly five times the actual time. Wadsworth showed that satisfaction ratings may improve if nurses can be influenced to sit with the patient as well. Camacho et al showed that visits less than 5 minutes nearly tripled dissatisfaction ratings from patients waiting longer than 20 minutes. Therefore, improving wait times and controlling the ratio between wait time and time spent with the surgeon may improve overall satisfaction ratings.

**PATIENT EXPECTATIONS AND SATISFACTION**

According to a recent review, meeting patients’ preoperative expectations seems to be the most significant predictor of overall satisfaction after spine, shoulder, knee, and hip procedures. Being married or employed were factors that seemed to lead to higher satisfaction ratings. Other factors include improvement in general health and function and if the patient experienced fewer postoperative complications. Patient factors that were associated with higher expectations across elective orthopaedic surgical procedures included younger age, worse preoperative functional status, higher education level, and the active search for orthopaedic information from non-orthopaedic sources.

Interestingly, studies have shown a correlation between patients’ higher expectations of improvement after surgical intervention and the postoperative satisfaction. Carr et al showed improved results of PROMs on the SF-36 survey in patients that expected no residual pain after anterior cervical discectomy and fusion. Yee et al found that higher expectations were associated with improvements on the SF-36 surveys at 1 year after undergoing posterior spinal treatment. Toyone et al noted that patients who expected more improvement from lumbar discectomy had greater satisfaction postoperatively than those who had lower expectations.

Regarding shoulder procedures, patients with higher preoperative expectations had better postoperative performance on the Disability of Arm, Shoulder, and Hand (commonly known as DASH), Visual analogue Scale (VAS), and quality of life scores after undergoing rotator cuff repair. Swarup et al showed that patients who expected more after a primary total shoulder arthroplasty had better PROMs on VAS and SF-36 scores.

For joint reconstruction, Gandhi et al found that patients with higher preoperative expectations of pain relief after undergoing total knee arthroplasty (TKA) and total hip arthroplasty (THA) had improved pain 1 year postoperatively. This was compared to those that held lower expectations for pain relief. Mahomed et al showed that the expectation of complete pain relief was a predictor of improved SF-36 scores and pain relief 6 months after TKA. Lastly, higher preoperative functional expectations have shown to correlate with a greater improvement in Western Ontario and McMaster Universities Arthritis Index scores 1 year after TKA.

**SETTING EXPECTATIONS AND IMPROVING OUTCOMES**

How then, should we prepare our patients’ expectations before an orthopaedic surgical procedure? Some try to lower expectations so that the intervention and results will easily meet those expectations; however, the data reviewed suggest that perhaps we should strive to increase patients’ expectations for improved clinical results. These patient expectations may be modified by face-to-face clinical visits and preoperative surgical classes that provide a positive outlook with realistic postoperative expectations.

In orthopaedic studies, no prospective data exist that specifically show that increasing patient expectations improves outcomes. However, preliminary prospective data within the field of cardiothoracic surgery suggest that presurgical modulation of expectations could influence both patient-reported outcomes and biologically measured outcomes. The PSY-HEART trial conducted by Rief et al noted that presurgical psychological intervention focusing on positive outcomes resulted in improved patient-reported outcome measures and also decreased inflammatory markers. This was when compared to the group without psychological intervention. This psychological intervention included the development and recording of personal short- and long-term goals and positive expectations after surgical treatment. The intervention also focused on discussing effective means of dealing with unpleasant experiences postoperatively. This type of psychological intervention may prove to be useful across other surgical specialties such as orthopaedics.

**CONCLUSION**

The medical service sector is new to the world of consumer evaluation. Although the systems in place for public and governmental evaluation are imperfect, the goals of increasing consumer satisfaction and improving patient outcomes are not mutually exclusive. High-yield areas to improve patient experience and satisfaction include improved care coordination, nursing follow-up, and provider listening skills. Sitting down with the patient has shown to drastically affect the patients’ perception of their care. Realistic, yet positive expectations have been shown to improve satisfaction and outcomes within the field of cardiothoracic surgery, and this phenomenon may translate to orthopaedics. As we attempt to understand how patients’ perceive and evaluate the medical and non-medical services provided by physicians and the hospital systems, we have an opportunity, as physicians, to improve their overall experience and perceived quality of medical care.
REFERENCES


Multimodal Analgesia in Orthopaedic Surgery and Presentation of a Comprehensive Postoperative Pain Protocol: A Review

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ABSTRACT

Rising opioid use in the United States has now been termed an epidemic. Opioid use is associated with considerable morbidity, mortality, and cost to the healthcare system. Orthopaedic surgeons play a key role in the opioid epidemic by prescribing postoperative narcotics. Although our understanding of the quantity of narcotics to prescribe postoperatively for analgesia is progressing, there is still a paucity of data focused on routine postoperative pain protocols. The purpose of this article is to review the current options for both opioid and non-opioid analgesia and put forth a multisubspecialty orthopaedic protocol of postoperative pain. On the basis of study findings and the individual experiences of surgeons within our orthopaedic department, our comprehensive pain protocol includes the following considerations: use of non-steroidal anti-inflammatory drugs on an individual basis, limited use of benzodiazepines, use of diazepam in only pediatric patients undergoing major procedures, lower doses of gabapentin after hip and knee arthroplasty, higher doses of gabapentin after spine procedures, general use of oxycodone owing to its accessibility, use of isolated opioids rather than combined forms, and close collaboration with anesthesiologists for determining use of peripheral nerve block. Our resultant comprehensive pain protocol can provide orthopaedic surgeons with a framework to build upon, which will benefit greatly from future studies that examine narcotic use with specific procedures.

Keywords: Pain, Postoperative, Narcotic, Opioid, Protocol

INTRODUCTION

Nociception is the mechanism by which tissue damage is communicated from the periphery to the central nervous system. The resulting pain has a large variability and is defined as the unpleasant experience associated with a given stimulus. Pain is a common concern in most fields of medicine, especially in orthopaedics. In fact, treatment algorithms used in orthopaedics are often guided by pain. Despite the common occurrence of pain, little is understood about the variability and postoperative treatment.

The increased availability of opioid medications and the effort to adequately treat pain has led to the dramatic rise of opioid use in the United States. Accordingly, opioid-related consequences have increased. The United States represents about 4.4% of the world’s population but consumes 80% of the global opioid supply. The Centers for Disease Control and Prevention estimates that 32,445 deaths occurred in 2016 due to prescription opioids, which is about 89 deaths per day. In comparison, 36,161 deaths occurred due to motor vehicle accidents in 2015.

It is estimated that orthopaedic surgeons prescribe about 7% of prescription opioids in the United States. Additionally, orthopaedic surgeons prescribe more opioids than most other specialty physicians owing to the pain associated with common orthopaedic procedures. Furthermore, orthopaedic surgeons often prescribe more narcotics than patients use, which can contribute to potential abuse and the diversion of prescription narcotics to other uses and users.

The challenge of prescribing postoperative narcotic medication is learning how to manage an amount needed for pain control during an unpredictable time. The goal is to find a balance in prescribing sufficient quantities of narcotics, offsetting postoperative pain, and minimizing potential risks of habituation and inappropriate use. Finding a sufficient quantity is dependent on multiple variables such as the surgical procedure, operating time, preoperative opioid exposure, use of non-narcotic agents, and patient variability in pain perception. Although several of these variables remain difficult to quantify, the typical opioid quantity for a given surgical procedure appears
to be more predictable. The aim of this article is to review frequently used postoperative pain regimens and put forth a comprehensive protocol of postoperative pain management that can be applied to common orthopaedic procedures.

IMPLICATIONS OF A STANDARDIZED PAIN PROTOCOL
Use of standardized protocols has become common in medicine. Although protocols often evolve as the studies expand, implementation of routine protocols has proven effective in reducing patient morbidity and mortality in multiple applications—ranging from preoperative timeout\(^{20,29}\) to acute management of unstable pelvic ring injuries.\(^{13}\) Despite emerging reports of average amounts of opioids to prescribe postoperatively, data are limited regarding the potential benefits of prescribing a defined amount. Routine protocols of postoperative pain management can potentially improve morbidity and mortality and change the landscape of the current opioid crisis.\(^{12,15}\)

NON-Steroidal ANTI-INFLAMMATory DRUGS
Since the discovery of acetylsalicylic acid (ie, aspirin) in the bark of a willow tree more than 70 years ago, non-steroidal anti-inflammatory medications (NSAIDs) have been used for analgesia.\(^{14}\) NSAIDs inhibit cyclooxygenase 1 (COX-1) and 2 (COX-2) to provide antipyretic, analgesic, anti-inflammatory, and antithrombotic effects.\(^{15}\) Historically, the use of NSAIDs in the management of orthopaedic injuries has been controversial because of concerns of bleeding, delayed wound healing, and fracture healing complication.\(^{15}\) In children, however, NSAIDs have been shown to decrease opioid consumption\(^{16,17}\) and are as effective as opioids in reducing pain associated with uncomplicated fractures.\(^{18}\)

Both the risks of NSAIDs and the benefits of decreased opioid use favor the inclusion of NSAIDs in a multimodal postoperative pain regimen.

Various NSAIDs are available, each one with a varying duration of action, adverse effect profiles, analgesic strength, and cost.\(^{19}\) Regarding orthopaedic surgical procedures, no standard has been set on the “perfect” NSAID, nor is there evidence that one NSAID regimen is more effective for one procedure over another. Therefore, the choice of NSAID should be left to the discretion of the surgeon and patient, taking into consideration the history of gastrointestinal bleed or upset, cardiovascular history, renal health, allergies, and associated anticoagulants. For this reason, our institution’s orthopaedic department has agreed to use NSAIDs on a case-by-case basis rather than universally for every procedure.

OTHER NON-OPIOID MEDICATIONS
Acetaminophen, also known as paracetamol, is a frequently employed and readily available analgesic in the United States.\(^{20}\) Acetaminophen imparts its antipyretic and analgesic effects to the central nervous system; additionally, it regulates impact on the inflammatory response.\(^{21}\) It is available in both oral and intravenous forms, with intravenous typically reserved for the immediate postoperative period when patients may experience limited oral intake. Acetaminophen has become a standard in our pain protocol because of favorable adverse effect profile.

Gabapentin is a gamma-aminobutyric acid agonist that acts primarily on spinal calcium channels, but there are likely other pharmacodynamics that are not understood.\(^{22}\) It has been well established that the role of gabapentin is reducing phantom limb pain after amputation\(^{23}\); however, the role of gabapentin as a multimodal agent is less clear in other orthopaedic procedures, particularly in arthroplasty.\(^{24-26}\) Two randomized controlled trials that used gabapentin postoperatively found slightly decreased opioid use within the 48-hour period in one trial and no benefit in the other.\(^{25,26}\) However, a meta-analysis by Han et al\(^{27}\) found that gabapentin significantly reduced opioid consumption within the first 24 and 48 hours after surgery. The use of gabapentin has been shown to be more effective in perioperative pain control after lumbar spine procedures,\(^{29}\) however these data are confounded by considerable preoperative use. As a result of these mixed findings, we incorporated lowered doses of gabapentin (300 mg every night) into our routine postoperative pain protocol for hip and knee arthroplasty. For patients recovering from a spine procedure, we use a higher dose (ie, 600 mg every night) because many of our patients were accustomed to this medication preoperatively.

Benzodiazepines inhibit transmission on the postsynaptic γ-aminobutyric acid (known as GABA) neurons.\(^{29}\) Additionally, they act centrally on the spinal cord and peripherally on muscle tissue to reduce muscle spasms. The risk of respiratory depression with opioids and benzodiazepines has been thoroughly studied,\(^{30}\) and thus our use of this medication is quite limited. In our protocol, diazepam is used solely in treating children undergoing major procedures. In our experience, this medication is typically used instead of opioids for this specific population.

OPIOID MEDICATIONS
In the central nervous system, opioid medications provide analgesia through their agonistic actions on the Mu receptor; however, our understanding of the various Mu receptors continues to evolve.\(^{31}\) Although opioids may be effective for postoperative analgesia, their use is not without drawbacks. Fletcher and Martinez\(^{32}\) linked intraoperative exposure to opioids to hyperalgesia in the immediate postoperative period, highlighting the potential risks and early development of tolerance. The association between duration of opioid use and potential for misuse has also been well studied. Brat et al\(^{32}\) found that with each refill, an additional week of opioid use, the risk of misuse increased by 44%. The many adverse effects of prolonged opioid exposure...
have been well described (e.g., nausea, vomiting, constipation, and respiratory depression). Thus, the primary aim of our multimodal pain protocol was to provide sufficient postoperative analgesia while minimizing opioid use.

There are many available choices for oral opioid analgesia. The options can be broadly categorized into isolated versus combined forms, long versus short acting, or by route of administration. For the purpose of this review, we limited our discussion to oral, short acting isolated, and combined forms. Isolated forms include hydrocodone, oxycodone, morphine, hydromorphone, methadone, among others. Potency, duration of action, and half-life are unique to each medication. To provide study uniformity for the comparison of opioids, the use of milligram morphine equivalents has become standard and is readily available on the Centers for Disease Control and Prevention website; however, the accuracy of conversion remains debatable. The isolated opioid should be chosen by both the patient and provider because the adverse effect profile and analgesic effect are similar and dependent on dosage. Furthermore, Basilico et al found no difference between the risk of prolonged opioid use and prescription opioid type after orthopaedic procedures. For the purposes of our protocol, oxycodone is the most easily accessible and readily available.

A few combined forms of opioid include oxycodone and ibuprofen, oxycodone and acetaminophen, or hydrocodone and acetaminophen. Many studies have found no differences in the analgesic efficacy of combined opioid and NSAID forms or opioid and acetaminophen forms. Furthermore, when combining opioid and NSAID medications, there is no evidence of synergistic analgesic effect. Anecdotally, there is a potential benefit of minimizing opioid overdose in combined forms, which suggests that a patient attempting to misuse or overdose oxycodone and acetaminophen will reach toxic levels of acetaminophen before respiratory depression. However, there is no evidence to support this claim and we strongly recommend that providers not rely on this method for safety when prescribing opioids. Although combined opioid forms may offer convenience, calculating safe dosages of acetaminophen and NSAIDs to use in conjunction can be burdensome and even dangerous for patients. Therefore, the use of isolated opioids in our protocol allows us to emphasize narcotic use solely as needed after maximizing use of non-narcotic agents. Additionally, it allows the patient to discontinue opioids early in the postoperative period while continuing the use of non-narcotics during recovery.

REGIONAL ANESTHESIA

Regional anesthesia refers to the use of peripheral nerve blocks for intraoperative and postoperative analgesia. Additionally, it can be used in conjunction with general anesthesia or monitored anesthesia care for a given procedure. The safety of regional anesthesia has been well established. Furthermore, regional anesthesia has been shown to significantly reduce opioid consumption in arthroplasty, fracture treatment, and arthroscopy. Although the use of peripheral nerve blocks has been widely adopted into our practice as orthopaedic surgeons, collaboration with anesthesiologists is crucial. Peripheral nerve block locations, medications, and dosages continue to change. Because of this, we defer their use to our anesthesia colleagues rather than implement them into a uniform and standardized protocol. Although the choice of peripheral nerve block may vary between cases, our anesthesia colleagues typically provide interscalene blocks for shoulder procedures; infraclavicular blocks for elbow, wrist, and hand procedures; combined femoral and sciatic blocks for arthroscopic knee procedures; popliteal and saphenous blocks for foot and ankle procedures; and spinal anesthesia for hip and knee arthroplasty.

CONCLUSION

To address the lack of a standardized pain protocol, surgeons of our orthopaedic department synthesized their individual protocols, with gaps subsidized by agreeable surgeon-specific preferences. In Appendices 1 through 7, we present the resultant comprehensive postoperative pain protocol. The purpose of the protocol is to maximize non-narcotic analgesia and provide a standard quantity of opioid for various orthopaedic procedures. Notably, the protocol focuses on common procedures and does not address every possible procedure that an orthopaedic surgeon could perform. However, it can be applied as a framework for less common procedures. Within the protocol, some procedures are identified as major or minor depending on the severity of the treatment and anticipated postoperative pain experienced. Furthermore, we expect deviations from the protocol in cases of patient allergies, prior opioid exposure, and preoperative medications.

Early results of implementing a standard pain protocol are encouraging but limited to single subspecialties. To our knowledge, this is the first review to put forth a multi-subspecialty protocol. Studies evaluating the benefits of a multi-subspecialty protocol are currently underway, and future work dedicated to minimizing narcotic use remain paramount.
REFERENCES


**Appendix 1. Postoperative protocol for managing pain after common foot and ankle procedures**

<table>
<thead>
<tr>
<th>Drug</th>
<th>ORIF for Ankle Injuries</th>
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<tr>
<td><strong>Acetaminophen</strong></td>
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<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>80 tablets (500 mg)</td>
<td>80 tablets (500 mg)</td>
</tr>
<tr>
<td>Duration(^a)</td>
<td>2 every 8 h</td>
<td>2 every 8 h</td>
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<tr>
<td><strong>Ibuprofen</strong></td>
<td></td>
<td></td>
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<td>40 tablets (800 mg)</td>
</tr>
<tr>
<td>Duration</td>
<td>1 TID as needed</td>
<td>1 TID as needed</td>
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<tr>
<td><strong>Oxycodone(^b)</strong></td>
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<td></td>
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<tr>
<td>Quantity</td>
<td>30 tablets (5 mg)</td>
<td>20 tablets (5 mg)</td>
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<tr>
<td>Duration</td>
<td>1 every 6 h as needed</td>
<td>1 every 6 h as needed</td>
</tr>
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</table>

\(^a\)Patients should take this until pain resolves.
\(^b\)Patients should take for breakthrough pain.

**Appendix 2. Postoperative protocol for managing pain after common hand procedures**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Trigger finger release</th>
<th>Carpal tunnel release</th>
<th>De Quervain’s release</th>
<th>ORIF for DR fractures</th>
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</thead>
<tbody>
<tr>
<td><strong>Acetaminophen</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>80 tablets (500 mg)</td>
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<td>“</td>
<td>“</td>
</tr>
<tr>
<td>Duration(^a)</td>
<td>2 every 8 h</td>
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<tr>
<td><strong>Ibuprofen</strong></td>
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<tr>
<td>Duration</td>
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<tr>
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</tbody>
</table>

\(^a\)Patients should take this until pain resolves.
\(^b\)Patients should take for breakthrough pain.
### Appendix 3. Postoperative protocol for managing pain after common pediatric procedures and conditions

<table>
<thead>
<tr>
<th>Drug</th>
<th>Minor procedures[^a]</th>
<th>Major procedures[^d]</th>
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<tr>
<td><strong>Liquids</strong></td>
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<tr>
<td>Hycet[^a]</td>
<td>0.1 mg/kg Every 6 h for 5 days</td>
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<tr>
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<td>10 mg/kg every 6 h for 5 days</td>
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<tr>
<td>Diazepam</td>
<td>-- Every 6 h for 5 days</td>
<td>5 mg/5 mL (0.1 mg/kg) Every 6 h for 7 days[^f]</td>
<td>5 mg/5 mL (0.1 mg/kg) Every 6 h for 7 days[^f]</td>
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<tr>
<td>Senna</td>
<td>8.8 mg/5 mL Oral syrup for 5 days</td>
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</tr>
<tr>
<td>Gabapentin</td>
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</tr>
<tr>
<td>Senna</td>
<td>--</td>
<td>--</td>
<td>17 g</td>
</tr>
<tr>
<td>Senna</td>
<td>--</td>
<td>--</td>
<td>Every day for 7 days (225 g)[^i]</td>
</tr>
<tr>
<td><strong>Pills</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ibuprofen</td>
<td>10 mg/kg every 6 h for 5 days</td>
<td>10 mg/kg every 6 h for 14 days</td>
<td>--</td>
</tr>
<tr>
<td>Tylenol</td>
<td>10 mg/kg every 4 h for 5 days</td>
<td>10 mg/kg every 4 h for 14 days</td>
<td>10 mg/kg every 4 h for 14 days</td>
</tr>
<tr>
<td>Oxycodone</td>
<td>0.1 mg/kg every 4 h for 5 days</td>
<td>0.1 mg/kg every 4 h for 7 days[^a, f]</td>
<td>0.1 mg/kg every 4 hours for 7 days[^a, f]</td>
</tr>
<tr>
<td>Diazepam</td>
<td>-- 5 mg/5 mL (0.1 mg/kg) Every 6 h[^h]</td>
<td>5 mg/5 mL (0.1 mg/kg) Every 6 h[^h]</td>
<td>--</td>
</tr>
<tr>
<td>Docusate</td>
<td>50 mg BID for 5 days</td>
<td>50 mg BID for 14 days</td>
<td>--</td>
</tr>
<tr>
<td>Gabapentin</td>
<td>--</td>
<td>--</td>
<td>300 mg</td>
</tr>
<tr>
<td>Gabapentin</td>
<td>--</td>
<td>--</td>
<td>Every evening for 14 days</td>
</tr>
<tr>
<td>Miralax</td>
<td>--</td>
<td>--</td>
<td>17 g</td>
</tr>
<tr>
<td>Miralax</td>
<td>--</td>
<td>--</td>
<td>Every day for 7 days (255 g)[^i]</td>
</tr>
</tbody>
</table>

[^a]: For infants < 1 year: use hycet (7.5 mg hydrocodone / 325 mg paracetamol in 15 mL) 0.1mg/kg every 6 h for 5 days. Solution comes in concentration as above, so typically give 2 mL for a 10 kg baby.

[^d]: Consider a daily aspirin 325 mg for 28 days for all adolescent females, especially those on birth control.

[^f]: Examples of minor procedures are as follows: tendon-Achilles lengthening, surgical fixation of supracondylar fractures, epiphysiodesis, tendon transfers, hardware removal, etc.

[^i]: For muscle spasms; do not exceed 60 tablets.

[^h]: For muscle spasms; do not exceed 30 tablets.

[^i]: Tirate to soft stools.
**Appendix 4. Postoperative protocol for managing pain after common spine procedures**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Inpatient management plan*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gabapentin</td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>600 mg</td>
</tr>
<tr>
<td>Duration</td>
<td>QHS</td>
</tr>
<tr>
<td>Acetaminophen</td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>1000 mg (≤ 4000 mg)</td>
</tr>
<tr>
<td>Duration</td>
<td>Every 6 h</td>
</tr>
<tr>
<td>Ketorolac&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>30 mg (≤ 210 mg)</td>
</tr>
<tr>
<td>Duration</td>
<td>Every 6 h for first 24 h</td>
</tr>
<tr>
<td>Ibuprofen&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>800 mg (≤ 3200 mg)</td>
</tr>
<tr>
<td>Duration</td>
<td>Every 6 h as needed after first 24 h</td>
</tr>
<tr>
<td>Dexamethasone&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>8 mg</td>
</tr>
<tr>
<td>Duration</td>
<td>PO daily for 48 h</td>
</tr>
<tr>
<td>Methocarbamol</td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>500 mg (≤ 4000 mg)</td>
</tr>
<tr>
<td>Duration</td>
<td>QID as needed for muscle spasm</td>
</tr>
</tbody>
</table>

**Opioids after inpatient management plan medications are maxed out**<sup>d</sup>

<table>
<thead>
<tr>
<th>Drug</th>
<th>Quantity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxycodone&lt;sup&gt;e&lt;/sup&gt;</td>
<td>5 mg</td>
<td>Every 4 h as needed for pain</td>
</tr>
<tr>
<td>Oxycodone&lt;sup&gt;e&lt;/sup&gt;</td>
<td>10 mg</td>
<td>Every 4 h as needed for pain</td>
</tr>
<tr>
<td>Morphine</td>
<td>2-4 mg</td>
<td>Every 4 h as needed for pain</td>
</tr>
<tr>
<td>Dilaudid</td>
<td>0.5-2 mg</td>
<td>Every 4 h as needed</td>
</tr>
</tbody>
</table>

**Bowel regimen**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Quantity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senna</td>
<td>--</td>
<td>BID</td>
</tr>
<tr>
<td>Miralax</td>
<td>17 g</td>
<td>Powder BID if no bowel movement by postoperative day 3</td>
</tr>
</tbody>
</table>

**Discharge medication (until 2 weeks postoperatively)**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Quantity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gabapentin&lt;sup&gt;e&lt;/sup&gt;</td>
<td>600 mg (28 300 mg tablets)</td>
<td>QHS</td>
</tr>
<tr>
<td>Acetaminophen</td>
<td>1000 mg (56 tablets)</td>
<td>Every 6 h (≤ 4000 mg daily)</td>
</tr>
<tr>
<td>Meloxicam</td>
<td>7.5 mg (14 tablets)</td>
<td>Every day as needed</td>
</tr>
<tr>
<td>Oxycodone</td>
<td>5 mg (80 tablets)</td>
<td>Every 4 h as needed</td>
</tr>
<tr>
<td>Senna</td>
<td>28 tablets</td>
<td>1 tablet BID while continuing opioid use</td>
</tr>
<tr>
<td>Promethazine</td>
<td>12.5 mg (30 tablets)</td>
<td>Every 6 h as needed for nausea</td>
</tr>
</tbody>
</table>

QHS, every night before bed; PO, orally; QID, for times a day; --, not applicable; BID, twice a day.

<sup>*</sup>Applied to both elective and trauma patients unless contraindicated. If previous opioid use is greater than 120 morphine equivalents (ie, 80 mg of oxycodone) per day, defer to consultation with inpatient pain management service.

<sup>b</sup>Because this is a nonsteroidal anti-inflammatory drug, it should be avoided if there is concern for poor bone healing. Give with proton pump inhibitors (ie, PPI) or H2 receptor blockers.

<sup>c</sup>Avoid if concern for poor wound healing.

<sup>d</sup>For continuous opioids, avoid basal rates—to be used in low dose for breakthrough pain in the immediate postoperative period.
**Appendix 5. Postoperative protocol for managing pain after total joint arthroplasty**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Inpatient management plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toradol</strong></td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>15 mg</td>
</tr>
<tr>
<td>Duration</td>
<td>IV Every 6 h for 48 h (hold for h/o GI bleed or GFR &lt; 60)</td>
</tr>
<tr>
<td><strong>Meloxicam</strong></td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>7.5 mg</td>
</tr>
<tr>
<td>Duration</td>
<td>PO every day for remainder of stay</td>
</tr>
<tr>
<td><strong>Tylenol</strong></td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>1 g</td>
</tr>
<tr>
<td>Duration</td>
<td>PO every 8 h (hold for hepatitis C)</td>
</tr>
<tr>
<td><strong>Decadron</strong></td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>4 mg</td>
</tr>
<tr>
<td>Duration</td>
<td>IV every day for 2 days (hold for diabetes)</td>
</tr>
<tr>
<td><strong>Gabapentin</strong></td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>300 mg</td>
</tr>
<tr>
<td>Duration</td>
<td>PO QHS</td>
</tr>
<tr>
<td><strong>Famotidine</strong></td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>20 mg</td>
</tr>
<tr>
<td>Duration</td>
<td>BID</td>
</tr>
</tbody>
</table>

**For patients aged < 70 years**

| **Oxycontin** |
| Quantity | 10 mg |
| Duration | PO BID (monitor closely in OSA) |
| **Oxycodone** |
| Quantity | 5 mg |
| Duration | PO every 4 h as needed for moderate pain |
| **Oxycodone** |
| Quantity | 10 mg |
| Duration | PO every 4 h as needed for severe pain |
| **Morphine** |
| Quantity | 2 mg |
| Duration | IV every 4 h as needed for intractable pain only |

**For patients aged > 70 years (hold oxycodone)**

| **Oxycodone** |
| Quantity | 5 mg |
| Duration | PO every 4 h (monitor closely for AMS and delirium) |
| **Tramadol** |
| Quantity | 50 mg |
| Duration | PO every 6 h as needed for moderate pain |
| **Oxycodone** |
| Quantity | 5 mg |
| Duration | PO every 4 h as needed for moderate pain |
| **Morphine** |
| Quantity | 2 mg |
| Duration | IV every 4 h as needed for intractable pain only |

**Outpatient management plan**

| **Aspirin** |
| Quantity | 81 mg (30 tablets) |
| Duration | BID (vs Lovenox) for 30 days |
| **Meloxicam** |
| Quantity | 7.5 mg (30 tablets) |
| Duration | PO daily for 30 days |
| **Gabapentin** |
| Quantity | 300 mg (30 tablets) |
| Duration | PO QHS for 30 days |
| **Famotidine** |
| Quantity | 20 mg (30 tablets) |
| Duration | PO daily for 30 days |

Continued on the next page
<table>
<thead>
<tr>
<th>Drug</th>
<th>Minor procedures&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Major procedures&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naprosyn</td>
<td>500 mg BID 1 tablet every 12 h for 3 days then BID (Disp #30 refill 2)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Tylenol</td>
<td>325 mg 2 tablets every 6 h for 3 days then 1-2 tablets every 6 h (Disp #60 refill 2)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Oxycodeone</td>
<td>5 mg 1 tablet every 6 h (Disp #10)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1 tablet every 6 h (Disp #30)&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lovenox</td>
<td>--</td>
<td>40 mg Daily for 2 weeks followed by aspirin</td>
</tr>
<tr>
<td>Aspirin</td>
<td>81 mg BID for 4 weeks (Disp #14)</td>
<td>&quot; to follow Zofran</td>
</tr>
<tr>
<td>Zofran</td>
<td>4 mg Every 8 h (Disp #5 refill 1)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Docusate</td>
<td>100 mg Daily for 14 days (Disp #14 refill 1)</td>
<td>&quot;</td>
</tr>
<tr>
<td>Gabapentin</td>
<td>--</td>
<td>300 mg Every evening for 14 days for amputations</td>
</tr>
</tbody>
</table>

<sup>a</sup>Minor procedures include debridement, surgical treatment of flexor tenosynovitis, surgical fixation of finger fractures, etc.

<sup>b</sup>Major procedures include surgical fixation of ankle, tibial plateau, acetabular, patella, both bone, and distal radius fractures as well as amputations, etc.

<sup>c</sup>As needed for pain.

<sup>d</sup>As needed for nausea.

GFR, glomerular filtration rate; GI, gastrointestinal; QHS, every night before bed; BID, twice a day; IV, intravenous; PO, orally; OSA, obstructive sleep apnea; AMS, altered mental status; TID, twice a day.

<sup>a</sup>Take after toradol.

<sup>b</sup>No narcotics beyond 6 weeks, switch to tramadol if as-needed medication is still required.

<sup>c</sup>For patients aged < 70 years, consider oxycodone if well tolerated while in-house and high pain level, or tramadol (50 mg, 60 tablets) at 1 tablet orally every 6 h.

<sup>d</sup>For patients aged > 70 years, consider oxycodone if well tolerated while in-house and high pain level, or tramadol (50 mg, 60 tablets) at 1 tablet orally every 6 h.
### Appendix 7. Postoperative protocol for managing pain after sports medicine procedures

<table>
<thead>
<tr>
<th>Drug</th>
<th>Minor procedures</th>
<th>Major procedures</th>
<th>Hip scope</th>
<th>Shoulder arthroplasty</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Naprosyn</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>500 mg</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Duration</td>
<td>1 tablet every 12 h for 3 days then BID(^d) (Disp #30 refill 2)</td>
<td>&quot;</td>
<td>1 tablet every 12 h for 30 days (Disp #60 refill 2)</td>
<td>1 tablet every 12 h for 3 days then BID(^d) (Disp #30 refill 2)</td>
</tr>
<tr>
<td><strong>Tylenol</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>325 mg</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Duration</td>
<td>2 tablets every 6 h for 3 days then 1-2 tablets every 6 h(^d) (Disp #60 refill 2)</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td><strong>Oxycodone</strong></td>
<td>5 mg</td>
<td>5 mg</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Quantity</td>
<td>1 tablet every 6 h(^d) (Disp #30)</td>
<td>1 tablet every 6 h(^d) (Disp #10)</td>
<td>1 tablet every 6 h(^d) (Disp #30)</td>
<td>&quot;</td>
</tr>
<tr>
<td><strong>Aspirin</strong></td>
<td>81 mg</td>
<td>&quot;</td>
<td>325 mg</td>
<td>&quot;</td>
</tr>
<tr>
<td>Quantity</td>
<td>BID for 2 weeks (Disp #28)</td>
<td>&quot;</td>
<td>QD for 4 weeks (Disp #5 refill 1)</td>
<td>OD for 4 weeks (Disp #28)</td>
</tr>
<tr>
<td><strong>Zofran</strong></td>
<td>4 mg</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Quantity</td>
<td>Every 8 h(^d) (Disp #5 refill 1)</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

\(^{d}\) As needed for pain.
\(^{e}\) As needed for nausea.

\(\ast\) Please use this for all patients undergoing treatment with sports medicine attendings unless directed otherwise by the attending, or if a contraindication is identified for an individual patient.

*Minor procedures include debridement, non-implant procedures, minimal to no bone work, and implant removal.

*Major procedures include those that require use of implants.

\(^{\circ}\) As needed for nausea.
Periprosthetic Joint Infections: A Review

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ABSTRACT

Joint replacement procedures are considered some of the most successful surgical procedures in orthopaedics. An increased demand for these procedures is expected owing to an aging population and improved techniques. Despite the success of these procedures, the complications can be devastating, especially periprosthetic joint infections. Considerable effort has been applied toward enhancing the understanding of the prevention, diagnoses, and treatment of these infections. In 2018, an international consensus meeting convened to discuss the most relevant issues in periprosthetic joint infections and to provide consensus based on published studies. Additionally, the criteria for periprosthetic joint infection diagnosis have been updated. The purpose of this review was to highlight a few topics of interest. The collective body of research in periprosthetic joint infections is massive and evolving, and surgeons should be aware of developments in this area that may improve patient care.

Keywords: Periprosthetic Joint Infection, Arthroplasty, Hip and Knee

INTRODUCTION

In the United States, more than 1 million joint replacements are performed annually, including an estimate of 7 million Americans living with a hip or knee replacement. The incidence of infection after primary total knee and hip replacement is about 1% to 2%. The average annual cost for an infected total knee can exceed $100,000, nearly four times the cost of an uncomplicated average annual cost for an infected total knee and hip replacement is about 1% to 2%. The incidence of infection after primary total knee and hip replacement is about 1% to 2%. The average annual cost for an infected total knee can exceed $100,000, nearly four times the cost of an uncomplicated procedure. In 2009, the estimated cost to the United States healthcare system was $566 million, which is estimated to increase to $1.6 billion in several years. Infection can lead to loss of function, increase in number of surgical procedures and hospital stays, and prolonged antibiotic administration with subsequent side effects. The morbidity and mortality of patients who experience a periprosthetic joint infection can be severe. Mortality rates can be grim, with an average of 22% at 5 years. Treating periprosthetic joint infections is challenging because they can vary considerably in presentation. The infections are usually considered to be either acute or chronic. Acute infections are established postoperatively by either direct inoculation or through hematogenous seeding. Various pathogens can cause periprosthetic joint infections. The most common is Staphylococcus aureus but the pathogen Staphylococcus epidermidis often presents in indolent chronic infections. There is no perfect test for confirming periprosthetic joint infections, and low virulent bacteria may evade our most sensitive detection methods. We are frequently unable to secure a culture, which creates challenges in deciding appropriate treatment. Complete eradication has proven extremely difficult, and much of that difficulty is attributed to the resilience of biofilms. Biofilms are a complex environment composed of bacteria within their extra cellular matrix. This adherent biofilm matrix provides protective properties to the bacteria residing in a sessile state, which makes both detection and treatment difficult. Biofilm creates an intricate system that can evade our immune system and enhance resistance to antibiotics by more than 1000 fold. The magnitude of problems regarding musculoskeletal infections has invoked international efforts. In 2018, a group of more than 600 international and multidisciplinary experts convened in Philadelphia to review questions regarding musculoskeletal infection. The Second International Consensus Meeting on Musculoskeletal Infection aimed to provide consensus on important topics in orthopaedic infections. Parvizi et al recently redefined the diagnostic algorithm for periprosthetic joint infections. The attention on this topic is well deserved, but we have a long way to go. The purpose of this article is to examine a few topics regarding the prevention, diagnosis, and treatments of periprosthetic joint infections.

PREVENTION

Prevention is the first line of defense and most important step in addressing periprosthetic joint infections. Intense effort has been made to identify the host factors, especially modifiable factors that predispose patients to infections. Authors have proposed using scoring tools to help in the preoperative selection and optimization of patients. Obesity is prevalent in prospective patients, and this host factor can notably increase complications. In regards to infection, there appears to be a linear risk with obesity. Surgeons may select different body mass index (BMI, kg/m²) cutoffs; a common cutoff is 40 BMI. Patients with a BMI above this threshold have twice the risk.
Two positive cultures of the same organism

Sinus tract with evidence of communication to the joint or visualization of the prosthesis

Minor Criteria Score

- Elevated CRP or D-Dimer 2
- Elevated ESR 1
- Elevated synovial WBC count or LE 3
- Positive alpha-defensin 3
- Elevated synovial PMN (%) 2
- Elevated synovial CRP 1

Preoperative Score

- Preoperative score -
- Positive histology 3
- Positive purulence 3
- Single positive culture 2

Inconclusive pre-op score or dry tap

Score Decision

- ≥6 Infected
- 4-5 Inconclusive
- ≤3 Not Infected

Figure 1. New scoring based definition for periprosthetic joint infection. Proceed with caution in: adverse local tissue reaction, crystal deposition disease, slow growing organisms. CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; LE, leukocyte esterase; PMN, polymorphonuclear; WBC, white blood cell. The superscript “a” indicates it is for patients with inconclusive minor criteria, operative criteria can also be used to fulfill definition for periprosthetic joint infections. The superscript “b” indicates to consider further molecular diagnostics such as next-generation sequencing. Figure reprinted with permission from Elsevier from The Journal of Arthroplasty, Vol 33, Parvizi J, Tan TL, Goswami K, et al, The 2018 definition of periprosthetic hip and knee infection: an evidence-based and validated criteria, page 1312, 2018.

of developing deep infections. Bariatric surgical procedures can be highly effective in weight loss, but meta-analysis has not shown any considerable reduction in infections. It is theorized that persistent malnutrition may be largely accountable.

In addition to identifying host factors, other preoperative measures have shown promising results in reducing periprosthetic joint infections. Screening for decolonization protocols and methicillin-resistant Staphylococcus aureus (MRSA) carriers still appear to be controversial with no conclusive evidence about utility and cost-effectiveness. Although concerns arise, cleansing the entire body preoperatively appears to be effective, particularly with chlorhexidine. Using antibiotic cement in primary total joints continues to be controversial without conclusive evidence. In consideration of antibiotic stewardship, its use should likely be reserved for specific indications. One indication of the controversy is the split vote among delegates during the Second International Consensus Meeting on Musculoskeletal Infection. Preoperative systemic antibiotics is a mainstay and a recommendation by the American Academy of Orthopaedic Surgeons; however, novel antibiotic delivery techniques may prove to be more effective when delivering concentrations of antibiotics to the tissues at the surgical site. Chin et al showed that administration of intraosseous vancomycin after tourniquet inflation resulted in nearly ten times the tissue concentrations around the knee compared to systemic antibiotics. There is still no evidence to support topical vancomycin at wound closure in total joints. The evidence for its use is isolated to retrospective spine studies.

Operating time efficiency has been shown to decrease infection rates in several surgical fields, but suction tips may be an overlooked source of intraoperative contamination. Givissis et al found that 66% of suction tips had positive cultures after 1 h of operating room time, with the predominant bacteria being Staphylococcus aureus. It may be reasonable to change suction tips during prolonged surgical procedures and avoid leaving suction tips in surgical wounds owing to risk of air contaminants. A common risk factor for infections are allogeneic blood transfusions. Blood transfusions have an immunoprophylaxis effect, and a two-fold risk of infection has been observed after one unit of transfused red blood cells. Although no current research shows a
direct effect of tranexamic acid on infection reduction, its use has recently become widespread as a safe and cost-effective blood saving modality. In one randomized controlled trial (RCT) of total knee arthroplasties, use of intraarticular tranexamic acid resulted in a decreased blood transfusion rate of 16.7% to 1.3%.15

Studies have suggested that dilute betadine solution reduces infection during surgical wound closure. Brown et al16 reported a reduction in primary joint infections using a dilute 0.35% betadine wash for 3 min. Compared to saline, the rate of infection decreased from 0.97% to 0.15%. There are novel closure techniques in total joint arthroplasty (TJA) but still no concrete evidence to support one modality over others. A recent and large RCT that investigated antimicrobial sutures in total joint replacement showed no difference in surgical site infection rates.17 There is some support for occlusive silver impregnated dressings in several studies, including one prospective RCT that described silver dressings as an independent factor reducing periprosthetic joint infections.18

Finally, genetics is an uncommon host factor that may explain infections in apparently healthy individuals. It is suggested that some patients may have subclinical immune deficiencies. A massive population-based study (66,000 patients with TJA) has identified familial clustering of periprosthetic joint infections.19 Investigators identified pedigrees with excessive clustering of periprosthetic joint infections that did not seem attributable to other risk factors. Other investigations have also implied genetic susceptibility. For example, a study out of the Czech Republic found that variations of the innate immunity protein, mannose-binding lectin, is linked to susceptibility to periprosthetic joint infections.20

**DIAGNOSIS**

Unfortunately, there is no perfect test for diagnosing periprosthetic joint infections and this presents a challenge. For example, culture test results can return negative, findings of serological tests are not sensitive, and modern synovial assays have limitations and results can yield false-positives and false-negatives. In 2011, the Musculoskeletal Infection Society proposed criteria to define periprosthetic joint infections.21 The original Musculoskeletal Infection Society criteria were an important step in standardizing the definition and eliminating subjectivity in diagnosing periprosthetic joint infections. In the 2013 Initial International Consensus Meeting, these criteria were revised and recently updated again by Parvizi et al22 in 2018. The new definition includes some novel markers such as synovial alpha defensin and synovial C-reactive protein (CRP). The scoring system is now weighted, and its design makes it easier to achieve preoperative diagnosis. When validated against an external cohort of patients, the new criteria exhibited improved results compared to original Musculoskeletal Infection Society criteria with a sensitivity of 97.7% and specificity of 99.5%.

Another indicator of periprosthetic joint infections is alpha defensin, an antimicrobial peptide generated by neutrophils. Alpha defensin may be the most accurate test for detecting periprosthetic joint infections; however, caution must be used in certain settings. Alpha defensin is not indicated in the early postoperative period and may yield false-positive results for metallosis. When diagnosing periprosthetic joint infections, Stone et al23 proposed an algorithm that used synovial CRP in combination with alpha defensin to reduce false-positive and false-negative rates.

Obtaining cultures is ideal in treating periprosthetic joint infections because it allows guidance on treatment protocols and the ability to target antibiotics. Despite best practices, negative culture results are common. Notably, obtaining multiple tissue samples can improve sensitivity of growing a pathogen. Synovial fluid should also be obtained when possible and blood culture vials may further enhance sensitivity.24 It has been shown that culture swabs have high false-positive rates. If implants are removed, sonication can improve sensitivity of cultures from 60% to 80%.24 It is suggested to incubate cultures for longer times if low virulent pathogens are suspected; additionally, repeating aspiration and culture tests is suggested if initial culture findings are negative.25

Despite our best culturing techniques, many culture findings are negative for infection, which presents a treatment dilemma. A novel application of genetic sequencing may find a larger role in diagnosing periprosthetic joint infections.26 Compared to traditional sequencing techniques, next-generation sequencing is a technology with reduced time and costs. Next-generation sequencing expands on prior polymerase chain reaction sequencing techniques. This allows DNA to be extracted from samples and sequenced in automated fashion to identify present pathogens. Furthermore, next-generation sequencing provides the ability to identify antibiotic resistance genes and has the potential to obtain results faster than cultures and detect pathogens in recent antibiotic administration. However, this technology is still in its infancy, and these techniques have shown to be extremely sensitive at detecting bacterial DNA—even to the point of detecting bacterial DNA in synovial fluid of native joints.27 These investigations may bring to light the concept of host colonization versus true infection.

**TREATMENT**

The initial treatment decision for periprosthetic joint infections is usually between implant retention or implant exchange, either one-stage or two-stage. Debridement, antibiotics, and implant retention (DAIR) can be successful in some situations. Important prognostic factors for successful DAIR include host factors, timing of operative treatment, pathogen involvement, exchanging modular components, aggressive debridement, and appropriate use of antibiotics.
Several factors make DAIR appealing, including reduced surgical morbidity to the patient and reduced cost of treatment if successful. Reported success rates for DAIR vary but are generally less successful than a full-component explant technique. To enhance biofilm eradication, different antiseptics as adjuncts to mechanical debridement have been investigated. Antiseptics have advantages of reaching areas of the joint that are difficult to mechanically debride. In the era of antibiotic resistance, they may prove to be a useful addition. Chlorhexidine, betadine, hydrogen peroxide, detergents, acetic acid, and even honey have been discussed in combatting biofilms; additionally, some of these have been used in vitro experiments and have shown chlorhexidine to be effective in biofilm eradication. Proprietary solutions have recently become available and are purported to be effective in disrupting the extracellular matrix of biofilms. In vitro studies have recorded the ability of proprietary solutions to reduce biofilms; however, clinical trials are still pending.

Two-stage exchange of periprosthetic joint infections has reported some of the highest success rates and remains the gold standard in the United States. On the other hand, one-stage exchange is an attractive option and has been shown to be effective in certain situations. The appeal of a one-stage exchange is quicker recovery, better functional outcomes, less surgical-related morbidity, and decreased hospital stays and costs. However, patient selection is critical and the ideal candidates are healthy with an identified non-resistant organism. Currently, no RCT directly compares one-stage to two-stage exchange. However, when the techniques were used on total knees, a meta-analysis found similar recurrence rates of infection at 2 years. Unfortunately, failure rates remain high regardless of treatment. Ford et al recently reported a reinfection rate of 27% in two-stage exchange patients who underwent re-implantation. Sadly, many patients never obtain a successful re-implantation and end up deceased, living with a spacer, or undergoing salvage procedures such as arthrodesis or amputation.

Other approaches to treating periprosthetic joint infections have been described. Whiteside et al used intraarticular antibiotic infusions in a cohort of 18 patients with MRSA prosthetic joint infections. For 6 weeks postoperatively, all 18 patients received intraarticular catheter infusions of vancomycin without the addition of systemic antibiotics. Seventeen patients were infection-free at the minimum follow-up of 27 months.

Immunoprophylaxis are vaccines that may enhance the ability of our immune system to combat bacteria. These are currently being investigated in treating periprosthetic joint infections. Bacteria that are multidrug resistant are effectively threatening the era of antibiotics. Pneumococcal vaccines have been shown to prevent meningitis from cochlear implant-associated infections. A novel Staphylococcus aureus vaccine is currently under study. The purported advantage of this vaccine is that it targets virulent factors involved in the establishment of infection. This multi-antigen staph vaccine has been shown to induce an immune response in a stage 1 clinical trial. There is now a stage 2 clinical trial underway that is investigating the vaccines’ ability to prevent infection in patients undergoing spine procedures. Additionally, studies are currently examining another pathway that disrupts biofilms: the utilization of biologic compounds to disrupt bacterial communication. These are known as quorum-sensing inhibitors, and these agents may be a last line of defense in the face of antibiotic resistance.

**CONCLUSION**

Periprosthetic joint infections present a complex challenge to our society. We are bound to see more infections with the increasing number of joint replacement procedures, which leads to staggering patient morbidity, patient mortality, and costs to our healthcare system. We continue to evolve our understanding of these infections; however, bacteria are evolving as well and antibiotic resistance is concerning. New approaches in prevention, diagnosis, and treatment of these infections will hopefully improve our ability to minimize these devastating complications.

**REFERENCES**


Biomechanical Strength and Bulk Comparisons Between the Open-Book Technique and the Pulvertaft Method for Peroneal Tendon Transfer: A Pilot Study

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ABSTRACT

Background: The Pulvertaft method has classically been used for the transfer of various tendon injuries owing to its biomechanical strength; however, this method has been shown to be bulky. We describe the open-book technique, which can offer comparable structural integrity with a decreased bulk. The purpose of this study was to determine whether the open-book technique is biomechanically equivalent to the Pulvertaft method for treating peroneal tendon injuries.

Methods: We evaluated five pairs of human cadaveric ankles. Within each pair, one specimen was randomly assigned to either the Pulvertaft or the open-book group. Using sharp dissection, the tendons were severed in a standardized method. Transfer was performed using one of the two randomly assigned techniques. The transferred peroneal tendons were stressed on a mechanical tensioning device until failure. Data were recorded and analysis was performed.

Results: There was a statistically significant difference ($P < 0.001$) between the thickness of the Pulvertaft method (7.6 mm) and open-book technique (5.7 mm). There was also a statistically significant difference in elongation, with the Pulvertaft undergoing more elongation at yield (9.7 mm vs 3.7 mm, respectively; $P = 0.04$). No statistical difference was detected in elongation at peak ($P = 0.52$), load at yield ($P = 0.9$), or peak load ($P = 0.69$).

Conclusions: The open-book technique appears to be a viable biomechanical alternative to the Pulvertaft method for peroneal tendon transfer. The peak load, load at yield, and elongation at peak were biomechanically equivalent. The open-book technique was found to provide a significant decrease in thickness, which could prove advantageous when dealing with anatomical locations.

Keywords: Tendon Transfer, Peroneal Tendons, Pulvertaft, Open-Book

INTRODUCTION

Surgically incised or ruptured peroneal tendons are commonly treated with operative transfer. For about 50 years, the Pulvertaft method has been a classic transfer technique that involves weaving the tendons inside one another and then suturing these weaves in place. Although this method results in a biomechanically stable junction, the woven tendons can be quite thick and bulky. The added bulk of the transfer is often volumetrically problematic when used in an anatomical location with a limited soft-tissue envelope.

Multiple tendon transfer techniques have been described, including double loop, lasso tendon transfers, loop tendon methods, side-to-side, and the spiral linking technique. When results of failure and ultimate load tests were evaluated, most transfer techniques provided equivalent or increased biomechanical strength. However, the volumetric bulkiness of the transfer footprint remained a concern. Another potential alternative method, called the open-book technique, involves the splicing and inlay of one tendon inside of the other with a locked running suture securing the transfer. This results in a transfer with an
end product that is more anatomically sized (Mckee DM, unpublished data, October 2018).

A recent study suggested that when applied to the extensor tendons of the hand, the open-book technique provides equivalent biomechanical strength while also decreasing the size burden of the transfer. To our knowledge, no study has specifically examined the different transfer techniques for peroneal tendons. This investigation sought to determine if these findings would hold true when applied to the peroneal tendons in the lower extremities.

METHODS
Five pairs of human cadaveric ankles and feet were used. Each cadaveric specimen was handled, stored, and disposed of in accordance with the guidelines and regulations of the Texas Tech University Health Sciences Center, which were set forth by the State Anatomical Board. Before dissection, inspection was performed to ensure equal tissue quality within pairs and absence of previous injury to the peroneal tendons.

To help minimize confounding variables, we chose to use a matched pair design for our study. For each pair of cadavers, one extremity was randomly assigned to either the Pulvertaft or open-book group. Randomization was performed using an Excel spreadsheet (Microsoft, Redmond, WA).

Careful dissection of the specimens was performed, taking care to identify the peroneal tendons including their musculotendinous junction and bony attachments. To control for the amount of tendon used in the transfer, we determined a location for our transection to be 2.5 cm proximal to the distal tip of the lateral malleolus. This location was identified and marked on each specimen. Volumetric data were recorded for each tendon. The tendons were transected, and the transfer was performed using the randomly predetermined technique.

For the Pulvertaft group, the weave consisted of three passes of the peroneus longus through the peroneus brevis performed over the 2.5 cm area (Figure 1). Each pass was secured in place on either side with a 3-0 Ethibond horizontal mattress suture (Ethicon, Somerville, NJ).

The open-book technique was performed in the same 2.5-cm area. The peroneus brevis was opened longitudinally without violating the posterior aspect of the tendon. The peroneus longus was then inlayed into the 2.5-cm opening. The tendon flaps of the peroneus brevis were then closed over the peroneus longus and secured in place with a running, locking, 3-0 Ethibond, Krackow suture (Figure 2). Before healing, it was hypothesized that a major component of the strength being tested was the result of suturing. To help account for this hypothesis, the same suture was used for both groups.

After the transfer, each tendon set was harvested from its cadaver. This removed any remaining soft tissue from the musculotendinous junction. Next, the transferred tendons were measured, ensuring that there was sufficient tendon (about 5 cm) proximally and distally to the transfer site. This allowed the testing device to attach to the tendon. The tendon size could vary from one cadaver to the next, which usually depended on the location that was being tested. To help control for this variability, all tendons were harvested at the same predetermined location. Additionally, to help account for the differences due to general body habitus, we randomized the cadavers to have one limb in each group.

After completing the harvest, the transferred tendons were fixed into sigmoid-shaped clamps covered in coarse grit sandpaper to prevent slippage. These clamps were then inserted into a Materials Testing System servohydraulic activator for stress analysis (Insight 10 kN, MTS Inc, Eden Prairie, MN). For conformity, the peroneus longus was inserted into the superior clamp and the peroneus brevis was inserted into the inferior clamp (Figure 3). The amount of visible...
Table 1. Comparison of thickness and biomechanical strength values between the Pulvertaft method and open-book technique used for tendon transfer

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pulvertaft mean (SD)</th>
<th>Open-Book mean (SD)</th>
<th>P valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peroneal longus thickness (mm)</td>
<td>3.1 (0.626)</td>
<td>2.9 (0.489)</td>
<td>0.66</td>
</tr>
<tr>
<td>Peroneal brevis thickness (mm)</td>
<td>2.4 (0.33)</td>
<td>2.2 (0.401)</td>
<td>0.43</td>
</tr>
<tr>
<td>Pulvertaft weave thickness (mm)</td>
<td>7.6 (0.941)</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>Open-book thickness (mm)</td>
<td>5.7 (0.825)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation at peak (mm)</td>
<td>16.3 (9.49)</td>
<td>12.5 (5.89)</td>
<td>0.52</td>
</tr>
<tr>
<td>Elongation at yield (mm)</td>
<td>9.7 (4.61)</td>
<td>3.7 (1.89)</td>
<td>0.04</td>
</tr>
<tr>
<td>Load at yield (N)</td>
<td>139.6 (92.81)</td>
<td>93.4 (46.60)</td>
<td>0.9</td>
</tr>
<tr>
<td>Peak load (N)</td>
<td>167.8 (88.18)</td>
<td>168.3 (70.31)</td>
<td>0.69</td>
</tr>
<tr>
<td>Strain at yield</td>
<td>0.19 (0.09)</td>
<td>0.15 (0.19)</td>
<td>0.69</td>
</tr>
</tbody>
</table>

SD, standard deviation.
aP value calculated using student t test.

The baseline for testing was in a resting position with no pretension force applied. We then used TestWorks 4 software (MTS Systems Corporation, Eden Prairie, MN), zeroed all force and position monitors, and initiated the sequence. The rate-of-pull was constant at 0.5 mm per second until failure was detected by the Materials Testing System. All the data were recorded and the analysis was then performed using SPSS Statistics 22.0 (IBM, Armonk, NY). To help facilitate data analysis, a student t test was performed. Differences were considered to be statistically significant between groups when P was less than 0.05. In this study, we were most interested in the peak load because it represented the maximum force that each method was able to sustain before failure.

RESULTS

As seen in Table 1, no statistical differences were detected between the open-book technique and Pulvertaft method regarding elongation at peak (P = 0.52), load at yield (P = 0.9), and peak load (P = 0.69). Statistical significance was noted when comparing the average thickness of the Pulvertaft weave of 7.6 mm to the open-book transfer of 5.7 mm (P < 0.001), and when the Pulvertaft group underwent additional elongation at yield (9.7 mm versus 3.7 mm, P = 0.04). These results suggest that use of the open-book technique would provide greater strength while maintaining a smaller anatomical footprint. It should be noted that the mode of failure for all specimens was at the suture-tendon junction.

DISCUSSION

When managing peroneal tendon transfers, we found that the open-book method appears to be a feasible alternative to the classically used Pulvertaft method. The open-book technique was biomechanically equivalent to the Pulvertaft method in peak load, load at yield, and elongation at peak. Because these results suggest biomechanical equivalence, we feel that the open-book technique is a suitable alternative.

The main difference between the two options is the bulk of the transfer. The bulky nature of the Pulvertaft transfer can lead to complications with tendon gliding. This can result in discomfort that could be avoided with a more anatomical transfer technique. In contrast, animal studies on the open-book technique9 have shown that the length of transfer does not change the strength or stiffness of the transfer. However, the Pulvertaft method gains significant strength after a fourth weave, requiring more tendon length that contributes to increased bulk.7,9

In our analysis, the open-book technique was found to have a significant decrease in thickness compared to that of the Pulvertaft method. This decreased bulk provides a more anatomical transfer that may prove advantageous when dealing with an anatomic location known for having fewer soft-tissue envelopes. Notably, research on the open-book technique has focused only on the flexor and extensor tendons of the hand. Thus, to our knowledge, the current study is the first to assess the equivalence and volumetric aspects between the Pulvertaft method and open-book technique for managing peroneal tendon transfer.

Despite the promising results, the current study has limitations. The first limitation is the number of transfers performed. Our analysis consisted of only five pairs of tendons, which is likely too underpowered to determine significance; subsequently, the results should be considered with caution owing to the low sample size. The second limitation is that we did not evaluate the healing and ultimate consolidation of the transferred tendon. It could be hypothesized that the healing process would alter the biomechanical integrity of the transfer.

Overall, the findings of the current study showed equivocal biomechanical strength between the Pulvertaft method and open-book technique when used...
for managing peroneal tendons. Additionally, we found a reduced bulkiness associated with the open-book technique. A future line of study could use an animal model to compare the two transfer techniques in regard to healing and ultimate integration of the transfers.

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Complete Great Toe Sesamoid Excision: A Case Series

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ABSTRACT

Background: Hallux sesamoids notably contribute to the biomechanics of the great toe. Although frequently ignored or forgotten, injury to the hallux sesamoids can be debilitating. Conservative management remains the initial approach for symptomatic sesamoid disorders, but surgical excision is an option. We performed a retrospective case series to examine the preoperative characteristics and postsurgical outcomes of patients who underwent great toe sesamoidectomy.

Methods: We reviewed medical records of patients who underwent great toe sesamoidectomy performed by a single surgeon (RAM) during a 10-year period (26 patients, 28 procedures). Data collected included smoking status, prior first ray surgical treatment, high-level athlete participation, diagnosis, preoperative treatment, length of time from symptoms to treatment, and visual analogue scale (VAS) pain score at final follow-up.

Results: The average length of symptoms before operative treatment was about 3 years. Pain at final postoperative visit averaged 1.35 (range, 0-7), with 23 of 26 patients rating pain 0 to 3 measured on a 10-point VAS. Additionally, eight of the nine patients in high-level athletics returned to sports. There were no surgical site infections or wound complications. Two patients with underlying nerve disorders required procedures for treating late-appearing cock-up deformities and great toe metatarsophalangeal pain.

Conclusions: The complete excision of the great toe sesamoid should be judiciously considered for recalcitrant pain attributable to the hallux sesamoids.

Keywords: Great Toe Sesamoid, Hallux Sesamoid, Sesamoid Excision, Sesamoidectomy, Forefoot

INTRODUCTION

The hallux sesamoids are every bit as interesting as their word origin. Roman grammarian, Sextus Pompeius Festus, reasonably claimed the great toe derived its Latin name “allus” from the Greek verb “αλλομαι”: “I spring, leap.” Anatomically, the sesamoid complex is centered over the plantar aspect of the metatarsophalangeal (MTP) joint of the great toe. The larger tibial sesamoid rests within the medial head of the flexor hallucis brevis (FHB), whereas the smaller fibular sesamoid rests within the lateral head of the FHB. Each tendon inserts into the base of the proximal phalanx, forming part of the plantar plate. Cartilage covers the dorsal facets of the sesamoids and articulates with the plantar aspect of the first metatarsal head. The strong intersesamoid ligament connects the two sesamoids, whereas the flexor hallucis longus tendon runs between them. Tendons from the abductor hallucis medially and adductor hallucis laterally also have fibrous insertions into the sesamoids. The lateral sesamoid additionally attaches to the deep transverse ligament.

These two seed-shaped sesamoid bones vitally contribute to the hallux MTP joint complex. Their functions include transmitting body weight, decreasing friction, powering plantar flexion of the hallux by increasing the moment arm of the FHB, cushioning the first MTP joint, and protecting the FHB tendons. Owing to considerable mechanical stresses and anatomical variations, the sesamoid complex can be involved in numerous pathological processes. Acute fractures, stress fractures, nonunions, osteonecrosis, chondromalacia, and various inflammatory conditions called sesamoiditis can disrupt the function of the hallux MTP joint complex. The hallucal sesamoid complex is involved in 4% of foot and ankle injuries and in 1.2% of running injuries. The medial sesamoid is larger than the lateral sesamoid, more commonly injured, and receives a greater weight-bearing load.

Conservative management remains the initial approach for treating symptomatic sesamoid disorders. If nonoperative treatment is unsuccessful, surgical procedures can be considered. The continuum of operative intervention includes sesamoid-preserving procedures, such as partial shaving to complete sesamoidectomy. During the last decade, the senior operating surgeon (RAM) has performed 28
complete sesamoidectomy procedures for treating 26 patients. We describe a retrospective case series that investigated preoperative characteristics and postoperative outcomes of these patients.

**METHODS**

After obtaining approval from our Human Research Review Committee (#18-379), we reviewed medical records and radiographs of all patients who underwent complete sesamoid excision from a single surgeon (RAM). In total, 26 patients were treated (21 female, 5 male) and 28 procedures were performed. The mean age of patients at surgical treatment was 44 years (range, 16-70 years). Particular note was made regarding diagnosis, preoperative treatment, length of time from symptoms to surgical treatment, and visual analogue scale (VAS) pain score at final follow-up. VAS pain scores were stratified by mild (score, 0-3), and moderate to severe (score, 4-10). Patient characteristics were noted such as smoking, prior first ray procedure, and high-level athletic participation. There were preoperative and intraoperative modalities frequently used to assess patients (Figures 1A through 1D).

Regarding surgical technique, the medial sesamoid was excised from a medial longitudinal incision made just plantar to the midline. The plantar-medial digital nerve was retracted inferiorly, and the fascia overlying the sesamoid was incised and elevated circumferentially off the sesamoid to remove the bone. The incision in the fascia was closed with vicryl suture, and the skin was closed with nylon suture. No separate effort was made to reattach the FHB tendon. The lateral sesamoid was removed through a curvilinear plantar incision. After spreading the soft tissues to the fascia overlying the lateral sesamoid, the fascia was removed by incision and elevated off the sesamoid.

Postoperatively, partial weight bearing was advised until the sutures were removed, typically at the 2-week visit. Patients were then advised to progressively increase their weight bearing in a protective sandal for 2 weeks. At 1 month postoperatively, patients returned to using shoes and performing unrestricted weight-bearing activities.

**RESULTS**

Of the 28 procedures, a total of 26 involved an isolated medial sesamoidectomy. The other two involved an isolated lateral sesamoidectomy and a bilateral sesamoidectomy. The average time to the last follow-up was 4.9 months (range, 0.6-22.7 months). The average VAS pain score at the last postoperative follow-up was 1.35 of 10 (range, 0-7). There were six active smokers

![Figure 1. A 29-year-old woman with pain due to medial sesamoid, showing (A, B, C) preoperative and (D) intraoperative imaging during post-sesamoid excision. A) Anteroposterior view of the foot. B) Sesamoid view shows medial sesamoid changes. C) Coronal magnetic resonance imaging with altered proton density signal in medial sesamoid. D) Intraoperative fluoroscopic image shows excision of the medial sesamoid.](image-url)
during the time of the surgical treatment. At the last follow-up, there was no significant difference in VAS pain score between smokers and nonsmokers ($P = 0.294$).

The average time between initial pain symptoms to surgical treatment was 35.17 months. At final follow-up, patients with mild VAS pain scores ($n = 20$) had a mean of 23.3 months of pain before surgical treatment. This was significantly different ($P = 0.0357$) than patients with moderate to severe VAS pain scores ($n = 4$), who had a mean of 94.3 months of pain before surgical treatment. Two patients underwent previous surgical management, and the duration of their symptoms before undergoing sesamoidectomy was unknown.

Of the 26 patients, a total of 23 had undergone preoperative treatment. Two underwent surgical procedures (ie, great toe MTP fusion and bunion correction) and 21 underwent trials of nonoperative management (ie, physical therapy, cast boot, hardened shoe, padding, nonsteroidal anti-inflammatory drugs, and ultrasounds). Comparing postoperative VAS pain scores between patients treated operatively and nonoperatively before the procedure yielded no significant difference ($P = 0.827$).

Regarding return to sports, nine patients were potentially able to return to higher-level athletics. One patient, a professional football player, underwent two separate complete medial sesamoidectomy procedures. The remaining eight returned to sports such as collegiate basketball, cross-country running, dance, and professional football. Of the eight, one patient who previously ran marathons returned to an unspecified sport. There was no significant difference in VAS pain scores between patients that had potential return to sport versus the remaining 18 ($P = 0.399$).

Postoperative complications caused by the sesamoidectomy were not noted in any patient. There were no surgical site infections or wound complications. No patient developed hallux valgus or varus deformity. A 55-year-old woman developed great toe cock-up deformity at 5 months after her procedure and underwent revision surgery. Notably, preoperatively, the woman had preexisting tethered cord, foot drop, and a nonunion great toe interphalangeal fusion. A 48-year-old woman with underlying polio, varus foot deformity, and preexisting extension deformity of all five toes underwent simultaneous complete great toe medial and lateral sesamoidectomy, and extensor tenotomies to all digits. She self-reported “minimal” pain at her 30-day follow-up; but 20 months after the sesamoidectomy, she developed MTP pain and subsequently underwent MTP fusion.

**DISCUSSION**

Although sesamoid injuries account for a minority of foot and ankle concerns, they can be considerably bothersome to patients. Sesamoid injuries include stress fractures, traumatic fractures, nonunions, and numerous inflammatory pathological features. Nonsurgical management continues to be the primary method for treating complex sesamoid injuries, with surgical intervention in refractory cases.

Before the mid-1980s, excision was the main surgical procedure for treating sesamoid injuries. Recently, numerous surgical options have emerged to treat the sesamoid complex such as curettage and grafting, shaving of the plantar surface of the sesamoid, open reduction and internal fixation using screws, and percutaneous internal fixation. Yet, other authors continue to advocate for complete excision of the sesamoid as the primary surgical intervention.

We contend that complete sesamoid excision may be a viable and beneficial surgical option for patients with sesamoid injuries refractory to extensive nonoperative management. In the current study, our 26 patients reported an average of 3 years of persistent pain before undergoing sesamoidectomy. After undergoing the procedure, 23 patients (88%) reported mild levels of pain (VAS score, 0-3), which is promising.

As with any surgical procedure, sesamoid excision may result in complications. Hallux varus and valgus misalignment can result from lateral and medial sesamoid excision, respectively. Cock-up and claw deformities can also result from excision of both sesamoid bones. Other reported complications include stiffness, wound dehiscence, surgical site infection, scar pain, transfer metatarsalgia, and nerve injury (particularly the plantar digital nerve). To mitigate these risks, it is essential to incorporate a meticulous surgical technique and proper repair of the soft tissues. It is important to maintain the integrity of the plantar plate and avoid combined tibial and fibular sesamoid excision to decrease possible complications. In the current study, no clear complications resulted due to sesamoidectomy. If we include the two patients who underwent revision procedures (ie, great toe MTP and interphalangeal fusion), the complication rate remains low at 2 of 28 procedures (7.1%).

Although complications are possible, single sesamoid excision does not appear to alter the mechanics of the FHB, to which the sesamoids provide a mechanical advantage. Aper et al showed that removal of the entire medial sesamoid has minimal effect on the FHB moment arm, yet removal of both sesamoids resulted in a one-third drop in great toe plantarflexion. This finding supports high return to activity in active and non-active individuals alike. The following studies have subsequently reported high percentages of patients who returned to preoperative levels of activity in daily living and leisure: Saxena and Krisdakumtorn showed 83%, Bichara et al showed 92%, and Lee et al showed 90%. Biedert and Hintermann found that four of five patients (80%) returned to sports completely, with the last patient having mild limitation. The current study reinforces these outcomes, with eight of nine patients (89%) returning to high-level athletic activities.
(ie, professional football, collegiate basketball, cross-country running, and dance).

The current study has several limitations. First, this case series describes outcomes of patients undergoing only sesamoidectomy; as such, there is no comparison of one treatment with another. Furthermore, the study is retrospective and therefore a direct and prospective comparison cannot be completed. Additionally, there is a wide range in the comparison of preoperative pain as well as time to follow-up, which may have skewed the reported averages.

Complete sesamoid excision may be a viable and beneficial surgical option for treating sesamoid injuries in patients with unsuccessful nonoperative management. Postoperative outcomes can include substantial pain relief and return to preoperative levels of physical activity, even with professional sports. Although present, risks of the surgical procedure can be minimal when meticulous surgical technique is employed.

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Comparison of Joint Compression and Pull-Out Strength of 6.5-mm Self-Drilling Screws With Headed and Headless in Subtalar Arthrodesis: A Pilot Study

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Conflict of Interest Jerry Grimes, MD receives research grant funding for an unrelated multicenter trial sponsored by Ferring Pharmaceuticals. The other authors report no conflicts of interest.

ABSTRACT

Background: In patients with degenerative osteoarthritis of the subtalar joint, surgical treatment can include subtalar arthrodesis. Notably, mechanical factors such as compression and pull-out strength contribute to successful union, which can be achieved through use of headed or headless cannulate screws. The purpose of this study was to compare the resultant joint compressive force and pull-out strength between use of a headless 6.5-mm self-drilling cannulated compression screw and a more traditional headed 6.5-mm self-drilling cannulated compression screw.

Methods: This study used the calcaneus and talus from six paired fresh frozen specimens. The soft tissues were stripped and the joint was separated. FujiFilm Prescale Compression Paper (Minato, Tokyo, Japan) was placed in the subtalar joint, and both the talus and calcaneus were fixed with either traditional headed or a headless cannulated screw. Pull-out strength was measured by fixing the fused subtalar joints to a servohydraulic activator and measuring peak load at failure in distraction. Imaging analysis of the compression paper determined peak compression across the joint.

Results: The resultant joint compressive force and pull-out strength were not statistically different between use of headed and headless cannulated compression screws (P = 0.30 and P = 0.67, respectively).

Conclusions: In a small sample, use of headless cannulated compression screws offered equivalent joint compression as that of a headed screw in subtalar arthrodesis and showed equivalent resistance to pull-out force.

Keywords: Subtalar Joint, Arthrodesis, Subtalar Fusion, Headless Compression Screw, Pull-Out Strength

INTRODUCTION

Degenerative osteoarthritis of the subtalar joint is a common chief concern. A few pathologies that can ultimately result in end-stage osteoarthritis of the subtalar joint are posttraumatic and inflammatory arthritis, Charcot arthropathy, pes planus due to posterior tibial tendon insufficiency, and talocalcaneal coalition.1 After exhausting nonoperative measures, treatment can include a subtalar arthrodesis, an accepted technique for obtaining a successful fusion that utilizes compression screws across the subtalar joint.2 Various methods for screw type, orientation, and quantity have been studied and reported.2,3 Compression and pull-out strength are two important mechanical factors that contribute to successful union of the arthrodesis. These studies have led to the use of large cancellous screws inserted in one of two orientations: dorsal to plantar or plantar to dorsal.4 Regardless of the approach, the heads of these large screws have the potential to impinge on surrounding soft tissues. This can cause symptoms related to hardware and the potential need for a revision procedure.5 Rates of hardware removal are reported to range from 7% to as high as 12%.6

In contrast, the original headless compression screws were designed to be used with small bones (eg, those in the carpus and forefoot) in which k-wire fixation was too unstable.7 Because of enhancements in the design, indications for use of headless cannulated compression screws have expanded. The headless nature of the
screw allows it to be completely buried beneath the surface of the bone without use of counter sink, thus avoiding the problem of impingement to surrounding soft tissues. To our knowledge, no study has directly compared joint compression and pull-out strength between use of the 6.5-mm headless cannulated compression screw to the standard 6.5 mm headed cannulated compression screw across the subtalar joint (Figure 1).

METHODS

Cadaveric Specimens

We obtained six matched pairs of frozen cadaveric feet and stored them at -18° C. The sex and cause of death of each cadaveric specimen were unknown. At 24 hours before harvesting, we thawed the cadaveric specimen at room temperature (ie, 21° C). We then dissected and stripped the skin, muscle, tendons, and ligamentous attachments across 12 subtalar joints. Using an Excel randomization model, we randomly assigned the type of screw (ie, headed or headless) to the right versus left ankle of each cadaver. After assignment, we prepared each specimen for arthrodesis and the measurement of the experiments two major data points: compression and pull-out strength.

Measurement of Compression

With a starting point posterior to the origin of the plantar fascia, a 5.0-mm drill was used antegrade and perpendicularly across the subtalar joint. After completing the tunnel, a depth gauge was used to measure for the length of screw needed for arthrodesis. We sized the screws to ensure that the threads crossed the joint line yet did not engage the dorsal cortex. The screw lengths ranged from 75 mm (smallest) to 95 mm (largest).

Before final tightening of the screw across the joint, two pieces of compression paper (Fujifilm Ultra Super Low Pressure) were introduced between the talus and calcaneus on each side of the joint (Fujifilm, Minato, Tokyo, Japan). This was completed by ensuring that the joint compression pressure could be visually quantified and recorded for computer analysis. The compression paper was secured between clear and adhesive tegaderm. This was done to ensure that the paper would remain dry and not affect the results.

The joint compression pressure between the surfaces of the posterior facet was recorded as pigmented areas on the film. We loosened the screw by one-half turn to withdraw the paper and retighten the screw. The compression paper was then scanned and uploaded into ImageJ software. We compared the peak saturation of the film’s pigmented areas to the temperature-adjusted standards provided by the manufacturer.

Measurement of Pull-Out Strength

After obtaining final fixation across each joint, we placed two to three additional flathead screws in the talus and calcaneus making sure to avoid trajectory of the compression screw. This was done to improve adherence of polymethyl methacrylate (PMMA) bone cement to the surface of the calcaneus and talus. The specimens were potted in polyvinyl chloride (commonly known as PVC) plastic piping cups, with a single bolt and accompanying washer out the bottom to attach to our servohydraulic loading device, the Materials Testing System (MTS, Figure 2). Care was taken to ensure that PMMA did not cross the subtalar joint or cover the head of the compression screw.

The MTS was used to apply uniform tension to the subtalar joints fixed by compression screws (Insight 10 kN, MTS Systems Corporation, Eden Prairie, MN). The mounting screws were secured tightly between the MTS tension plates. The joints were loaded so that the talus was superior to the calcaneus and the distraction force would pull perpendicular to the subtalar joint line. Once mounted into the MTS, we zeroed both the forceplates and position monitors and then initiated the testing sequence into TestWorks 4 software. The subtalar joints were pulled at a constant rate of 1.0 until the MTS detected failure. No pretension was applied to the subtalar joints.

Peak load (N) was the dependent variable of primary interest. It represented the amount of load that each subtalar joint (which were fixed by an arthrodesis screw) was able to withstand during tension testing. For the purpose of this study, peak load was considered the pull-out strength of the construct. Additional
Table 1. Comparison of measured variables between 6.5-mm headed screws and 6.5-mm headless screws used in six matched pairs of frozen cadaveric feet

<table>
<thead>
<tr>
<th>Variable</th>
<th>Headed screws mean (SD)</th>
<th>Headless screws mean (SD)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (mm)</td>
<td>85 (6.93)</td>
<td>83.3 (4.85)</td>
<td>0.74</td>
</tr>
<tr>
<td>Elongation at peak (mm)</td>
<td>6.91 (1.88)</td>
<td>10.01 (8.27)</td>
<td>0.83</td>
</tr>
<tr>
<td>Elongation at yield (mm)</td>
<td>1.73 (0.90)</td>
<td>3.23 (2.36)</td>
<td>0.39</td>
</tr>
<tr>
<td>Load at yield (N)</td>
<td>348.78 (237.46)</td>
<td>426.24 (142.4)</td>
<td>0.67</td>
</tr>
<tr>
<td>Peak load (N)</td>
<td>637.13 (362.84)</td>
<td>774.94 (188.64)</td>
<td>0.67</td>
</tr>
<tr>
<td>Strain at yield</td>
<td>0.03 (0.02)</td>
<td>0.06 (0.05)</td>
<td>0.39</td>
</tr>
</tbody>
</table>

SD, standard deviation.
*Values were obtained from the Mann-Whitney U test.

RESULTS
The average peak compression for the headless screw specimens was 0.58 MPa (range, 0.55 - 0.60 MPa, SD 0.02), which was greater than the average peak compression obtained in the headed screw specimens with an average of 0.57 MPa (range 0.54 - 0.59 MPa, SD 0.03). This value, however, did not reach statistical significance with a P value of 0.31.

Comparison of Pull-out Strength
We compared the specimen between headless and headed matched pairs in terms of their elongation at peak, elongation at yield, load at yield, peak load, and strain at yield. The average peak load for the headless group was 774.94 N, which was greater than the average peak load of 637.13 N for the headed screws (Table 1). With a P value of 0.67, there was no statistical difference between the groups.

DISCUSSION
An established method for subtalar arthrodesis is fixation using cannulated screws that are large and headed. Several studies have compared compression across the subtalar joint with different screw positions, number of screws used, and compression staples. In 2016, Matsumoto et al compared compression across the subtalar joint using a two and a three headless compression screw construct. To our knowledge, no study has compared the compression and pull-out strengths of headed cannulated screws to that of headless cannulated compression screws. Our study, however, shows that headless compression screws may produce equivalent peak compression across the subtalar joint. It also shows that when compared to headed screws in a cadaveric model, headless compression screws may have equivalent pull-out forces.

Headed cannulated screws are common constructs used to treat subtalar arthrodesis; however, screws can create a prominence that irritate local tissues because the screw heads rest outside of the bone. By reducing prominence of hardware, the advent of cannulated headless compression screws can help reduce the incidence of symptomatic hardware. Headless compression screws have equivalent compression and are therefore a reasonable option for fixation of a subtalar arthrodesis. Additionally, headless compression screws may potentially reduce the incidence of symptomatic hardware.

Another important measure is pull-out strength because it shows a construct’s resistance to failure when subject to a load. Between the headless screw and headed screw, our experiment shows no difference in “load at yield” and “peak load” across the arthrodesis constructs. This suggests that headless screws, in addition to offering comparable compressive force, is equally as resistant to pull-out forces as the headed screw. When comparing the torsional resistance of a two and a three headless construct, Riedl et al found no difference in torsional strength. Therefore, headless screws may be a reasonable option for subtalar arthrodesis fixation, particularly in situations where prominence of hardware is a concern.
statistical significance. Our study validates the findings of Riedl et al. Additionally, our study even compares the pull-out strength to the headed cannulated screw, which showed equal resistance to pull-out.

One limitation of this study is that a cadaveric model cannot fully simulate the in vivo environment. The mechanical characteristics of the fixation is only one factor in the success of an arthrodesis procedure, and the equivalence of mechanical characteristics does not directly imply clinical performance. The typical forces at the subtalar joint are not distractions as measured by our study. More physiologic loads would improve the real world comparison, but are difficult to simulate in a mechanical testing laboratory. We used a simplified model intended to find marked difference in fixation. That process might in-turn indicate concerns for using the headless design in the hindfoot setting.

In our study, the use of cadaveric specimens introduces variability. We attempted to minimize this variation by using matched pairs. A bone density scan would further improve the external validity of our study. Additionally, the limited number of specimens increases the risk for type II error; however, the small differences noted between the two comparison groups would require a large number of specimens to detect a statistical difference. This is unlikely to be clinically relevant.

After analyzing the data, we have concluded that headless cannulated compression screws provide a viable alternative to headed screws for subtalar arthrodesis, showing equivalent compression and pull-out strength.

REFERENCES
The Future of Infection Surveillance at Ambulatory Surgical Centers

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ABSTRACT

Background: The Centers for Medicare and Medicaid (CMS) has begun mandating infection surveillance at surgical sites, which started in hospitals and is now in ambulatory surgical centers (ASCs). We found a 0.1% increase in infection rate between 2005 and 2007, which prompted us to examine the issue further. The purpose of the current study was to summarize the results of an investigation after an outbreak of infection at our ASC, specifically attempting to identify a common pathogen, vector, or unknown lapses in infection prevention. Additionally, we relate our experience to current trends in infection prevention at ASCs by examining the most recent CMS infection surveillance requirements.

Methods: We performed a retrospective review of patients with infections after orthopaedic procedures at our ASC from 2005 to 2008. Infections were identified by the Centers for Disease Control and Prevention surveillance definitions, with a total of 17 patients included in the study. We also reviewed the site inspection and documented the resultant interventions.

Results: No common pathogen was found in the 17 patients. The results of the site review noted a contaminated tendon-stripper used in half of the cases, poor disassembly of instruments before cleaning, overuse of “flash” sterilization, and poor ventilation in the operating suites. In 2011, infection rates returned to 1.3%.

Conclusions: An ongoing infection surveillance program, periodic site inspections, and process reviews are essential to prevent surgical site infections at ASCs.

Keywords: Ambulatory Surgery, Outpatient Surgery, Arthritis, Infectious, Arthroscopy

INTRODUCTION

According to the Centers for Medicare and Medicaid Services (CMS), an ambulatory surgical center (ASC) is defined as: “a distinct entity that operates exclusively for the purpose of providing surgical services to patients not requiring hospitalization and in which the expected duration of services would not exceed 24 hours following an admission.” As of 2010, there were 5316 Medicare-certified ASCs, representing more than a 54% increase from 2001. In 2007, an estimated 6 million surgical procedures were performed at ASCs, with a $3 billion cost to Medicare. As the number of ACSs and number of procedures continues to grow, few data are available regarding the complications of procedures performed in these settings, specifically surgical site infections (SSIs).

To participate in the CMS “Pay for Performance” program beginning January 2012, acute care hospitals were required to perform surveillance on SSIs (specifically infections in patients undergoing colectomies and abdominal hysterectomies) and enter the data into the National Healthcare Safety Network, a secure database of the Centers for Disease Control and Prevention (CDC). Although currently voluntary, surveillance and data entry efforts are anticipated to extend to more procedures and settings such as ASCs.

SSI rates after outpatient orthopaedic procedures tend to be less than 1%. Some studies have reported a lower SSI rate at single-specialty ASCs. A 2010 article from Edmonston and Foulkes reviewed more than 11,000 cases during a 5-year period at a single orthopaedic ASC. They found the overall infection rate to be 0.33%. Infection rates after anterior cruciate ligament (ACL) reconstructions are estimated to be between 0.14% to 0.78%. Similarly, infection rates after orthopaedic arthroscopic procedures are estimated to be between 0.10% to 1.1%.
At our inpatient institution, SSI surveillance began in 2003 and has evolved from a retrospective review of single procedures to a prospective program of multiple procedures. In 2005, surveillance was expanded to include our affiliated ASC. There was a noted increase in postoperative infections after outpatient orthopaedic procedures seen in the Outpatient Parenteral Antimicrobial Therapy Clinic. Because of this, surveillance on orthopaedic SSIs was instituted for ACL reconstructions and eventually expanded to include all arthroscopic knee and shoulder procedures. Retrospective review of orthopaedic SSIs between 2005 and 2008 indicated an increased infection rate of 2.5% in 2005 and 2.6% in 2007 (Figure 1). These results prompted an outbreak investigation at the facility to determine if there was a common pathogen or vector contributing to the increased infection rate.

The purpose of this paper was to first summarize the results of the outbreak investigation, specifically looking for a common pathogen, vector, or other lapse in infection control. Secondly, we wanted to relate our experience to current requirements in infection control. Lastly, we examined infection control records on infections that occurred within 30 days of the index procedure (with the exception of procedures involving implants, which were monitored for 1 year). For this investigation, surveillance was limited to organ space SSIs which correlates to a clinical diagnosis of septic arthritis. Diagnosis of an organ space SSI required at least one of the following factors to be documented in the medical records: purulent drainage from a drain that is placed through a stab wound into the organ or space; organisms isolated from an aseptically obtained culture of fluid or tissue in the organ or space; an abscess or other evidence of infection involving the organ or space that is found on direct examination, during reoperation, or by histopathological or radiological examination; or diagnosis of an organ or space SSI by a surgeon or attending physician.

**Diagnosis of Septic Arthritis**
Clinical diagnosis of septic arthritis is based on physical examination findings such as joint swelling, warmth, or positive joint aspiration. Other factors include pain, difficulty, or inability to bear weight in conjunction with elevated inflammatory markers during laboratory examination. At our facility, we consider the following levels to be elevated: erythrocyte sedimentation rate (ESR), > 20 mm/hr; C-reactive protein (CRP), > 0.4 mg/dL; and white blood cell count (WBC), > 10.6 x 103 cells/mm³. There are two gold standards for the diagnosis of septic arthritis. The first is a joint aspiration with a positive gram stain or culture, and the second is a total nucleated cell count greater than 50,000 WBC/mL in a native joint or greater than 2500 WBC/mL in a prosthetic joint. Although a CDC definition for septic arthritis has been developed along with an orthopaedic definition for periprosthetic joint infections, no surveillance definition specifically addresses infections of arthroscopic joint infections. Notably, there is considerable morbidity with superficial infections but we focused on the commonalities between patients who had septic arthritis.

**Data Gathered**
We reviewed the ESR, CRP, WBC, and joint aspiration results. Additionally, we collected data regarding patient age, date of index procedure, preoperative diagnosis, index procedure, graft used, number of days from surgical procedure to diagnosis of infection, subsequent procedures (ie, type and number), antibiotic treatment (ie, type and duration), and preoperative antibiotic administration.

We also examined infection control records on facility inspections, findings, and interventions. In the medical records, several aspects of patient care and safe practices were evaluated on the basis of multiple visits. These included patient preoperative preparation, perioperative antibiotic administration, instrument processing and sterilization, operating room ventilation, and personnel adherence to the best infection control practices.
Table 1. Age and diagnosis details of the 17 patients with surgical site infections

<table>
<thead>
<tr>
<th>Patient Age, Years</th>
<th>Diagnosis</th>
<th>Surgical Procedure</th>
<th>Graft</th>
<th>Days to Infection</th>
<th>Laboratory Results</th>
<th>Cultures Results</th>
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</thead>
<tbody>
<tr>
<td>22</td>
<td>ACLt, MMt, ACLr, MMd</td>
<td>ACLr, MMd</td>
<td>BPTB autograft</td>
<td>21</td>
<td>WBC, 7.4, ESR, 84 CRP, 25.7, TNC, 96,160</td>
<td>No growth</td>
</tr>
<tr>
<td>45</td>
<td>ACLt, MCLt, PCLt, ACLr, MMd</td>
<td>ACLr, MCLr PCLR</td>
<td>HS autograft and allograft</td>
<td>29</td>
<td>WBC, 9.7, ESR, 123 CRP, 15.8, TNC, --</td>
<td>Pseudomonas aeruginosa, Enterobacter cloacae, Corynebacterium lipophiloflavum</td>
</tr>
<tr>
<td>19</td>
<td>ACLt</td>
<td>ACLr</td>
<td>HS autograft</td>
<td>19</td>
<td>WBC, 11.8, ESR, 73 CRP, --, TNC, 121,400</td>
<td>Staphylococcus epidermidis</td>
</tr>
<tr>
<td>60</td>
<td>RCT, SLAP, ACA</td>
<td>RCTr, SLAPr, SAD,</td>
<td>--</td>
<td>14</td>
<td>WBC, 13.8, ESR, 56 CRP, 27, TNC, --</td>
<td>Methicillin-sensitive Staphylococcus aureus</td>
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<tr>
<td>56</td>
<td>Shoulder synovitis</td>
<td>Synovectomy</td>
<td>--</td>
<td>8</td>
<td>WBC, 14.3, ESR, 6 CRP, 2.8, TNC, 57,000</td>
<td>Methicillin-sensitive Staphylococcus aureus</td>
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<td>19</td>
<td>ACLt</td>
<td>ACLr</td>
<td>HS autograft</td>
<td>26</td>
<td>WBC, 10.5, ESR, -- CRP, 13.7, TNC, 38,000</td>
<td>Staphylococcus haemolyticus*</td>
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<td>51</td>
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<td>ACLr, MMd</td>
<td>HS autograft</td>
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<td>WBC, 7.7, ESR, 68 CRP, 1.4, TNC, 41,400</td>
<td>Staphylococcus epidermidis</td>
</tr>
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<td>21</td>
<td>ACLt, MMt, LMr</td>
<td>ACLr, MMd LMr</td>
<td>HS autograft</td>
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<td>WBC, 10.1, ESR, 90 CRP, 4.6, TNC, 80,840</td>
<td>Staphylococcus epidermidis</td>
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<tr>
<td>54</td>
<td>MMr</td>
<td>MMd</td>
<td>--</td>
<td>13</td>
<td>WBC, 7.0, ESR, 51 CRP, 11.3, TNC, 81,100</td>
<td>Enterococcus faecalis, Staphylococcus capitis*</td>
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<tr>
<td>48</td>
<td>PLCi</td>
<td>PLCr</td>
<td>Achilles and TA allografts</td>
<td>27</td>
<td>WBC, 8.2, ESR, 29 CRP, 9.5, TNC, 87,990</td>
<td>No growth</td>
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<tr>
<td>34</td>
<td>ACLt</td>
<td>ACLr</td>
<td>HS autograft</td>
<td>20</td>
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<tr>
<td>14</td>
<td>ACLt</td>
<td>ACLr</td>
<td>HS autograft</td>
<td>17</td>
<td>WBC, 7.9, ESR, 45 CRP, 6.4, TNC, 46,000</td>
<td>Enterobacter cloacae</td>
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<tr>
<td>54</td>
<td>Loose body removal</td>
<td>Loose body removal</td>
<td>--</td>
<td>12</td>
<td>WBC, 8.8, ESR, 5 CRP, 2.6, TNC, 18,360</td>
<td>No growth</td>
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<td>29</td>
<td>ACLt, LMr</td>
<td>ACLr, LMr repair</td>
<td>HS autograft</td>
<td>140</td>
<td>WBC, 8.6, ESR, 107 CRP, 12.6, TNC, 73,370</td>
<td>Staphylococcus capitis, Staphylococcus epidermidis, Corynebacterium</td>
</tr>
<tr>
<td>19</td>
<td>Knee synovitis</td>
<td>Synovectomy</td>
<td>--</td>
<td>14</td>
<td>WBC, 10.2, ESR, 44 CRP, 14.3, TNC, 73,370</td>
<td>No growth</td>
</tr>
<tr>
<td>53</td>
<td>ACLt, MMt</td>
<td>ACLr, MMd</td>
<td>HS autograft</td>
<td>36</td>
<td>WBC, 7.3, ESR, 42 CRP, 11.5, TNC, 37,140</td>
<td>Staphylococcus epidermidis</td>
</tr>
<tr>
<td>58</td>
<td>LMr</td>
<td>LMr</td>
<td>--</td>
<td>22</td>
<td>WBC, 6.3, ESR, 29 CRP, 3.8, TNC, 37,140</td>
<td>Staphylococcus epidermidis</td>
</tr>
</tbody>
</table>

ACA, acromioclavicular arthritis; ACLt, anterior cruciate ligament tear; ACLr, anterior cruciate ligament reconstruction; BPTB, bone-patellar tendon-bone; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; HS, hamstrings; MCLt, medial collateral ligament tear; MCLR, medial collateral ligament reconstruction; MMd, medial meniscus debridement; MMr, medial meniscus repair; MMt, medial meniscus tear; LMd, lateral meniscus debridement; LMr, lateral meniscus repair; LMT, lateral meniscus tear; PLCi, posterolateral corner injury; PLCr, posterolateral corner reconstruction; RCRi, rotator cuff repair; RCRr, rotator cuff tear repair; SAD, subacromial decompression; SLAP, superior labrum anterior to posterior; TA, tibialis anterior; TNC, total nucleated cells; WBC, white blood cell count; --, not applicable.

All patients diagnosed with septic arthritis had purulence in the joint with the exception of this patient who was diagnosed with a superficial wound infection.

*Considered to be contaminants.

*At our facility, the following levels are elevated and suggestive of infection: erythrocyte sedimentation rate, > 20 mm/hr; C-reactive protein, > 0.4 mg/dL; white blood cell count (WBC), > 10.6 x 10³ cells/mm³; and total nucleated cell count, > 50,000 WBC/mL.
RESULTS
Table 1 shows patient demographics and diagnosis details. Of the 17 patients, two had undergone shoulder arthroscopies and 15 had undergone knee arthroscopies. Of the 15 knee arthroscopies, there were nine ACL reconstructions (ie, four meniscal debridements and one meniscal repair), two meniscal debridements, one multiligament reconstruction, one posterolateral corner reconstruction, one loose body removal, and one synovectomy. There were nine hamstring autografts, one bone-patella tendon-bone autograft, and three allografts used for reconstruction. Of the two patients with shoulder arthroscopies, one involved a rotator cuff and SLAP (ie, superior labral tear from anterior to posterior) repair and the other involved synovectomy.

Diagnosis and Treatment
The average time to diagnosis and treatment of infection was 28 days from the index procedure. One patient who was identified with a late infection was treated at 140 days. Culture results were negative for infection in 6 of the 17 patients. The remaining patients developed Staphylococcus epidermidis, multiple organisms, methicillin-susceptible Staphylococcus aureus, and gram-negative rods (Figure 2).

All patients were treated with irrigation and debridement in the operative suite, with 16 of the 17 patients treated arthroscopically and one patient treated with open debridement. Subsequent debridements were required for five patients. Hardware and grafts were removed in three patients, and three patients had antibiotic beads placed and subsequently removed. Perioperative antibiotics were given to 14 of the 17 patients. In 16 patients, septic arthritis was treated with intravenous antibiotics. The two remaining patients were treated with oral antibiotics. There were various combinations of medications, route, and duration of the treatments (Table 2).

Two surgeons performed 16 of the 17 index procedures. The remaining index procedure was performed by a different surgeon. It should be noted that one surgeon performed six of the eight ACL reconstructions that developed infection.

Infection Rates
Infection rates by year are reviewed in Figure 3. SSI rates after all arthroscopic procedures from 2005 to 2011 were 0.81%, 0.91%, 0.73%, and 0.38% for each sequential year. Infection rates after ACL reconstruction were 2.5%, 1.6%, 2.6% and 1.3% for each sequential year.

Site Investigation Findings
Results of the site investigation revealed important deficiencies in infection control, with most issues being in sterile processing. On one site visit, positive airflow in the operating rooms was found to be inadequate. Interviews with the sterile processing department revealed a lack of understanding of instrument disassembly and cleaning, brushes being re-used and not cleaned, and employees running short cycles during the pre-sterilization wash process at the end of the day. At that time, none of the sterilization technicians were certified.

Three patients did not receive perioperative antibiotics. During the study period, a povidone-iodine mixture was used for skin preparation on all patients. Additionally, a tendon-stripper commonly used by the two surgeons in this study was not being completely disassembled before cleaning. After properly disassembling the tendon-stripper, it was found to have visible adherent debris.
### Table 2. Treatment details of the 17 patients with surgical site infections

<table>
<thead>
<tr>
<th>Patient age, years</th>
<th>No. postoperative procedures and details</th>
<th>Antibiotic treatment (type, method)</th>
<th>Antibiotic duration, weeks</th>
<th>Peri-op antibiotic</th>
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</thead>
<tbody>
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<td>22</td>
<td>1 - AD</td>
<td>Ceftriaxone IV Levofloxacin PO</td>
<td>5</td>
<td>Yes</td>
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<tr>
<td>45</td>
<td>3 - AD, HWR, GR, antibiotic beads</td>
<td>Ciprofloxacin PO, Zosyn IV, Linezolid PO</td>
<td>18</td>
<td>Yes</td>
</tr>
<tr>
<td>19</td>
<td>3 - AD, GR, HWR, antibiotic beads</td>
<td>Vancomycin IV, Clindamycin IV, Rifampin PO</td>
<td>8</td>
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<tr>
<td>60</td>
<td>3 - AD, antibiotics beads</td>
<td>Nafcillin IV, Rifampin PO, Linezolid PO</td>
<td>16</td>
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<tr>
<td>56</td>
<td>2 - AD</td>
<td>Cefazolin IV, Bactrim PO</td>
<td>6</td>
<td>Yes</td>
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<td>1 - AD</td>
<td>Cefepime PO</td>
<td>2</td>
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<tr>
<td>51</td>
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<td>Nafcillin/Cefazolin IV</td>
<td>18</td>
<td>Yes</td>
</tr>
<tr>
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<td>1 - AD</td>
<td>Nafcillin IV</td>
<td>6</td>
<td>No</td>
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<tr>
<td>54</td>
<td>1 - AD</td>
<td>Ceftriaxone IV, Amoxicillin PO</td>
<td>5</td>
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<tr>
<td>48</td>
<td>1 - open I&amp;D, HWR, GR</td>
<td>Linezolid PO</td>
<td>4</td>
<td>Yes</td>
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<tr>
<td>34</td>
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<td>Vancomycin IV, Rifampin PO, Linezolid PO</td>
<td>6</td>
<td>No</td>
</tr>
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<td>14</td>
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<td>6</td>
<td>Yes</td>
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<tr>
<td>54</td>
<td>2 - AD</td>
<td>Vancomycin IV, Ciprofloxacin PO, Rifampin PO, Linezolid PO</td>
<td>6</td>
<td>Yes</td>
</tr>
<tr>
<td>29</td>
<td>1 - AD</td>
<td>Vancomycin IV, Ciprofloxacin PO, Rifampin IV</td>
<td>6</td>
<td>Yes</td>
</tr>
<tr>
<td>19</td>
<td>1 - AD</td>
<td>Nafcillin IV, Cephalexin PO</td>
<td>6</td>
<td>Yes</td>
</tr>
<tr>
<td>53</td>
<td>2 - AD</td>
<td>Linezolid PO</td>
<td>4</td>
<td>Yes</td>
</tr>
<tr>
<td>58</td>
<td>1 - AD</td>
<td>Vancomycin IV</td>
<td>4</td>
<td>Yes</td>
</tr>
</tbody>
</table>

AD, arthroscopic debridement; GR, graft removal; HWR, hardware removal; IV, intravenous; peri-op, perioperative; PO, oral.

*aAll treated with repair/reconstruction, meniscal debridement, synovectomy or loose body removal as indicated by the diagnosis with the exception of one who underwent lateral meniscal repair and anterior cruciate ligament reconstruction.

**Increased creatinine, switched to Cefazolin.

**DISCUSSION**

Before the start of this study, we observed an increase in orthopaedic SSIs at our ASC between 2005 and 2008 (ie, 2.5% in 2005 and 2.6% in 2007). Results of a thorough review of medical records and a site investigation indicated that most patients with infections had undergone knee ligament reconstructive procedures (primarily ACL reconstruction) performed by two orthopaedic surgeons. Additionally, the SSIs were likely the result of a lack of standardization in sterile processing.

In the current study, there were 17 patients diagnosed with deep SSI. Of these patients, nine received hamstring autografts and four received hamstring allografts. Although there is an increased risk of SSI with both hamstrings autograft and allograft, our infection rate was far greater than what could be explained by graft choice alone. For reconstructions, we used nine hamstring autografts, one bone-patella tendon-bone autograft, and three allografts. Although it appeared that the inappropriately handled tendon stripper may have contributed to some of the infections, there was no common infectious agent found indicating one source. Additionally, the povidone-iodine mixture used on all patients primarily used for skin preparation. One prospective randomized controlled study found that a chlorhexidine-alcohol mixture is superior to iodine for prevention of SSIs; however, these findings have not yet been incorporated into formal guidelines. Among our patients with negative culture findings, there was a low-grade yet persistent inflammatory reaction. It was suggested that it may have been a reaction to the sterile debris in contaminated instruments.

Healthcare-associated infections are a leading cause of death in the United States, with an estimated 1.7 million healthcare-related infections and 99,000 deaths attributed to these infections in 2002. These data, however, do not reflect the burden of infections acquired in ambulatory settings and day-time surgical procedures. In response to the growing concerns surrounding healthcare-associated infections, the United States Department of Health and Human Services released an action plan in January 2009 to help prevent healthcare-associated infections. The first phase of recommendations focused on six related areas of healthcare-associated infections such as SSIs at acute inpatient facilities. However, it did not focus on ASCs.

In 2008, an outbreak at one Nevada ASC prompted
an investigation into infection control at all 51 ASCs in Nevada. The investigation used an audit tool developed by the CDC and found lapses in infection control in 28 of the ASCs. These findings prompted CMS to conduct further investigation in three additional states (Maryland, North Carolina, and Oklahoma) and found that 46 of the 68 facilities surveyed had at least one major lapse in infection control. Subsequently, the United States Department of Health and Human Services recognized the need to address the prevention of healthcare-associated infections. This therefore led to the second phase of planning, which includes the prevention of healthcare-associated infections at ASCs. CMS current conditions of participation include: an infection control program based on nationally recognized infection control guidelines that is under the direct control of trained infection control personnel; integration of the infection control program into the ASC’s quality improvement program; and documentation that the ASC is controlling and monitoring infections using this program.

Infection surveillance at ASCs can pose particular challenges. Post-discharge surveillance from ASCs requires various methods of tracking patients (e.g., follow-up calls, surgeon surveys, and medical record review). Unfortunately, high sensitivity is difficult to achieve outside integrated healthcare systems with common electronic records. Patients with infections are typically admitted for diagnosis, debridement, and initiation of antimicrobial therapy at acute care facilities. Yet, there is a lack of communication in acute care facilities that makes identifying cases difficult. Therefore, a good working relationship with infection professionals in local acute care hospitals is essential. In some states, such as Texas, acute care hospitals are required to notify the originating facility when any patient is found to have a healthcare-associated infection, which is now a requirement for acute care facilities due to efforts by the Joint Commission.

In response to the observed infection outbreak at our ASC, several changes were enacted. First, the ventilation system was updated. Additionally, the sterile processing technicians are now certified and all instrumentation assembly and disassembly instructions are readily available in the processing room. A continuous improvement program is in place for immediate-use sterilization (previously known as “flash” sterilization). Furthermore, we continued to perform prospective surveillance on all arthroscopic procedures performed in our ASC; notably, this ended in 2011 when a temporary reallocation of resources was required by new CMS requirements and a change in the electronic health record.

The current study is a retrospective review and therefore has some inherent limitations. First, there is the potential of selection bias. The patients were identified by medical records, and thus accuracy of report was dependent on the clinical notes. Also, the patients who experienced SSIs did return to our healthcare system. It is possible that they sought treatment for SSI elsewhere, but that was not noted in the record. On the basis of these limitations, it is impossible to draw definitive conclusions; however, this review does give insights about the increased infection rate that was found at our ASC.

Ultimately, our infections were recognized and corrected because of a close partnership with infectious diseases clinicians, our hospital epidemiologist, and certified infection prevention specialists. ASCs may require expert consultation to ensure that appropriate infection surveillance and preventive processes are put in place to meet the evolving standards of patient safety.

REFERENCES


Comparison of Intraoperative Fluoroscopy to Postoperative Weight-Bearing Radiographs Obtained 4 to 6 Weeks After Bunion Repair With A Chevron Osteotomy

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Conflict of Interest The authors report no conflicts of interest.

ABSTRACT

Background: During operative treatment of bunions, an attempt is made to correct the hallux valgus angle (HVA) and the intermetatarsal angle (IMA). In this study, the HVA and the IMA were measured using intraoperative C-arm fluoroscopic images obtained during surgical treatment of a bunion with chevron osteotomy. These angles were again measured using weight-bearing radiographs obtained 4 to 6 weeks postoperatively.

Methods: At our institution, we reviewed medical records of patients who underwent a bunion repair with chevron osteotomy between January 2013 and October 2017. A total of 26 feet from 24 patients were included. Three authors (ALP, TMH, and RAM) measured the HVA and IMA using intraoperative fluoroscopic images and postoperative weight-bearing radiographs (4 measurements per foot; total, 104 measurements). The authors were blinded to their previous angular measurements and to measurements made by the others. An intraclass correlation coefficient was calculated for the HVA and IMA measurements between groups (ie, intraoperative fluoroscopic images and postoperative weight-bearing radiographs) to determine interobserver reliability. We compared the angles measured by the authors between groups and used a paired t test for statistical evaluation.

Results: Interobserver difference of the HVA and IMA was low between intraoperative fluoroscopic images and postoperative weight-bearing radiographs (0.98 and 0.79; 0.78 and 0.95, respectively). The measured IMAs were relatively consistent between groups (6.21° and 6.37°, respectively); only two patients had a difference > 3°. There was a greater difference in HVAs between groups (11.5° and 14.2°, respectively). In 11 feet, the HVA was > 5° (range, 5.3-12.7°) in the postoperative radiograph compared to the fluoroscopic image. In one foot, we noted a 7° decrease of the HVA on the postoperative radiograph. The average difference of HVA between groups was 2.6° (P < 0.0001), whereas the IMA was 0.16° (P = 0.002).

Conclusions: Interobserver measurements of the HVA and IMA were reliable on both the intraoperative fluoroscopic images and the postoperative weight-bearing radiographs. The IMA was similar between groups; however, the HVA was often greater on the postoperative weight-bearing radiographs.

Keywords: Hallux Valgus, Fluoroscopy, Intermetatarsal Joint, Bunion Surgery

INTRODUCTION

During operative treatment of bunions, the objective is to correct the hallux valgus angle (HVA) and the intermetatarsal angle (IMA). Correction of these angles decreases the chance of reoccurring deformity. Intraoperative imaging is necessary to assess great toe alignment during surgical treatment. Fluoroscopic images or plain weight-bearing radiographs can be obtained during the procedure. Intraoperative fluoroscopy has the advantage of decreased operating time compared with obtaining plain weight-bearing radiographs. This eases the ability to make intraoperative adjustments.

Chevron osteotomy is one of the most common procedures for treating a bunion. During this procedure, an osteotomy is made in the first metatarsal
head, which is then translated laterally to decrease the IMA. The location of the osteotomy distorts the relationship between the metatarsal head and neck, which might make radiographic interpretation difficult.

This study aimed to determine whether intraoperative C-arm fluoroscopic images, with the foot held in a simulated weight-bearing position, gives an accurate assessment of the bunion correction. Specifically, we evaluated 1) any difference in HVA and IMA measurements between the three examiners and 2) any difference in HVA and IMA measurements between intraoperative fluoroscopic images and weight-bearing radiographs obtained 4 to 6 weeks postoperatively. We hypothesized that HVA and IMA measurements would be similar between groups.

METHODS
After obtaining approval from our institutional review board (HRRC #17-451), we reviewed medical records of patients who underwent a bunion repair with a chevron osteotomy performed by the senior author (RAM) between January 2013 and October 2017. We included patients who had intraoperative fluoroscopic images, with the C-arm in a simulated weight-bearing position, and weight-bearing radiographs at 4 to 6 weeks postoperatively. The intraoperative fluoroscopic images were obtained with the knee bent and the foot flat against the operating room table to simulate a weight-bearing position. These images were saved to the IntelliSpace PACS program (Philips Healthcare, Andover, MA) and were available to review electronically. A total of 26 feet from 24 patients were included in the study.

Four angular measurements were made for each foot. The HVA and the IMA were measured using intraoperative fluoroscopic images. The HVA and IMA were measured again using weight-bearing radiographs obtained in clinic 4 to 6 weeks postoperatively (Figures 1 and 2). To obtain the postoperative radiographs, the patients stood and placed their foot on the radiographic plate.

The HVA and IMA measurements were made independently by three of the authors. One author was a second-year orthopaedic resident (ALP), one a third-year orthopaedic resident (TMH), and one a foot and ankle fellowship-trained orthopaedic surgeon (RAM). Each examiner made 104 measurements. Several days after measuring the HVA and IMA using the intraoperative fluoroscopic images, the examiners measured the same angles on the postoperative weight-bearing radiographs. The examiners were blinded to their previous angular measurements and to the measurements made by the others. Comparisons were made between the HVA and IMA measurements.

Figure 1. Radiograph showing the hallux valgus angle in a patient who underwent bunion repair with chevron osteotomy. The angle is formed between a line drawn down the center of the great toe proximal phalanx and a line from the center of the metatarsal head to the center of the base of the first metatarsal.

Figure 2. Radiograph showing the intermetatarsal angle in a patient who underwent bunion repair with chevron osteotomy. The angle is formed between two lines: one line from the center of the first metatarsal head through its base, and the other line from the center of the second metatarsal head through its base.
**Table 1. Results of the interobserver reliability test, showing the cumulative difference of measurements between examiners (by degrees) and corresponding intraclass correlation values**

<table>
<thead>
<tr>
<th>Imaging modality used for measurement</th>
<th>No. times different by 0-4°</th>
<th>No. times different by 5°</th>
<th>No. times different by &gt;5°</th>
<th>ICC²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoroscopic intraoperative radiograph</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HVA</td>
<td>24</td>
<td>1</td>
<td>1</td>
<td>0.98</td>
</tr>
<tr>
<td>IMA</td>
<td>24</td>
<td>2</td>
<td>0</td>
<td>0.78</td>
</tr>
<tr>
<td>Postoperative weight-bearing radiograph</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HVA</td>
<td>25</td>
<td>1</td>
<td>0</td>
<td>0.79</td>
</tr>
<tr>
<td>IMA</td>
<td>26</td>
<td>0</td>
<td>0</td>
<td>0.95</td>
</tr>
</tbody>
</table>

ICC, intraclass correlation coefficient; HVA, hallux valgus angle; IMA, intermetatarsal angle.

²Each of the three examiners measured the hallux valgus angle and intermetatarsal angle of 26 feet using intraoperative fluoroscopic images and postoperative weight-bearing radiographs. Four measurements were made per foot, totaling 104 measurements. The groups of 0-4°, 5°, and >5° difference were arbitrarily assigned on the basis of the senior author’s (RAM) discretion.

²Intraclass correlation coefficient values of < 0.5 indicate poor correlation, 0.5-0.75 indicate moderate correlation, 0.75-0.9 indicate good correlation, and 0.9-1 indicate excellent correlation between examiners. ¹⁻²

The interobserver reliability measurements between intraoperative fluoroscopic images and postoperative weight-bearing radiographs. The PACS angular measurement function was used to make all measurements electronically.

Statistical analyses were performed using Statistical Analysis Software 9.4 (Cary, North Carolina). Comparisons of HVA and IMA measurements between intraoperative fluoroscopic images and postoperative weight-bearing radiographs were completed using a paired t test. Interobserver reliability for each group of angles measured by the examiners was determined by calculating an intraclass correlation coefficient.

**RESULTS**

The interobserver difference for the four measurements was low. On four of the 104 measurements, one examiner was 5° different from the others (3.8%). Only once was an examiner more than 5° different from the other two. For the other 99 angles measured, the three examiners measured less than 5° different from one another (Table 1). ¹⁻² On six occasions, the same angle was measured by all three examiners. Two of the three examiners had the same angle 46 times. On another 28 occasions, the examiners each measured a different angle with a spread of 2°. Overall, the interobserver reliability for each group of angles was excellent, ranging from 0.78 to 0.98.

The IMA measurement was similar between the groups (ie, intraoperative fluoroscopic images and postoperative weight-bearing radiographs). Using the average angle of the three examiners, we noted a 4° difference between groups in only one foot. Another foot had a 3° difference, and the remaining 24 feet had less than a 3° difference of IMA measured between groups.

The mean HVA measurements between groups were 11.5° and 14.2° respectively, with a mean difference of 2.6° (P < 0.0001). The mean IMA measurements between groups were 6.21° and 6.37° respectively, with a mean difference of 0.16° (P = 0.002).

The HVA measurement had a greater difference between groups. Using the average of the three examiners, a total of 11 feet (42%) showed an HVA greater than 5° on the postoperative weight-bearing radiographs compared to the intraoperative fluoroscopic images (range, 5.3-12.7°). One foot had a 7° improvement of the HVA on the postoperative weight-bearing radiograph.

**DISCUSSION**

The IMA and HVA are important to assess the bunion deformity. Weight-bearing radiographs reveal the deformity more clearly than non–weight-bearing radiographs. ¹⁻² In the current study, we found a small but statistically significant difference in IMA and HVA measurements between intraoperative fluoroscopic images that simulated weight bearing and postoperative weight-bearing radiographs. A post hoc power analysis was completed (P = 0.002 and 0.001, respectively). The difference in angle measurements was relatively minor (HVA, 2.6° and IMA, 0.16°).

Previous studies have shown a high reliability of interobserver measurement of these angles on plain radiographs. ³⁻⁷ Using photographs of radiographs, Coughlin et al ⁸ showed that 96.7% of IMAs were repeatedly measured within a range of 5° or less. The measurements were less reliable for the HVA, with 86.2% of photographs measured within 5° or less. These findings are consistent with those of our own study. We found good to excellent interrater reliability between the three examiners despite different levels of experience.

Kuyucu et al ⁹ noted that foot position changes the HVA to a greater extent than that of the IMA. This might explain the greater difference noted in HVA compared to IMA between the intraoperative fluoroscopic images and postoperative weight-bearing radiographs. Another possible explanation could be stretching of the medial
capsular repair, resulting in some reoccurrence of deformity seen on the postoperative radiograph at 4 to 6 weeks.

There are few studies comparing intraoperative fluoroscopic images to postoperative radiographs in operative treatment of bunions. Elliot et al. reviewed fluoroscopic images and 6-week postoperative radiographs of 28 patients after bunion correction with a scarf osteotomy. The IMA increased an average of only 1.2°; however, the HVA increased an average of 9.1° between the groups. Gutteck et al. found no difference in the angles between fluoroscopic images and 8-week postoperative radiographs of patients who underwent Lapidus bunion repair.

We found the intraoperative fluoroscopic images to be adequate to measure the HVA and the IMA. The angles measured correlated between examiners. Similarly, there was good interobserver correlation with the angles measured using the postoperative weight-bearing radiographs. The IMA measurement was similar between groups. There was worsening HVA of greater than 5° seen on the postoperative radiographs of 11 feet, with improvement greater than 5° in one foot.

This study was limited by small sample size. Despite this, there was sufficient statistical power. All patients were treated by the same surgeon (RAM) at a single hospital, limiting the variability and generalizability of the data. In this study, one examiner was a fellowship-trained, board-certified foot and ankle surgeon (RAM), while the other examiners were second-year (ALP) and third-year (TMH) orthopaedic residents. However, the interrater variability of measured angles was very low, indicating that angle interpretation can accurately be performed at various levels of training. Follow-up studies may benefit from measurements made by additional specialty-trained foot surgeons compared with a larger pool of examiners.

Previous research has shown that weight-bearing radiographs are more reliable in measuring HVA and IMA, with high intraobserver reliability. In this study, we hoped to show that HVA and IMA measurements from intraoperative fluoroscopic images with simulated weight bearing would be comparable to those of postoperative weight-bearing radiographs. Although we saw a statistically significant difference between the angle measurements, the difference was clinically insignificant. Fluoroscopic images obtained intraoperatively may be adequate for measuring HVA and IMA. Subsequently, immediate postoperative radiographs may not always be necessary in assessing HVA and IMA of patients undergoing bunion repair.

REFERENCES
Accuracy and Reliability of Examiners’ Observations of Pre-Practice Warm-Up and FIFA 11+ Injury Prevention Program Exercises

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ABSTRACT

Background: The Fédération Internationale de Football Association (FIFA) 11+ is an injury prevention program that decreases the incidence of lower extremity injuries. The purpose of the current study was to understand what specific exercises prevented injury from occurring. We thus developed and tested a form to identify these exercises. We hypothesize that trained examiners could accurately and reliably use this form to identify and record individual exercises performed during pre-participation warm-up.

Methods: A repeated-measures study design was used in this investigation. After observing five pre-practice warm-up videos obtained from multiple high schools, 11 examiners observed and recorded performed exercises at two different times. The videos included four soccer teams and one American football team. Accuracy, interexaminer reliability, and intraexaminer reliability were assessed. Sensitivity, specificity, accuracy, and percent agreement with a FIFA 11+ expert were measured for each exercise component.

Results: The intraclass correlation coefficients between examiners and individually ranged from 0.22 to 1.00 and 0.58 to 1.00, respectively. Reliability was lowest for exercises with similar movements. The percent agreement across all examiners for individual exercises ranged from 20% to 100%. Additionally, the percent agreement between each examiner and the “gold standard” examiner was high (range, 69.6% to 90.4%). For exercises with similar movements, accuracy and reliability were considerably improved (97%) when combined into one category.

Conclusion: We determined that trained examiners with different backgrounds and experience can make accurate and reliable observations of most exercises observed in warm-up programs. Using the proposed form, researchers can accurately record exercises and perform quality and fidelity assessments of warm-up exercise routines.

Keywords: Anterior Cruciate Ligament, Anterior Cruciate Ligament Injuries, Validation Studies, Randomized Controlled Trial
INTRODUCTION

Lower extremity injuries are common in high school athletes, with an estimated 800,000 injuries occurring per year. Treatment is expensive, and there is a possibility of long-term health effects. For example, providing medical care for high school varsity sports in North Carolina was estimated to be nearly $10 million in medical costs, $45 million in capital costs, and $145 million in comprehensive costs. Additionally, the long-term health effects of serious lower extremity sport injuries are concerning because of the high risk of developing posttraumatic early-onset osteoarthritis after a severe knee injury.3,4

Results of a recent meta-analysis confirmed that anterior cruciate ligament (ACL) injury prevention programs can decrease lower extremity injuries by 37% and ACL injuries by 51%. One of the more popular programs is the FIFA 11+ injury prevention program, which is used as a replacement for a pre-practice warm-up and consists of strengthening, conditioning, and dynamic stretching exercises. Specifically, the FIFA 11+ program has been shown to decrease lower extremity injuries by up to 72% in soccer athletes aged 13 to 25 years. We are unaware of any warm-up exercises that lead to both decreased injury and increased performance.

Before we understand how specific exercises reduce the occurrence of injury, we must be able to accurately and reproducibly identify specific exercises performed by teams in the field. Currently, no measurement tool can be used to accurately characterize the exercises performed by athletes during injury prevention routines. Therefore, the goal of this investigation was to develop and evaluate an exercise form that can be used by 1) individuals with various backgrounds and experiences and 2) high school sports teams that participate in different pre-participation warm-up programs. This data collection tool will be used in a prospective study to determine the quality and fidelity of exercises performed in a warm-up program. We hypothesized that trained examiners could accurately and reliably use the exercise form to identify and record individual exercises performed during a pre-participation warm-up.

METHODS

Experimental Approach

The project received approval from our University Committee on Human Research (CHRMS #15-580), and the athletes and their parents provided informed consent before participation. In this investigation, we used a repeated-measures study design. Eleven examiners observed five videos of pre-practice warm-ups. These videos were obtained from high schools and showed recorded exercises at two different times. Accuracy, interexaminer reliability, and intraexaminer reliability were assessed.

Procedures

A former Division I National Collegiate Athletic Association (NCAA), head-university, athletic trainer (RC) observed 130 pre-participation high school workout sessions. Additionally, the trainer recorded the exercises performed. A group of sports medicine surgeons, epidemiologists, and athletic trainers reviewed the exercise descriptions. They then created an exercise form to characterize 30 individual exercises during a typical pre-practice warm-up (Appendix 1). Additionally, all the exercises in the FIFA 11+ warm-up were added to the form. The exercises were divided into categories that described the type of activity completed such as running, dynamic mobility training, dynamic stretching, static stretching, strengthening, plyometric training, agility and balance training, and sports-specific exercising components. These exercise categories were subdivided into additional descriptive component exercises.

Eleven different examiners observed five videos of pre-practice warm-ups. The videos included complete uninterrupted footage of live practice sessions that were obtained from local high schools. The pre-participation warm-up programs included teams that used a FIFA 11+ warm-up or their standard warm-up routine, which included four soccer teams (ie, two junior varsity boys, one varsity boys, and one varsity girls) and one football team (ie, junior varsity and varsity combined). On a data sheet, the examiners recorded the specific exercises performed at two time points (14 to 21 days apart).

A total of 11 examiners participated in this study; one certified athletic trainer, four athletic training students, three medical students, and three post-baccalaureate pre-medical students. Each examiner was trained by an expert (RC) to recognize and record the warm-up routine. The expert evaluator was a former Division I NCAA, head university, athletic trainer with more than 25 years of experience with implementing the FIFA 11+ and other warm-up programs. The training for the examiners included about 6 h of direct observation and training at local high school sites. Training continued until the examiners mastered documenting the observed exercises with the exercise form.

The examiners then characterized the high school team’s pre-practice warm-up for the entire fall 2016 season. They received ongoing feedback from the expert athletic trainer before participating in the accuracy and reliability study. The sessions were shown through video presentation. This was because we thought that having 11 examiners and an expert examiner all standing on the sidelines of a practice session would bias the quality and effort of the performance of the exercises. The players and teams were all used to having video analysis of their practices; therefore, the intrusion at practice and potential bias were negligible.

The examiners were asked to attend two 1-hour testing sessions. During each session, the examiner observed six videos of pre-participation team exercises...
that were obtained from six high school teams, each lasting about 10 min. The examiners were not told that they were going to evaluate the same videos at the second session. At each session, they were provided with the same instructions and were required to immediately complete an exercise form for each video they observed (Appendix 1).

**Statistical Analysis**
Examiner reliability of the observations were evaluated using a repeated-measures study design and computing intraclass correlations coefficients (ICC). ICC were calculated between the 11 examiners and individually. Accuracy was assessed by comparing the observations of 10 examiners to that of one expert athletic trainer, which was considered the “gold standard.” Sensitivity, specificity, and percent agreement were computed across examiners for each exercise component.

**RESULTS**

**Reliability Results**
Of the 27 FIFA 11+ and 64 non-FIFA exercise components included in the form, there were 37 observed in the warm-up videos at least once. These exercises and ICC (individually and between examiners) are shown in Table 1. Of 110 observations, there were 46 (41.8%) that included at least one component of the FIFA 11+ program; however, only six FIFA 11+ running components were observed. Individual examiners were consistent about whether a warm-up included a FIFA 11+ exercise or not (ICC = 0.87). However, there was less agreement between examiners (ICC = 0.69).

The reliability associated with identification of the six FIFA 11+ running components was varied (Table 1). Agreement was high of individual examiners (ICC = 1.00) and between examiners (ICC = 0.80-0.87) for “circling partner,” “shoulder contact,” and “quick forward and backward running” exercises. Agreement of individual examiners was also high for “straight ahead running” (ICC = 0.85); however, agreement between examiners was low (ICC = 0.31). For “hip in” and “hip out” exercises, agreement of individual examiners and between examiners was low (ICC = 0.47 and 0.28, respectively).

The reliability regarding observations of non-FIFA 11+ running exercises also varied considerably. The lowest agreements were observed for the “straight ahead” exercise and the “increase pace” exercise (ICC of individual examiners = 0.64 and 0.67, ICC between examiners = 0.22 and 0.33, respectively). There was moderate agreement of individual examiners for non-FIFA dynamic mobility components; however, for most of these exercises there was low agreement between examiners (ICC < 0.50). Only the exercise “leg swings: back with forward touch” had a higher reliability between examiners (ICC = 0.72). A number of exercises with non-FIFA dynamic stretching were recorded with high reliability in individual examiners and between examiners. However, there was a low reliability between examiners for “heel on ground forward lean-hold” (ICC = 0.25), “heel on ground forward lean-scoop ground” (ICC = 0.44), “front lunge with UB rotation” (ICC = 0.57), and “side lunge - hold” (ICC = 0.50).

To determine if the low reliability between examiners for both the FIFA 11+ and non-FIFA “straight ahead” running components was attributable to disagreement about whether the exercise should be classified as a component of FIFA 11+, the responses were combined. This did not improve agreement between examiners (ICC = 0.24), which indicated that identification of the exercise, not its classification as a FIFA 11+ component, was responsible for the low reliability. In contrast, combining the FIFA 11+ “hip out” running component with the non-FIFA “hip out” dynamic mobility component substantially improved reliability of individual examiners (ICC = 1.00) and between examiners (ICC = 0.69). Similar reliability results were obtained for individual examiners and between examiners when the corresponding “hip in” exercises were combined (ICC = 0.92 and 0.70, respectively).

Additionally, improvements in reliability were obtained when similar non-FIFA warm-up exercises were combined. For example, when combining “leg swings” with “back or diagonal” and “back with forward touch,” there was improved reliability of individual examiners (ICC = 0.94) and between examiners (ICC = 0.94). Similarly, when the dynamic mobility exercise “side lunge - side to side” was combined with the dynamic stretch exercise “side lunge - hold,” the ICC of individual examiners and between examiners was 0.97 and 0.86, respectively.

**Accuracy Results**
Table 2 compares the examiners’ and expert examiner’s accuracy of observations regarding exercises included in the reliability analysis. Sensitivity ranged from 22.5% for non-FIFA dynamic stretching (ie, “heel on the ground forward lean-hold”) to 100% for the non-FIFA dynamic stretching exercises (ie, “knee to chest” and “heel to butt”). For most exercise components, specificity was higher than sensitivity.

However, two exercises had particularly low specificity: the dynamic mobility exercise “leg swings: front/back” (68%) and the dynamic stretching exercise “heel on ground forward lean – scoop ground” (62.5%). Based on the expert examiner, the exercise “leg swings front/back” was not performed in any of the videos but the similar exercise “leg swings: front or front diagonal” was performed in all videos. The exercise “leg swings: front or front diagonal” was observed with only 65% sensitivity; however, the sensitivity improved to 97.0% when the two exercises were combined. This increase in sensitivity indicated that the examiners had difficulty distinguishing between the two exercises. Similarity, the low specificity for the stretching exercise “heel on ground forward lean – scoop ground” appears to be because of its similarity to “heel on ground forward lean – hold,” which had very low sensitivity (22.5%). When these two exercises were combined, sensitivity improved to 96.7% and specificity to 100%.
| Table 1. Observation of exercise components: frequency and estimated reliability in individual examiners and between examiners |
|--------------------------------------------------|-----------------|-----------------|-----------------|
| Component                                         | Frequency (%)   | ICC individual examiners | ICC between examiners |
| FIFA 11+ Part 1 running components                |                 |                             |                             |
| Straight ahead                                    | 23              | 20.9                        | 0.85                        | 0.31                        |
| Hip out                                           | 22              | 20.0                        | 0.47                        | 0.28                        |
| Hip in                                            | 22              | 20.0                        | 0.47                        | 0.28                        |
| Circling partner                                  | 40              | 36.4                        | 1.00                        | 0.87                        |
| Shoulder contact                                  | 40              | 36.4                        | 1.00                        | 0.87                        |
| Quick forwards and backwards                      | 18              | 16.4                        | 1.00                        | 0.80                        |
| Non-FIFA 11+ running components                   |                 |                             |                             |
| Jogging                                           | 70              | 63.6                        | 0.73                        | 0.66                        |
| Jogging straight ahead                            | 23              | 20.9                        | 0.64                        | 0.22                        |
| Jogging backwards                                 | 20              | 18.2                        | 0.90                        | 0.81                        |
| Side shuffle                                      | 21              | 19.1                        | 0.77                        | 0.77                        |
| Karaoke                                           | 17              | 15.5                        | 0.94                        | 0.75                        |
| Increased pace                                    | 58              | 52.7                        | 0.67                        | 0.33                        |
| Change of direction: front/back                   | 5               | 4.5                         | --                          | --                          |
| Change of direction: side/side                   | 3               | 2.7                         | --                          | --                          |
| Sports specific/progression of running: sprinting | 6               | 5.5                         | --                          | --                          |
| Non-FIFA dynamic mobility exercises               |                 |                             |                             |
| High knee                                         | 109             | 99.1                        | --                          | --                          |
| Butt kicks                                        | 108             | 98.2                        | --                          | --                          |
| Leg swings: front/back                            | 32              | 29.1                        | 0.68                        | 0.30                        |
| Leg swings: front/front diagonal                  | 75              | 68.2                        | 0.65                        | 0.26                        |
| Leg swings: back/back diagonal                    | 9               | 8.2                         | --                          | --                          |
| Leg swings: back with front touch                 | 33              | 30.0                        | 0.74                        | 0.72                        |
| Hip in                                            | 60              | 54.5                        | 0.67                        | 0.44                        |
| Hip out                                           | 60              | 54.5                        | 0.74                        | 0.48                        |
| Hip internal rotation                             | 6               | 5.5                         | --                          | --                          |
| Hip external rotation                             | 9               | 8.2                         | --                          | --                          |
| Power karaoke                                     | 4               | 3.6                         | --                          | --                          |
| Side lunge: side to side                          | 22              | 20.0                        | 0.58                        | 0.34                        |
| Non-FIFA dynamic stretching                       |                 |                             |                             |
| Knee to chest                                     | 44              | 40.0                        | 1.00                        | 1.00                        |
| Heel to butt                                      | 24              | 21.8                        | 0.92                        | 0.92                        |
| Heel to butt, front touch                         | 2               | 1.8                         | --                          | --                          |
| Heel on ground, forward lean, hold                | 25              | 22.7                        | 0.47                        | 0.25                        |
| Heel on ground, forward lean, scoop               | 41              | 37.3                        | 0.69                        | 0.44                        |
| Hip external rotation/glut hold                   | 20              | 18.2                        | 0.90                        | 0.90                        |
| Front lunge, hold                                 | 68              | 61.8                        | 0.80                        | 0.77                        |
| Front lunge with upper body rotation              | 15              | 13.6                        | 0.57                        | 0.57                        |
| Back lunge, hold                                  | 1               | 0.9                         | --                          | --                          |
| Side lunge, hold                                  | 49              | 44.5                        | 0.71                        | 0.50                        |

FIFA, Fédération Internationale de Football Association; ICC, intraclass correlation coefficients; --, not applicable.
Table 2. Accuracy of the 11 examiners’ observations compared to those of the “gold standard” examiner

<table>
<thead>
<tr>
<th>Component</th>
<th>Performed</th>
<th>Not performed</th>
<th>Total (n = 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Sensitivity</td>
<td>n</td>
</tr>
<tr>
<td>FIFA 11+ Part 1 running components</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>Straight ahead</td>
<td>20</td>
<td>60.0</td>
<td>80</td>
</tr>
<tr>
<td>Hip out</td>
<td>40</td>
<td>37.5</td>
<td>60</td>
</tr>
<tr>
<td>Hip in</td>
<td>40</td>
<td>37.5</td>
<td>60</td>
</tr>
<tr>
<td>Circling partner</td>
<td>40</td>
<td>90.0</td>
<td>60</td>
</tr>
<tr>
<td>Shoulder contact</td>
<td>40</td>
<td>90.0</td>
<td>60</td>
</tr>
<tr>
<td>Quick forwards and backwards</td>
<td>20</td>
<td>80.0</td>
<td>80</td>
</tr>
<tr>
<td>Non-FIFA 11+ running components</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jogging</td>
<td>60</td>
<td>93.3</td>
<td>40</td>
</tr>
<tr>
<td>Jogging straight ahead</td>
<td>40</td>
<td>32.5</td>
<td>60</td>
</tr>
<tr>
<td>Jogging backwards</td>
<td>20</td>
<td>85.0</td>
<td>80</td>
</tr>
<tr>
<td>Side shuffle</td>
<td>20</td>
<td>85.0</td>
<td>80</td>
</tr>
<tr>
<td>Karaoke</td>
<td>20</td>
<td>75.0</td>
<td>80</td>
</tr>
<tr>
<td>Increased pace</td>
<td>80</td>
<td>62.5</td>
<td>20</td>
</tr>
<tr>
<td>Non-FIFA - dynamic mobility exercises</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg swings: front and back</td>
<td>0</td>
<td>--</td>
<td>100</td>
</tr>
<tr>
<td>Leg swings: front/front diagonal</td>
<td>100</td>
<td>65.0</td>
<td>0</td>
</tr>
<tr>
<td>Leg swings: back with front touch</td>
<td>20</td>
<td>90.0</td>
<td>80</td>
</tr>
<tr>
<td>Hip in</td>
<td>60</td>
<td>78.3</td>
<td>40</td>
</tr>
<tr>
<td>Hip out</td>
<td>60</td>
<td>80.0</td>
<td>40</td>
</tr>
<tr>
<td>Side lunge: side to side</td>
<td>20</td>
<td>60.0</td>
<td>80</td>
</tr>
<tr>
<td>Non-FIFA - dynamic stretching</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee to chest</td>
<td>40</td>
<td>100.0</td>
<td>60</td>
</tr>
<tr>
<td>Heel to butt</td>
<td>20</td>
<td>100.0</td>
<td>80</td>
</tr>
<tr>
<td>Heel on ground, forward lean, hold</td>
<td>40</td>
<td>22.5</td>
<td>60</td>
</tr>
<tr>
<td>Heel on ground, forward lean, scoop</td>
<td>20</td>
<td>50.0</td>
<td>80</td>
</tr>
<tr>
<td>Hip external rotation/glut, hold</td>
<td>20</td>
<td>90.0</td>
<td>80</td>
</tr>
<tr>
<td>Front lunge, hold</td>
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<td>95.0</td>
<td>40</td>
</tr>
<tr>
<td>Front lunge with upper body rotation</td>
<td>20</td>
<td>65.0</td>
<td>80</td>
</tr>
<tr>
<td>Side lunge, hold</td>
<td>40</td>
<td>82.5</td>
<td>60</td>
</tr>
</tbody>
</table>

FIFA, Fédération Internationale de Football Association; --, not applicable.

DISCUSSION
To our knowledge, this is the first study to determine a form’s accuracy and reliability at characterizing pre-practice exercises with the intention of preventing injury in high school athletic teams. Most exercises observed were non-FIFA 11+. Of the FIFA 11+ exercises, we only performed and identified part 1 and not parts 2 or 3. Although examiners’ observations varied, the accuracy and reliability improved considerably when the exercise categories were combined into common groups. There were several factors that affected reliability and accuracy, and these should therefore be addressed for future studies.

Observations of FIFA 11+ running components were more reliable in individual examiners than between examiners and varied considerably across specific exercises. Reliability was low in individual examiners and between examiners for the exercises “hip in running” and “hip out running.” Additionally, reliability was low between examiners for “run straight ahead.” Varying considerably, observations of non-FIFA 11+ exercise components were more reliable in individual examiners than between examiners. The exercises “running straight ahead,” “increasing pace,” “placing heel on ground forward lean and hold,” “placing heel on ground forward lean and scoop ground,” and performing “front lunge” and “side lunge” had low reliability between examiners. Most other exercise components had high reliability individually and between examiners.

The lower reliability of examiners’ observations of similar exercises can be partly attributed to variation in the athletes’ performance of the movements. As the similarity between two exercises increases (eg, hip in vs hip out running), individual athletes might be performing different exercises. This lack of uniformity may have affected the examiners’ ability to determine which group exercise to report. When similar exercises with low ICC were grouped together, the observations became more reliable. For example, combining the exercises “hip in and out” with “leg swings back and
diagonal” and “leg swings back and forward with touch” improved ICC individually and between examiners. Another example is combining “side lunge - side to side” with “side lunge - hold.”

Similar to reliability, the accuracy of observations varied across individual exercise components. Exercise observations of non-FIFA dynamic stretching had the greatest variation, with sensitivity ranging from 22% to 100%. Specificity was higher than sensitivity for most of the comparisons, which indicated that examiners were more likely to miss exercises that were performed than to identify ones that were not performed. When similar exercises were combined (eg, “leg swings” and “heel on ground”), the sensitivity and specificity improved from low to above 95%.

The current study has strengths and limitations. The strengths of this investigation were the diversity of the examiners’ educational backgrounds, the inclusion of an expert athletic trainer, and the review of both FIFA and non-FIFA 11+ warm-up exercises performed by high school students who have increased risk of lower extremity injuries. A potential limitation was that instead of teaching the FIFA and non-FIFA warm-up programs to the high school teams, we simply observed the exercises performed. Subsequently, this factor may have made it more difficult for the examiners to identify specific exercises. However, it did have the advantage of simulating the conditions that examiners encounter at typical high school sports programs that are self-trained on FIFA 11+ or perform their own warm-up routine. Furthermore, the form we developed included all exercise components in the FIFA 11+ injury prevention program and was designed to collect information on the focus, cueing, technique, and completeness of each exercise performed. Such detailed information is necessary for evaluating the efficacy of FIFA 11+ and identifying the component exercises most highly associated with injury reduction. Notably, we could not evaluate the accuracy and reliability of the examiners in reporting this information. This is because this study only used the FIFA 11+ running components performed during team warm-ups.

We determined that examiners with different educational backgrounds can make accurate and reproducible observations of warm-ups that include FIFA 11+ running components and other exercises. When observing similar exercises, reliability and accuracy can be improved if exercises are grouped together. To begin to understand how individual exercises decrease risk of injury, it is crucial that examiners can first accurately and reproducibly characterize the individual exercises being completed. Ultimately, this form can be used to study the fidelity and quality of the FIFA 11+ program. Additionally, it can be used to determine which exercises might be related to decreased rates of injury.

REFERENCES
Appendix 1
Observation of Team Warm-Up Form
University of Vermont FIFA 11+ Injury Prevention Study

Date of Observation: ________________________  
School: ________________________  
Sport: Soccer / Football  
Team: Freshman / JV / Varsity  
Sex: Boys __ Girls __  
Data Collector: ________________________  
Total Duration of Warm-Up: ________________________

Were components of the FIFA 11+ program used as a warm-up? __ Yes ____ No  
Was the FIFA 11+ program followed in order from start to finish? __ Yes ____ No  
Were there modifications in distance, cones, repetitions, exercises etc? __ Yes ____ No

Components of FIFA 11+ Exercises Observed

Part 1 Running: (8 min) Time spent on Part 1 running exercises: ____________
<table>
<thead>
<tr>
<th>Focus</th>
<th>Cueing</th>
<th>Technique % Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight ahead</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Hip Out</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Hip In</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Circling partner</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Shoulder contact</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Quick forwards and backwards</td>
<td></td>
<td>yes / no / partial</td>
</tr>
</tbody>
</table>

Part 2 Strength / Plyometrics / Balance: (10 min) Time spent on Part 2: ____________
<table>
<thead>
<tr>
<th>Focus</th>
<th>Cueing</th>
<th>Technique % Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>The bench</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Static</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Alternate legs</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>One leg lift and hold</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Sideways bench</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Static</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Raise &amp; lower hips</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>With leg lift</td>
<td></td>
<td>yes / no / partial</td>
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<tr>
<td>Hamstrings</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Beginner</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Intermediate</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Advanced</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Single leg stance</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Hold the ball</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Throwing ball partner</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Test your partner</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Squats</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>With toe raise</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Walking lunges</td>
<td></td>
<td>yes / no / partial</td>
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<tr>
<td>One-leg squats</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Jumping</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Vertical jumps</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Lateral jumps</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Box jumps</td>
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<td>yes / no / partial</td>
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</table>

Part 3 Running: (2 min) Time spent on Part 3 running exercises: ____________
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<thead>
<tr>
<th>Focus</th>
<th>Cueing</th>
<th>Technique % Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Across the field/court</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Bounding</td>
<td></td>
<td>yes / no / partial</td>
</tr>
<tr>
<td>Plant &amp; cut</td>
<td></td>
<td>yes / no / partial</td>
</tr>
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</table>

Components of NON-FIFA 11+ Warm-Up Observed

**Part 1 Running Components:**

<table>
<thead>
<tr>
<th>Time spent on running components:</th>
<th>Jogging:</th>
<th>Time</th>
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<tbody>
<tr>
<td></td>
<td>____</td>
<td>______</td>
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<td>____</td>
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<tr>
<td></td>
<td>____</td>
<td>______</td>
<td>Side shuffles</td>
<td>____</td>
<td>Karaoke</td>
<td>____</td>
</tr>
</tbody>
</table>

**Dynamic mobility:** Time spent on dynamic mobility/stretch: Walking Jogging

<table>
<thead>
<tr>
<th>High knees</th>
<th>Butt kicks</th>
<th>Leg swings: front/back</th>
<th>Leg swings: front or front diagonal</th>
<th>Leg swings: back or back diagonal</th>
<th>Leg swings: back with forward touch</th>
<th>Leg swings: add/abd</th>
</tr>
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</table>

**Dynamic stretch:**

<table>
<thead>
<tr>
<th>Knee to chest</th>
<th>Heel to butt</th>
<th>Heel to butt, bend to touch toes</th>
<th>Heel on ground forward lean- hold</th>
<th>Heel on ground forward lean- scoop ground</th>
<th>Ext Rot- glut- hold</th>
<th>Front lunge-hold</th>
<th>Front lunge with UB rot</th>
<th>Side lunge- hold</th>
</tr>
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</table>

**Static stretch:** Time spent on static stretch: Seated Standing

<table>
<thead>
<tr>
<th>&quot;Stretch on your own&quot;</th>
</tr>
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<tbody>
<tr>
<td>________</td>
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</table>

**Part 2 Strength/Plyometrics/Balance Components:**

**Strength:**

<table>
<thead>
<tr>
<th>Sit ups</th>
<th>Push ups</th>
<th>Front plank</th>
<th>Side planks</th>
<th>Bridging</th>
<th>Jumping jacks</th>
</tr>
</thead>
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**Plyometrics:**

<table>
<thead>
<tr>
<th>Single leg</th>
<th>Double leg</th>
<th>Combined (SL-DL or DL-SL)</th>
</tr>
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<tbody>
<tr>
<td>Time: _____</td>
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**Agility/balance:**

<table>
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<tr>
<th>Agility/balance static:</th>
<th>Single leg</th>
<th>Double leg</th>
<th>Combined (SL-DL or DL-SL)</th>
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<tbody>
<tr>
<td>Time: _____</td>
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**Agility/balance dynamic:**

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<tr>
<th>Agility/balance dynamic:</th>
<th>Single leg</th>
<th>Double leg</th>
<th>Combined (SL-DL or DL-SL)</th>
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<tbody>
<tr>
<td>Time: _____</td>
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</table>

**Part 3 Sports specific and Progression of Running Components:**

<table>
<thead>
<tr>
<th>Running/sprinting across the field/court</th>
<th>Bounding</th>
<th>Plant &amp; Cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time: _______</td>
<td>_______</td>
<td>_______</td>
</tr>
</tbody>
</table>

**Other Sports Specific Warm-Up**

| Time: ______ |

**General questions/observations:**

Who was leading the warm-up? coach captain no-one other

Was the warm-up done as: a team individuals (on own) by position

Was the team generally focused throughout the warm-up? Yes / No / Partial

Was there correct form/technique done throughout warm-up? Yes / No / Partial

Did the warm-up run continuously? Yes / No / Partial

Did the warm-up have significant stop/stand time? Yes / No / Partial

Time of total warm-up: _______
Patient Compliance With Follow-Up After Open Reduction and Internal Fixation for Treating Malleolar Ankle Fractures: A Retrospective Review

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Conflict of Interest The authors report no conflicts of interest.

ABSTRACT
Background: Compliance with follow-up after orthopaedic procedures is variable and does not always occur as recommended. Various factors such as medical, financial, cultural, and logistical reasons may contribute to this lack of compliance. The purpose of this study was to determine follow-up compliance of patients who had undergone open reduction and internal fixation (ORIF) for treating closed malleolar ankle fractures.

Methods: Medical records of patients who underwent ORIF for treating closed malleolar ankle fractures by the senior author (RAM) were reviewed to evaluate compliance with postoperative follow-up (n = 267). Inclusion criteria were patients with isolated, acute, closed fractures (n = 229). Patients were considered to have followed up appropriately if they returned to clinic after a removable cast boot was issued at 4 to 8 weeks postoperatively. A 2-tailed t test was performed to analyze age and visual analogue scale score at the time of obtaining the removable cast boot. Chi-square testing was performed to analyze the other variables studied.

Results: Of the 229 patients included, a total of 183 complied with follow-up whereas 46 did not. Younger age, male sex, and living greater than 160.9 km (100 mi) from the hospital were statistically significant variables associated with decreased compliance with follow-up.

Conclusions: In our patient population, 80% of patients followed up in clinic as scheduled. The remaining 20% did not adhere with scheduled follow-up either before or after obtaining a removable cast boot. Younger age, male sex, and living greater than 100 miles from the hospital were associated with decreased compliance. Consideration should be paid to these factors when treating patients with ankle fractures.

Keywords: Follow-Up Care, Ankle Fracture, Surgical Cast

INTRODUCTION
After undergoing orthopaedic procedures, patients do not always follow-up as recommended. Reasons for loss to follow-up can be multifactorial, potentially including medical, financial, cultural, social, and logistical variables. In addition to potential problems with treatment outcomes, loss to follow-up may introduce bias in clinical studies. This is because the patients lost to follow-up may have a different outcome than those who returned.

In the current study, we reviewed patient compliance with follow-up to clinic appointments after surgical treatment of closed malleolar ankle fractures. These patients underwent open reduction and internal fixation (ORIF) between 2012 through 2016. Medical records were evaluated to determine follow-up length; furthermore, we analyzed factors that might be associated with failure to return for follow-up. We hypothesized that there would be variables associated with noncompliance.

METHODS
After obtaining approval from our Human Research Review Committee (HRRC #18-362), we reviewed medical records of patients who underwent ORIF for treating closed malleolar ankle fractures. The procedures were performed by a single surgeon, the senior author (RAM), from 2012 through 2016. A total of 267 patients were initially identified. Inclusion criteria were patients with isolated, acute, closed fractures. Patients with open fractures, other fractures in their body, and treated initially using an external fixator were excluded. In total, 229 patients were included in the study.

The recorded variables were as follows: age, sex, number of anatomical locations internally fixed, inpatient or outpatient surgical procedure, primary language, clinic of follow-up, distance to hospital from city of residence, week obtained removable cast boot, visual
analogue scale (VAS) score at time of obtaining the removable cast boot, and week of final follow-up visit.

After undergoing ORIF, patients were placed in a splint. The splint was exchanged for a cast when the staples were removed at 2 to 3 weeks postoperatively. Patients remained non-weight bearing and used crutches until 4 to 8 weeks postoperatively. At that time, they received a removable cast boot and began progressive weight bearing and ankle motion. Patients were given monthly follow-up appointments to assess radiographic healing and functional recovery. Compliance with follow-up was noted when patients returned for a clinic visit after receiving a removable cast boot. Noncompliance was considered when patients did not return for the clinic appointment before or after receiving the removable cast boot.

Statistical analysis was performed on the recorded variables to determine any significant association with loss to follow-up. A 2-tailed t test was performed to analyze age and VAS score at the time of obtaining the removable cast boot. The other variables were analyzed using the chi-square test.

RESULTS
Of the 229 patients included, 183 (80%) complied with follow-up and 46 (20%) did not. A total of 181 patients in the follow-up group had a minimum of 10 weeks postoperative follow-up. Two patients had less than 10 weeks postoperative follow-up but were placed in the compliant group because they returned after receiving the removable cast boot and were discharged from clinical on their final visit.

For those that did not comply with follow-up (n = 46), two patients did not return at all postoperatively. Nine patients did not return after staple removal at 2 weeks postoperatively, although they were placed in a cast. The remaining 35 patients did not return after receiving the removable cast boot at 4 to 8 weeks postoperatively. Of the patients who received the removable cast boot 4 to 8 weeks postoperatively, a total of 16% had no further follow-up (Table 1).

As shown in Table 1, variables such as younger age, male sex, and living greater than 160.9 km (100 mi) from the hospital were statistical predictors for noncompliance with follow-up. The number of anatomical parts treated surgically, whether performed as inpatient or outpatient, and the primary language of the patient were not statistically significant. The VAS score at the time of obtaining the removable cast boot and living less than 160.9 km (100 mi) from the hospital were also not significantly different between the two groups.

DISCUSSION
In the current study, we examined variables affecting follow-up rates in patients who underwent surgical treatment of malleolar ankle fractures. Patients who were younger, male, and living greater than 160.9 km (100 mi) from the hospital were statistically less likely to comply with follow-up. Overall, a total of 20% of patients did not comply with follow-up. Of those that followed up enough times to obtain a removable cast boot, a total of 16% did not return for another clinic appointment. Several studies have examined compliance with follow-up in patients with orthopaedic-related traumatic injuries, with results similar to our own findings.

Stone et al reviewed 1818 trauma patients who were discharged from a level I trauma center. This study included patients with and without orthopaedic-related injuries. Only 31% of patients complied with follow-up within 4 weeks from discharge. In a smaller population size, Zelle et al studied 307 patients who underwent surgical treatment of orthopaedic-related injuries at a level I trauma center. Of those, only 215 attended at least one of their follow-up appointments between hospital discharge and the 6-month follow-up. In this study, patients who were male, uninsured or had government insurance, and smoked were statistically more likely to be noncompliant with the 6-month follow-up. Illicit drug abuse was significantly associated with noncompliance to any of the follow-up appointments during the 6-month period. In another level I trauma center study, a total of 33.1% of 2165 patients were not compliant with attending their first clinic appointment after undergoing orthopaedic treatment. Patients who used tobacco, lived more than 160.9 km (100 mi) from the clinic, did not have private insurance, or had a fracture of the hip or pelvis were significantly less likely to follow-up. In this study, the variables of age, sex, and race were not significantly associated with failure to follow-up.

Other variables associated with noncompliance have been evaluated, including homelessness and country. Kay et al studied 63 uninsured homeless patients with orthopaedic-related injuries and compared their compliance with follow-up to that of 63 non-homeless patients. The homeless patients returned to fewer orthopaedic follow-up appointments than did the non-homeless patients after their initial visit to the emergency department. Somerson et al reviewed randomized controlled trials associated with orthopaedic surgery from 2008 to 2011. There were no significantly different follow-up rates between the subspecialties; however, studies with at least 3 years of follow-up had significantly higher rates of loss to follow-up than those of studies with less than 3 years. In addition, studies performed in the United States had significantly higher rates of loss to follow-up than those of other countries.

Our study has several limitations. It is a retrospective review, and no intervention was performed in an attempt to improve the rate of follow-up. We only reviewed patients who underwent operative fixation of isolated, closed malleolar ankle fractures and did not examine other orthopaedic-related injuries or patients with multiple injuries. Furthermore, it is possible that patients lost to follow-up were seen outside of our hospital system.
Table 1. Variables of the patients who followed up and of those that did not (n = 229) after operative treatment of closed malleolar ankle fractures

<table>
<thead>
<tr>
<th>Patient variable</th>
<th>Follow-up group (n = 183)</th>
<th>Non-follow-up group (n = 46)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, y (range)</td>
<td>38 (18-75)</td>
<td>31.8 (18-56)</td>
<td>0.0008</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td>0.029</td>
</tr>
<tr>
<td>Male</td>
<td>103</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>80</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Number of anatomical parts treated</td>
<td></td>
<td></td>
<td>0.81</td>
</tr>
<tr>
<td>1</td>
<td>70</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Hospital setting</td>
<td></td>
<td></td>
<td>0.8</td>
</tr>
<tr>
<td>Inpatient</td>
<td>29</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Outpatient</td>
<td>154</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Primary Language</td>
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<td>0.43</td>
</tr>
<tr>
<td>English</td>
<td>169</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Spanish</td>
<td>14</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Clinic</td>
<td></td>
<td></td>
<td>0.67</td>
</tr>
<tr>
<td>General orthopaedic clinic</td>
<td>137</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Faculty orthopaedic clinic</td>
<td>19</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td>27</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>VAS score when obtained RCR (range)*</td>
<td>1.88 (0-10)</td>
<td>2.19 (0-9)</td>
<td>0.52</td>
</tr>
<tr>
<td>Distance of city of residence from hospital:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same city</td>
<td>148</td>
<td>33</td>
<td>--</td>
</tr>
<tr>
<td>&lt; 80.5 km (50 mi)</td>
<td>16</td>
<td>4</td>
<td>0.85</td>
</tr>
<tr>
<td>&lt; 80.5–160.9 km (50-100 mi)</td>
<td>9</td>
<td>1</td>
<td>0.51</td>
</tr>
<tr>
<td>&gt; 160.9 km (100 mi)</td>
<td>10</td>
<td>8</td>
<td>0.0087</td>
</tr>
</tbody>
</table>

*, not applicable; VAS, visual analogue scale; RCR, removable cast boot.
*A total of 177 VAS scores were available from the follow-up group, and 41 VAS numbers were available from the non-follow-up group. Patients received a removable cast boot between 4 to 8 weeks postoperatively.

In conclusion, our study was unique by only evaluating patients with isolated, closed malleolar ankle fractures. The significant variables associated with lack of follow-up (ie, age, male sex, and distance to hospital) should be kept in mind when treating patients with ankle fractures. It is not known what type of intervention might improve the follow-up rate in this patient population. Results of future prospective multicenter studies may help determine effective, individualized methods to consistently follow-up with patients after operative treatment of malleolar ankle fractures.

REFERENCES
Training Orthopaedic Residents to Formulate Evidence-Based Questions

Jonathan D. Eldredge, PhD

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Department of Family & Community Medicine, The University of New Mexico Health Sciences Center, Albuquerque, New Mexico

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Conflict of Interest: The author reports no conflicts of interest.

ABSTRACT
Background: Formulating questions that are both focused and answerable is an essential clinical skill for evidence-based practice (EBP). Possessing this skill can successfully launch research projects. Yet studies have depicted mixed results pertaining to the teaching of question formulation. This report describes introducing orthopaedic residents to question formulation and showcases an accompanying evaluation rubric originally developed for training second-year medical students.

Methods: In this prospective cohort study, a total of 23 orthopaedic residents at The University of New Mexico Health Sciences Center participated in a 1-hour training. The study included application exercises using an evaluation rubric for learners to assess each other’s formulated questions followed by faculty members’ feedback. A Likert scale was used to evaluate participant responses.

Results: Anonymous student evaluations rated the training and application exercises highly (>4.0 of 5.0 on the Likert scale).

Conclusions: Future collaborations with other residency programs could foster increased success rates in teaching question formulation skills. With these skills, orthopaedic residents could better integrate EBP into their daily clinical service and likely develop better clinical research questions.

Keywords: Question Formulation, Evidence Based Practice, Medical Education, Logic, Concept Formation

INTRODUCTION
The skill to formulate effective questions offers various benefits for orthopaedic residents and practitioners. In evidence-based practice (EBP), being able to formulate a clear question serves as the first step towards making a sound clinical decision. Additionally, this skill promotes lifelong learning and facilitates the research process. Clinicians pose an average of one question for every two patients seen, and according to a systematic review, this frequency increases in teaching hospitals. Clinicians raise questions pertaining to treatment and diagnosis about 52% and 25% of the time, respectively, according to a content analysis of clinical questions.

Despite the importance of question formulation in EBP, few studies have reported exclusively on this first step. The second and third steps (ie, information seeking and critical appraisal, respectively) have attracted considerably more attention in EBP studies. For example, only 10 of 678 pages of the most famous EBP manual teach question formulation skills.

To help train and assess learners, the widely cited and validated Fresno Test of Evidence Based Medicine includes two segments on assessing skills in question formulation. However, the Fresno test places greater emphasis toward the second and third steps. Regarding question formulation, the test asks the learner to select either a scenario about breastfeeding or bedwetting; subsequently, it prompts the learner to construct a question according to the EBP Population, Intervention, Comparison, and Outcome (PICO) question structure. The Fresno test’s scoring rubric does not extend into other dimensions that a well-formulated question might include. Another rubric for evaluating learned EBP skills is the Berlin Questionnaire, which resembles the PICO structure. Additionally, Wyer et al devised a rubric that adds the conceptual dimension of foreground versus background question typology, a concept originally developed by W. Scott Richardson.

A Cochrane-sponsored systematic review studied interventions, most involving residents and physicians, to teach question formulation skills. Specifically, the authors reported that these interventions produced mixed results and recommended a more robust intervention to teach EBP question formulation skills. This Cochrane systematic review on question formulation training motivated the author to develop a more robust intervention to teach EBP question formulation skills. The training was linked to a rubric that evaluated first- and second-year medical students’ formulated questions. The training and use of the rubric began in 2012, through a series of trial and error approaches with students’ providing course-based
feedback (immediate and formal) for an EBP course. The rubric was designed to ensure interrater reliability scores that assured students that their grades were fair.

Over several years, the author used the same rubric and similar training to instruct physician-assistant students and public-health students. The author discovered that little adaptation was needed to the student-training programs despite the different professions. In regards to the most recent training for second-year medical students, anonymous end-of-semester student evaluations indicated a high rating with an average of 3.5 on a 5.0 Likert scale. This education article provides a brief report on using question formulation training with an evaluation rubric for orthopaedic residents at The University of New Mexico Health Sciences Center.

METHODS

After receiving approval from our Human Research Review Committee (HRRC #18-792), the author conducted a prospective cohort study with 23 orthopaedic residents. On October 11, 2017, the exposure involved a 1-hour training session that included exercises on the use of the evaluation rubric (Figure 1). This session was the first of 3 monthly sessions regarding EBP. It was titled “Formulating High Yield Research Questions” and included modeled examples with residents applying what they learned. During the 1-hour session, residents worked together in groups of two or three to formulate and evaluate each other’s questions using the rubric criteria. Afterward, the groups reported their final questions and received comments by either the instructor or the faculty-research advisor.

The 23 residents who participated in the training were asked to turn in evaluation forms, of which 17 residents completed (74% response rate). Table 1 summarizes the core four questions related to their training. Likert scale ratings of 1.0 (disagree) to 5.0 (agree) were used to assess residents’ responses.

RESULTS

In Table 1, the first three evaluation questions pertained specifically to EBP training. With a mean score of 4.53 of 5.0 on the Likert scale, the residents reported that they gained an appreciation for the importance of question formulation (question 1). Residents assigned the highest mean score of 4.76 for learning at least two techniques to formulate effective questions (question 2). Finally, residents believed that the training had improved their question formulation skills with a mean score of 4.53 (question 3). The faculty members at the session were encouraged that the residents also could apply the skills learned toward future research projects (question 4), despite the training being directed within an EBP framework.

DISCUSSION

This 1-hour training session in question formulation using a rubric showed promising results with orthopaedic residents. Previously, this question formulation training and rubric evaluation had been developed and refined for second-year medical students. The rubric was designed to include interrater reliability in the grading of more than 100 questions formulated by medical students per year.16-18

The principal limitation of this study was the small number of residents (n = 23). However, this question...
formulation training and rubric evaluation was endorsed by orthopaedic residents according to their high, anonymous evaluation scores. By publishing the successful findings of this report, the author hopes to prompt colleagues in other residency programs to replicate this study. The author looks forward to collaborating with colleagues and adapting the teaching materials and copyrighted rubric to other teaching contexts. Results of the current study and any future work might help the medical profession improve teaching question formulation skills to residency programs, which might subsequently help overcome the mixed results reported in the Cochrane systematic review. Therefore, including this brief training in the curriculum or orthopaedic residency programs will likely improve valuable question formulation skills.

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Comparison of Narcotic Prescribing Habits Between Trainee and Attending Orthopaedic Surgeons

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Conflict of Interest
The authors report no conflicts of interest.

ABSTRACT

Background: Orthopaedic surgeons are among the highest prescribing physicians of narcotics to opioid-naïve patients. Despite the current opioid epidemic, few studies have specifically quantified the appropriate amount of opioids necessary for postoperative pain control. We hypothesized a significant variability in the quantity of postoperative opioids prescribed among trainee (ie, residents and fellows) and attending surgeons at a single institution.

Methods: Postoperative narcotic prescribing habits were assessed using an anonymous survey. Ultimately, 28 trainee physicians and 17 attending physicians responded to the survey (86.5%). The survey recorded the amount of 5-mg oxycodone tablets that were commonly prescribed to manage pain after various typical orthopaedic procedures (eg, total knee arthroplasty). Non-narcotic analgesic use was also measured. Mean, standard deviation, and variance values were calculated, with significance set at $\alpha = 0.05$.

Results: After the following procedures, the respondents reported prescribing the following quantities of 5-mg oxycodone tablets: total knee arthroplasty, 56 (SD, 16); total hip arthroplasty, 53 (SD, 13); anterior cruciate ligament reconstruction, 38 (SD, 16); partial meniscectomy, 23 (SD, 14); arthroscopic rotator cuff repair, 39 (SD, 16); carpal tunnel release, 10 (SD, 10); A1 pulley release for treating trigger finger, 9 (SD, 9); open reduction and internal fixation (ORIF) for treating distal radius fractures, 32 (SD, 16); and ORIF for treating ankle fractures, 39 (SD, 15). Statistically significant variation existed between trainee and attending physicians for total hip arthroplasty and A1 pulley release. There was no difference for acetaminophen or nonsteroidal anti-inflammatory drugs, with about 70% of patients receiving at least one of these adjuncts.

Conclusions: Variability exists in postoperative opioid prescribing habits between trainee and attending physicians at the academic training institution we accessed. In light of the ongoing opioid epidemic, institutions may benefit from standardized postoperative pain protocols.

Keywords: Narcotic, Opioid, Postoperative, Pain Control

INTRODUCTION

The opioid epidemic in the United States has reached catastrophic proportions, with opioid overdoses now the leading cause of death related to unintentional injury.1,2 In certain states, deaths due to fentanyl and other synthetic opioids have increased by 219% from 2010 to 2015—an increase driven largely by illicitly manufactured fentanyl.3,4 The state of New Mexico ranks twelfth in the country in drug overdose deaths, with a rate that is 25% higher than the national average.5 Data from 2017 indicate that prescription drugs were involved in 68% of drug overdose deaths in the state.6 Additionally, the New Mexico Department of Health reported that prescription opioids caused the most unintentional drug overdoses at 47% between 2011 and 2015.5

Orthopaedic surgeons play a vital role in the opioid epidemic. Nationally, they account for about 7.7% of total opioid prescriptions filled and are only surpassed by general practitioners, internists, and dentists.7 To further complicate the situation, between 21% to 29% of patients misuse prescribed opioids for chronic pain, with an estimated 4% to 6% of those transitioning to heroin.7,10

Despite the opioid epidemic, few studies have quantified the optimal number of opioids needed for managing...
postoperative pain, particularly in relation to specific procedures. The resources that do exist typically offer broad-based suggestions on multimodal pain management. Owing to the lack of data, we hypothesized that there would be a high variability in the quantity of postoperative opioids prescribed among trainee physicians (ie, residents and fellows) and attending physicians in an orthopaedic department at a single institution.

METHODS
We received approval from our Human Research Review Committee (HRRC #17-483). Study participants included trainee and attending physicians of the orthopaedic residency program at a level 1 trauma center, The University of New Mexico Hospital. An anonymous online survey (SurveyMonkey Inc, San Mateo, CA) was distributed and completed by 28 trainee physicians and 17 attending physicians, with an 86.5% response rate. Prescribing habits were evaluated by querying the quantity of 5-mg oxycodone tablets routinely prescribed postoperatively after common orthopaedic procedures. Prescribing habits for non-narcotic analgesia, specifically acetaminophen and nonsteroidal anti-inflammatory medications (NSAIDs), were also queried. The following procedures were included: total knee arthroplasty (TKA), total hip arthroplasty (THA), anterior cruciate ligament (ACL) reconstruction, partial meniscectomy (PM), arthroscopic rotator cuff repair (RCR), carpal tunnel release (CTR), A1 pulley release for treating trigger finger, open reduction and internal fixation (ORIF) for treating distal radius fractures, and ORIF for treating ankle fractures. The mean, standard deviation, and variance between trainee and attending physicians were calculated. The \( \alpha \) was set to a 0.05 significance level.

RESULTS
The average number of 5-mg oxycodone tablets prescribed for each procedure was as follows: TKA, 56 (SD, 16); THA, 53 (SD, 13); ACL reconstruction, 38 (SD, 16); PM, 23 (SD, 14); arthroscopic RCR, 39 (SD, 16); CTR, 10 (SD, 10); A1 pulley release for treating trigger finger, 9 (SD, 9); ORIF for treating distal radius fractures, 32 (SD, 16); and ORIF for treating ankle fractures, 39 (SD, 15).

There was a statistically significant difference in the number of tablets prescribed between trainee and attending physicians after THA (\( P = 0.03 \)) and A1 pulley release for treating trigger finger (\( P = 0.05 \); Figure 1). Notably, there were differences in prescribing that approached statistical significance after TKA (\( P = 0.08 \)) and PM (\( P = 0.06 \)). There was no statistical difference in prescribing habits for acetaminophen or NSAIDs, with about 70% of patients receiving at least one of these adjuncts (Figure 2). There were various responses regarding the amounts of 5-mg oxycodone tablets prescribed after procedures (Table 1). There were no observed prescribing differences among trainee physicians by postgraduate year.

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Figure 1. Trainee versus attending physicians’ quantity of opioid prescribed after various orthopedics procedures. Star (*) denotes statistically significant difference. Error bars represent standard deviation. TKA, total knee arthroplasty; THA, total hip arthroplasty; ACL, anterior cruciate ligament; PM, partial meniscectomy; RCR, rotator cuff repair; CTR, carpal tunnel release; TF, trigger finger; ORIF DR, open reduction and internal fixation for treating distal radius fractures; ORIF ankle, open reduction and internal fixation for treating ankle fractures.
DISCUSSION
In our study at a single institution, we found a high rate of variation in the self-reported narcotic prescribing habits of the respondents. Specifically, there were significant differences between trainee and attending physicians for number of prescribed opioids after THA and A1 pulley release for treating trigger finger. Attending physicians typically prescribed more than did trainees.

Reasons for this difference are likely multifactorial. First, THA and A1 pulley release for treating trigger finger represent both extremes of expected postoperative pain, with A1 pulley release being one of the least painful procedures and THA being one of the most. Second, both procedures are almost exclusively performed by hand and joint surgeons within our department. The surgeons who do not perform these procedures regularly are less likely to have developed routine prescribing habits. Third, attending physicians who were trained before recognition of the opioid epidemic and who do not routinely perform A1 pulley release and THA are more likely to prescribe more opioids for these procedures. Both procedures were associated with a wide range of 5-mg oxycodone tablet

Table 1. Survey results showing reported ranges of postoperative oxycodone tablets (5 mg) prescribed after common procedures by trainee physicians, attending physicians, and both

<table>
<thead>
<tr>
<th>Procedure</th>
<th>No. prescribed by trainee physicians (range)</th>
<th>No. prescribed by attending physicians (range)</th>
<th>No. prescribed by trainee and attending physicians combined (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TKA</td>
<td>28-90</td>
<td>45-120</td>
<td>28-120</td>
</tr>
<tr>
<td>THA</td>
<td>28-90</td>
<td>45-60</td>
<td>28-90</td>
</tr>
<tr>
<td>ACL reconstruction</td>
<td>20-60</td>
<td>20-90</td>
<td>20-90</td>
</tr>
<tr>
<td>PM</td>
<td>5-60</td>
<td>0-60</td>
<td>5-60</td>
</tr>
<tr>
<td>Arthroscopic RCR</td>
<td>20-80</td>
<td>20-90</td>
<td>20-90</td>
</tr>
<tr>
<td>CTR</td>
<td>0-40</td>
<td>0-30</td>
<td>0-40</td>
</tr>
<tr>
<td>A1 pulley release for treating TF</td>
<td>0-30</td>
<td>0-30</td>
<td>0-30</td>
</tr>
<tr>
<td>ORIF for treating DR fractures</td>
<td>10-60</td>
<td>15-90</td>
<td>10-90</td>
</tr>
<tr>
<td>ORIF for treating ankle fractures</td>
<td>15-60</td>
<td>20-90</td>
<td>15-90</td>
</tr>
</tbody>
</table>

TKA, total knee arthroplasty; THA, total hip arthroplasty; ACL, anterior cruciate ligament; PM, partial meniscectomy; RCR, rotator cuff repair; CTR, carpal tunnel release; TF, trigger finger; ORIF, open reduction and internal fixation; DR, distal radius.
quantities that the respondents reported prescribing for a given procedure.

In the current study, each procedure was associated with a surprisingly wide range of 5-mg oxycodone tablets prescribed to the patients. Regarding trainee physicians, the prescribed quantity for arthroscopic RCR ranged from 20 to 80 of the 5-mg oxycodone tablets. This difference is even more apparent when including both trainee and attending physicians, ranging from 28 to 120 of the 5-mg oxycodone tablets after TKA (Figure 1).

Large variations in narcotic prescribing habits have been well documented in emergency medicine and obstetric studies. In a single institution review of narcotic prescriptions for women discharged postpartum, Badreldin et al13 found that the total milligram morphine equivalents for women discharged after vaginal delivery and after cesarean section ranged from 25 to 1200 and 50 to 1800, respectively. In a national study of opioid-naïve patients prescribed narcotics by an emergency department for treating ankle sprains, Delgado et al14 found prescribed ranges of 0 to 450 milligram morphine equivalents. These findings support our own and highlight that large variations in prescribing habits exist not only between trainee and attending physicians, but among all physicians across many specialties.

The cause of the large variation in prescribing is likely multifactorial. Despite the current opioid epidemic and recent guidelines of the Centers for Disease Control and Prevention,15 there are few standardized protocols for prescribing narcotics in the postoperative period. Although some postoperative pain protocols have been successful in reducing milligram morphine equivalents prescribed,16 it is challenging to define a sufficient quantity of narcotics for postoperative pain control after a given procedure. This is because of multiple variables including surgical procedure, surgical time, preoperative opioid exposure, use of non-narcotic agents, and patient variability in pain perception.17 For example, a recent review by Wojahn et al18 found that the number of opiate pills consumed after knee arthroscopy varied greatly. Among individuals who were undergoing meniscal repair, patients who smoked and those taking preoperative opioids were significantly more likely to take higher numbers of opiates (≥ 20 pills vs a median of 7 pills). Furthermore, a debate exists as to whether postoperative narcotics should be prescribed on the basis of a given procedure or by patient-specific opioid usage during hospital admission.12 This is further convoluted by the known differences in patient opioid consumption versus opioids prescribed.19 Although our findings revealed that about 75% of respondents stated they prescribe non-narcotic analgesia, it is still unknown whether prescribing or recommending over-the-counter acetaminophen and NSAIDs results in higher patient compliance with these medications.

Despite these challenges, it appears clear that patients would benefit from more standardized postoperative pain protocols. We published a companion article that explores potential protocols.20

There are several limitations to our study. First, there may be larger disparities in what respondents stated they prescribe as opposed to what they actually prescribe because of the limitations of survey design. Furthermore, all orthopaedic subspecialties were queried and might account for some of the large variation. For example, a survey respondent who practices pediatric orthopaedics may be unfamiliar with studies regarding opioid consumption after arthroplasty. Although most studies quantify milligram morphine equivalents, our study limited our definition to 5-mg oxycodone tablets. This was intentional because we presumed that many of our prescribers were unfamiliar with milligram morphine equivalents conversion. This may limit the external validity of these data. We also did not query length of time for which a narcotic should be prescribed, which may have yielded more or less variability. Lastly, this study was limited to a single, high-volume academic tertiary institution. There may be differences in variability of prescribing at other academic centers or community hospitals.

In light of the ongoing opioid epidemic, institutions may benefit from standardized postoperative pain protocols. Multimodal analgesia should be included in these protocols, including acetaminophen and NSAIDs, as well as preoperative discussions with patients regarding expectations to optimize postoperative pain control. Studies evaluating the benefits of a multisubspecialty postoperative pain protocol are currently underway, and future work dedicated to minimizing narcotic use remains paramount.

REFERENCES


Design for Transtibial Modifiable Socket for Immediate Postoperative Prosthesis

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Conflict of Interest The authors report no conflicts of interest.

ABSTRACT Amputations are long-standing surgical procedures that have been performed for centuries; however, very little attention and urgency have been given to immediate restoration of movement and return to a normal lifestyle. In many cases, the time between amputation and prosthetic fitting can pause recovery and development of new routines. To increase recovery, immediate postoperative prostheses (IPOPs) have been developed yet these are under-utilized because of concerns for wound healing and complications with vascular diseases. Subsequently, we designed a transtibial IPO that utilizes an ergonomic modifiable socket that allows for examination, wound care, and situ edema control. Additionally, the IPO facilitates early weight bearing and protects the amputated limb from external trauma postoperatively. Our purpose is to introduce this technology and describe how its unique design will serve to provide potential benefits and positive effects on patients who have undergone amputations.

Keywords: Leg, Amputation, Amputation Stumps, Artificial Limbs

INTRODUCTION Patient care and rehabilitation after amputation presents considerable social, psychological, and economic challenges. As of 2005, an estimated 1.6 million Americans were living with the loss of a limb, at an estimated cost of $350,000 to $500,000 for treatment, rehabilitation, prosthetics, and follow-up care.1-3 Individual limb loss is expected to double by 2050, with more than 185,000 lower limb amputations performed annually.4,5 Furthermore, amputation most commonly involves the lower extremities. The age-adjusted incidence rate is 2.6 in 10,000 individuals and continues to rise.5 Main causes of lower limb amputation include vascular complications (83%), trauma (12%), malignancy (3%), infection (2%), and congenital limb defects (0.2%). Notably, diabetes remains the single greatest cause of lower limb amputation with 68% of procedures performed as a result of diabetic complications.6-8 Postoperatively, patients typically undergo three periods of adjustment before receiving a final prosthetic: wound care and rehabilitation, immediate recovery phase, and limb stabilization. Wound care and rehabilitation occur after the amputation and may extend several months after hospital discharge. The aim of rehabilitation is to restore functional independence by promoting ambulation and use of a prosthetic limb, yet the fitting of conventional prosthetics is iterative and labor intensive owing to changes in volume, shape, composition, sensitivity, and scarring of residual limb soft tissues. Changes may also occur day-to-day due to temperature, activity, hydration, or swelling.9 Additional changes may occur after several months because of muscular atrophy and soft tissue remodeling.10 After complete healing of the surgical site, the immediate recovery phase begins, 3 to 6 months postoperatively, during which most patients are fitted with a temporary
prosthetic. During this period, considerable changes in residual limb volume and shape necessitate continual prosthetic adjustments. Due to lack of muscle use, joint contractures may also occur and require treatment and physical therapy. Finally, limb stabilization occurs between preliminary prosthesis and final prosthetic fitting, in which relatively frequent prosthetic adjustments occur. Around 1 year postoperatively, patients can be fitted with a definitive prosthetic.

Lower limb amputations not only affect a patient’s ability to walk, but they also influence the patient’s psyche, body image, and quality of life. Patients are physically unable to participate in valued life activities with current treatment methods such as gauze and elastic wrap, rigid plaster dressings, and prefabricated pneumatic postoperative prostheses. This may lead to lowered confidence in prosthetic use and reduced social activity. Such behavior can result in a lack of engagement by the patient, the development of new routines, and a slower recovery process.

In the 1950s, immediate postoperative prostheses (IPOPs) were introduced to increase patient recovery and prosthetic acceptance. IPOPs are placed on patients’ residual limbs in the operating room, are used instead of a rigid removable dressing, and allow for early ambulation and rehabilitation. Traditional IPOPs are placed over (or comprise) plaster that attaches to and protects the limb, whereas current technology allows IPOPs to be secured using various strapping methods and composite materials (ie, soft inner gel liners with rigid outer plastic).

Although studies prove their benefit, IPOPs are currently only prescribed in about 5% of cases owing to concerns of monitoring wound health, edema and swelling changes, and unfamiliarity with the technology. To overcome these limitations, we developed a transtibial IPOP that utilizes a fully adjustable ergonomic design. It is easily removable for examination and wound care, allows for in situ edema control, facilitates early weight bearing, and protects the amputated limb from external trauma immediately after amputation.

**DESIGN**
The transtibial modifiable socket is designed to replace rigid removable dressing, traditional IPOPs, and temporary prosthetic devices currently used in the first year after amputation. Six advancements over previous technology have been implemented:

1. The modifiable socket protects the residual limb while remaining accessible for inspection and wound care.
2. The design uses a woven biaxial mesh sock to provide uniform compression on the residual limb for shaping, edema control, and day-to-day variations in limb swelling.
3. The socket has an open architecture so that the wound receives proper air circulation, can be inspected, and potentially drained.
4. The socket is continually modifiable through ratcheting components that adjust pressure on anatomically safe contact points, all while avoiding loading placed on the surgical site.
5. To transfer load from the residual limb, this design has an upper leg support attached to the socket with a locking knee joint.
6. The locking knee joint helps stabilize patients during early recovery or ambulation while simultaneously helping to restore range of motion and prevent knee flexion contractures by applying an adjustable angular deflection.

**PROSTHETIC SOCKET**
To adjust the overall fit of the socket, the front and rear supports connect at the base of the socket (Figures 1A and 1B) while remaining adjustable to accommodate larger or swollen limbs. Once the socket is in place, the ratcheting tensioner around the upper section of the socket is tightened, which pulls the front and rear supports together and secures the socket to the patient’s residual limb. Because the socket is adjustable, it can be premanufactured in a set of standard sizes (ie, small, medium, large, extra-large), and still gives the patient a secure and comfortable fit. The adjustment system also helps control loading on the residual limb. The front support loads the mid-patellar ligament and tendon, tibial flares, and medial (primary) and lateral (secondary) flares of the tibial condyles (Figure 2C). The rear support loads the knee and popliteal areas (Figure 2D), whereas the tensioning system can be used by physicians and prosthetists to adjust the pressure distribution on these load-bearing sites. During use of the socket, an air gap exists between the proximal end of the amputated limb and base of the plate, with the intention of preventing impact and discomfort to the surgical site. Finally, the socket base is designed to accept any commercially available pylon by utilizing the industry-standard attachment screw pattern for a prosthetic leg or blade (Figure 1A). This feature allows individual users to customize the device.

**BIAXIAL SOCK**
The inner sock surrounds the residual limb, suspending it inside the socket (Figures 1A and 1B). Similar to compressive sportswear fabrics, the use of a biaxial weave in the sock provides circumferential compression, which controls edema in the healing limb while remaining flexible and adjustable when donning or doffing. The sock is fitted by rolling the sleeve over the end of the residual limb and wound dressings before donning of the socket, thereby minimizing application time and contact with the incision site. The excess material is folded over the top of the socket and attached to an adjustment mechanism on the outside surface. The amount of circumferential pressure produced by the sock is controlled by the amount of tension applied to the end of the sock by the patient. 

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Figure 1. Computer-aided model of immediate postoperative prosthesis socket. A) Foot assembly that includes socket, support sock, knee brace, and above-knee supports. B) Side view with sock removed, showing knee flexion and bending.

Figure 2. A) Prosthetic socket and B) prosthetic base plate union. C) Posterior-oblique and D) anterior-oblique views of immediate postoperative prosthesis socket, with load-bearing regions highlighted in blue.
residual limb. This is done after the user’s weight is fully counter-balanced by the socket.

**Load Transfer Above the Knee**

To transfer load away from the end of the residual limb, the socket is connected to a thigh support using a hinged knee brace made of lightweight metal and carbon fiber (Figures 1A and 1B). The thigh strap comprises a compressible padding surrounded by a washable fabric and adjustable straps that can be tightened or loosened to apply load on the upper limb, which allows for a comfortable fit. The upper limb support also helps prevent pistonning and holds the socket onto the residual limb, which would normally be accomplished using vacuum suction or non-breathable liners in the standard socket design. Additionally, users can lock the knee joint that connects the socket to the upper limb. This limits the knee’s range of motion to control for muscle contractures and stabilizes the patient during early ambulation; furthermore, it unlocks the knee to allow for motion during gait retraining.

**Pain and Patient Compliance**

To ensure the greatest possibility of patient compliance, the transtibial modifiable socket was designed with emphasis placed on reduction of pain and ease of use. The segmented components, biaxial sock liner, socket, and knee brace are intended to be donned in sequential order, with the ability to independently adjust each component for comfort and fit. It has been noted that overall patient adoption and recovery are dependent on comfort of the socket and ability to accommodate changes in limb volume and remodeling. As such, the overall design of the transtibial modifiable socket aims to achieve the greatest adjustability and comfort while allowing for a universal fabrication technique and availability for patients immediately after amputation. As such, considerable patient feedback and discovery of the comfort factors will be undertaken to determine optimal final design parameters of the device for the desired user experience.

**CONCLUSION**

We have outlined a design of a modifiable socket for use as an IPOP among patients with transtibial amputations. The design utilizes an adjustable socket that suspends the residual limb by applying loads to anatomical loading sites below the knee and above the knee brace, which reduces end-loading on the recently amputated limb. This allows for immediate adoption by preventing contact with the suture site. The design also implements a compressive sock that suspends the residual limb, provides edema control, and accommodates shape changes of the limb over time. Additionally, the device provides an open air design, which allows for limb inspection and breathability missing from current socket liners. Meanwhile, the surrounding socket serves as a rigid removable dressing that helps prevent strikes and falls that could result in damage to the amputation site. Finally, the adjustable nature of this device allows for pre-fabrication and availability of the socket for use immediately after amputation. This differs from the current sockets that do not allow for custom fitting for days to weeks postoperatively, followed by regular modification and adjustments with changes in limb size and shape.

Overall, the design of this device allows for wound protection while remaining accessible during the immediate recovery phase after amputation. However, the modular and adjustable design should allow for continuous use of the device up to and possibly through the final prosthesis stage. This new universal design should result in early adoption by the patient, with the options of earlier ambulation and faster transition to rehabilitation and recovery.

**REFERENCES**


Technique of Proximal Pole Scaphoid Fracture Fixation Using a Retrograde Pin Placement but Antegrade Screw Placement: A Case Example

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Informed Consent The patient’s family was informed that the data concerning his case would be submitted for publication, and they provided verbal consent.

ABSTRACT

The scaphoid is the most commonly fractured bone of the carpal row. Because of its precarious blood supply, scaphoid fractures are predisposed to avascular necrosis (AVN) and nonunion. This is especially true with fractures of the proximal pole. To decrease the risk of nonunion and AVN, surgical treatment of proximal pole scaphoid fractures is recommended, which facilitates fracture consolidation and long-term wrist function. We describe a 16-year-old adolescent boy who presented with a fracture of the proximal pole of the scaphoid, initially managed nonoperatively. Subsequent imaging findings revealed nonunion of the scaphoid bone. For treatment, a percutaneous fixation was chosen with a retrograde pin placement and antegrade screw placement. At 3 months postoperatively, the patient returned to competitive sports (ie, American football and basketball). Radiographs at 6 months postoperatively revealed promising healing. The described approach can provide an effective option for treating scaphoid fractures with nonunion.

INTRODUCTION

The scaphoid is a complex bone that presents a unique challenge for fracture healing and surgical fixation. The gold standard of treatment remains controversial, despite numerous studies on management of nonunion. Scaphoid fractures rarely involve the proximal pole (6%) and more often involve the tuberosity (17%), waist (66%), and distal pole (11%). Fractures of the proximal pole are especially prone to nonunion and avascular necrosis owing to their tenuous and retrograde blood supply.

Scaphoid fractures are most commonly seen in men between the ages 10 to 29 years, especially men with high physical demands (eg, military training or sports). In patients with displaced fractures or proximal pole involvement, surgical treatment is indicated owing to lower rates of long-term complications compared to nonoperative management. An analysis of different surgical fixation techniques can help minimize complications and improve long-term outcomes. We describe a surgical technique using retrograde placement of a K-wire and antegrade placement of a screw.

TECHNIQUE

A healthy 16-year-old adolescent boy presented to the orthopaedic clinic with a proximal pole scaphoid fracture and an ulnar collateral ligament (UCL) injury of the right thumb at the metacarpophalangeal joint. The patient was a student athlete and right-hand dominant. He reported a history of experiencing multiple right-hand injuries while playing American football. His first scaphoid fracture was treated with immobilization for 3 months in an outside facility; however, the patient was still experiencing pain and reduced range of motion without considerable improvement.

Physical examination findings revealed tenderness to palpation over the ulnar side of the thumb and over the proximal pole of the scaphoid. The patient’s range of motion was grossly intact, with some pain experienced during wrist extension. Slight laxity of the UCL was noted at the right thumb metacarpophalangeal joint. Radiographs showed nonunion of the scaphoid fracture about the right proximal pole (Figures 1A and 1B). After discussing the diagnosis and radiographic results with the patient and his parents, surgical fixation of the scaphoid fracture and repair of the UCL were recommended.
Figure 1. At initial presentation 4 months after the injury, radiographs of the right wrist show nonunion of the proximal pole of the scaphoid fracture without displacement. A) Scaphoid view. B) Anteroposterior view.

Fixation was performed using a slightly modified percutaneous approach. Under fluoroscopic guidance, the scaphoid K-wire was placed in a center-center position in a retrograde fashion using a volar approach, with the wrist in hyperextension (Figure 2). The starting point of the pin placement was slightly radial to ensure proper capture of the central portion of the proximal pole. Fluoroscopy was then used to confirm central capture of the proximal pole fracture fragment. The wrist was then flexed and the 0.045 K-wire pin was advanced dorsally. A stab incision was made along the dorsal K-wire to allow drilling in an antegrade fashion, through the nonunion site of the fracture and into the distal pole of the scaphoid. Owing to the fragment size, a 2.5-mm Reduct screw (Skeletal Dynamics, Miami, FL) was used. Successful placement of the screw, compression, and re-approximation at the nonunion site was appreciated on fluoroscopic images (Figures 3A and 3B). The patient was placed in a thermoplastic volar resting splint, which was prefabricated by our occupational therapy team at the preoperative visit.

At 3 weeks postoperatively, the patient reported minimal pain that was well managed with immobilization and over-the-counter pain medication. Radiographs at the first postoperative visit confirmed adequate screw placement and compression at the fracture site. The patient was advised to avoid bearing weight and use his thermoplastic splint for immobilization.

At every subsequent follow-up visit, the patient reported decreased pain and increased range of motion. At 3 months postoperatively, radiographs showed more than 50% of trabeculation across the fracture site; thus, the patient was allowed to return to playing American football and basketball. At the final follow-up 6 months postoperatively, radiographs showed promising trabeculation across the fracture site, which provided evidence of fracture consolidation (Figures 4A and 4B).

DISCUSSION
Surgical fixation techniques used for treating the scaphoid are still a topic of discussion among hand surgeons, especially in the context of nonunion. We present a slightly modified surgical fixation technique that generated fracture reduction and compression, which resulted in fracture union and our patient’s return to competitive sports.

Some authors have recommended the dorsal antegrade approach when treating proximal pole fractures to ensure adequate capture of the proximal fragment. Other authors have found that fracture union and functional outcome remain the same regardless of use of dorsal or volar approaches. The current case showed the capture of a small proximal pole fragment.
using a volar approach to retrograde pin placement and a dorsal approach to antegrade screw placement. Using this technique through a volar approach, we captured the scaphoid in a center-center fashion with the guide wire without notable difficulty. This technique allowed successful capture of the central axis of the scaphoid, maximizing the screw length, which has been shown to be biomechanically optimal.\textsuperscript{10,11}

Most scaphoid fractures treated by the senior author (DM) are waist fractures, approached volarly. The senior author has been developing skills for a volar approach to retrograde placement of K-wires. Therefore, even when treating proximal pole fractures, the K-wire is placed volarly because of ease of this technique. However, percutaneous scaphoid fixation is technically challenging even for experienced surgeons. Surgeons should consider the scaphoid bone geometry and visualize its 3D shape while inserting the K-wire. This can be facilitated by drawing the axis of the scaphoid bone on the patient under fluoroscopic guidance. When treating proximal pole fractures, there is a risk of fragmentation of the small proximal fragment. Subsequently, an attempt to place the K-wire should be minimized.

Using a volar approach for drilling can be complicated by the local anatomy, such as the trapezium that can impede proper screw placement. Therefore, the second step of this technique involves placing the screw using a dorsal antegrade approach. This also ensures successful capture of the proximal

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**Figure 3.** Intraoperative view of the wrist position during antegrade screw placement. A) Screw insertion. B) Anteroposterior fluoroscopic view.

**Figure 4.** At 6 months postoperatively, radiographs show complete consolidation of the fracture site. A) Scaphoid view. B) Anteroposterior view.
pole fragment and helps minimize its displacement during drilling and screw placement.

In recent years, surgeons have advocated to change the surgical techniques used to treat nonunion of the scaphoid bone. When treating patients with this injury, the recognized management has been to use either non-vascularized or vascularized bone graft during internal fixation using a cannulated screw.\textsuperscript{12,13} However, Slade et al\textsuperscript{14} has contested this approach and found that nonunion of the scaphoid can be treated with internal fixation alone. Authors have used this technique with a union rate varying between 85.7% and 100%.\textsuperscript{15-19} Notably, fixation alone. Authors have used this technique with a nonunion of the scaphoid can be treated with internal fixation. Slade et al\textsuperscript{14} has contested this approach and found that nonunion of the scaphoid can be treated with internal fixation alone. Authors have used this technique with a union rate varying between 85.7% and 100%.\textsuperscript{15-19} Notably, most cases involved patients with scaphoid waist fractures and not the proximal pole, as in the current case. The findings of the current case show that even with proximal pole fracture nonunion, it is possible to obtain union without the added morbidity of a bone graft. Because these findings will not change surgical plans, it has led surgeons such as the senior author to forgo advanced imaging preoperatively. This represents a radical change in the way we treat nonunion of scaphoid fractures, and it is not widely accepted among hand surgeons.

We describe a case study using a technique that offers an alternative option for treating nonunion of proximal pole scaphoid fractures. It allows for optimal guidewire placement using the volar retrograde approach; additionally, it captures the proximal pole fragment with compression using the dorsal approach and antegrade screw placement. Further studies with more patients are needed to understand and compare different techniques for treating proximal pole scaphoid nonunion, especially regarding fixation alone. However, the described surgical approach can provide an effective method of treating fracture nonunions. The difficulty of treating scaphoid fractures presents an opportunity for improvement in surgical techniques to decrease the rates of nonunion, reduce time of immobilization, and improve long-term patient outcomes.

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Intraoperative Finding of Vascular Malformation During Carpal Tunnel Release: A Case Report

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ABSTRACT
Carpal tunnel release is a common surgical procedure performed by hand surgeons. The procedure is typically straightforward; however, uncommon causes of median nerve compression encountered intraoperatively may add complexity. We describe a 67-year-old man with carpal tunnel syndrome and an intraoperative finding of a compressive vascular malformation during a mini-open carpal tunnel release. A space-occupying malformation of a persistent median artery was bisecting the nerve and thought to be responsible for the patient’s symptoms. The compression was relieved through extended carpal tunnel release without requiring removal of the vascular malformation. The patient’s symptoms improved postoperatively. Hand surgeons undertaking this procedure should be aware of a potential vascular malformation and be prepared to address the condition intraoperatively.

Keywords: Carpal Tunnel, Vascular Malformation, Persistent Median Artery, Median Nerve

INTRODUCTION
Carpal tunnel release (CTR) is a common procedure used to treat carpal tunnel syndrome (CTS), which can be performed open or endoscopically.1 CTS is a compressive neuropathy of the median nerve within the fibro-osseous confines of the carpal tunnel. The cause of chronic median nerve compression is divided into four categories: idiopathic, systemic, exertional, and anatomic.2

The most common cause is idiopathic, referring to tenosynovial edema and perineural fibrosis leading to compression.3 Systemic causes refer to inflammatory disorders (eg, rheumatologic disorders and diabetes), or pregnancy-related changes.4,5 Exertional causes refer to repetitive or vibratory tasks, usually work related, increasing pressure within the carpal tunnel. However, this relationship has not been definitively established.2,4 Anatomical causes may be due to ganglion cysts, tumors, or other space-occupying lesions such as vascular malformations.6,6 Surgery is typically indicated if symptomatic CTS has failed nonoperative treatment.1,7 We describe an adult man who underwent operative treatment of carpal tunnel syndrome, with additional findings noticed intraoperatively.

CASE REPORT
A 67-year-old man presented to our office with right-hand numbness and pain that had been progressing for 9 months. The symptoms he described were isolated to the right hand and experienced both day and night. Conservative treatment with a wrist brace was attempted but failed to resolve his symptoms. On physical examination, the patient revealed no weakness or atrophy; however, findings of the compression test, Tinel sign, and Phalen Maneuver were positive for carpal tunnel. Findings of a preoperative electromyogram showed median nerve compression at the wrist with peak sensory latency of 5.68 ms and motor latency of 5.83 ms. The patient showed no cutaneous evidence suggestive of vascular anomaly. Medical history revealed that the patient had undergone lumbar spine fusion surgical treatment and prostate cancer treatment with a radiation seed implant.

The patient underwent CTR, with a mini-open approach using a 1.5-cm palmar incision distal to the wrist crease. A bifid median nerve was intraoperatively encountered, which included an enlarged and disorganized median artery suggestive of a vascular malformation. The malformation extended proximally and was unable to be fully inspected from the initial incision. A decision was then made to explore for further compression of the nerve. The incision was proximally extended an additional 1 cm to better visualize the nerve and vascular malformation to ensure complete decompression. It was found to be a space-occupying malformation that was compressing the nerve within the carpal tunnel, without further
compression proximally. It was tethered to the transverse carpal ligament radially. The malformation was dissected free from the nerve to avoid injury. Should excessive bleeding have occurred, we were prepared to resect the lesion and ligate the persistent median artery proximally. After transverse carpal ligament release, exploration, and freeing the vascular malformation tether, we elected not to perform resection because the lesion was no longer compressing the nerve.

At 2 weeks postoperatively, the patient presented with preserved strength, resolution of pain and numbness, and no reported cold intolerance pre- or postoperatively. Therefore, we felt that he did not require any further scheduled follow-up; however, the patient wished to return if additional or worsening symptoms developed.

DISCUSSION
Vascular malformations within the carpal tunnel arise from the persistent median artery. Reports are frequent regarding persistent median artery within the carpal tunnel, and many variations are possible.8,9 A persistent median artery commonly presents with a bifid median nerve.10 However, vascular malformations of the persistent median artery acting as space are uncommon.

Gutowski et al11 reported a large arteriovenous malformation (5x4 cm) of a persistent median artery in a 12-year-old boy. The malformation extended from the forearm into the carpal tunnel. The patient’s symptoms resolved after complete excision of the vascular malformation. González Porto et al12 described a 2-year-old boy who presented with a 2.5-cm long intraneural venous malformation within the carpal tunnel, which was excised from the wrist and palm. At 10 years postoperatively, the mass reoccurred with symptoms and was subsequently reexcised, resulting in resolution of symptoms. Petrovici13 reported two adults with cavernous hemangiomas in the palm, which were excised surgically. Symptoms resolved after excision, but reoccurrence of lesion and symptoms were reported in one of the two patients. Hariri et al14 described a 34-year-old man with venous malformation at the wrist level and 1 month of symptoms that resolved after excision of the lesion. Mauersberger and Meese15 described three cases of persistent median artery with anomalous vasculature causing median nerve compression within the carpal tunnel. In one case, they did not resect the vessel, as they suspected it was a major contributor of blood flow to the hand and resection risked compromising the vascular supply.

The surgeon must decide intraoperatively whether to resect the lesion when a vascular malformation is encountered. In our case, after releasing the transverse carpal ligament and freeing the malformation from surrounding adhesions, there was no further evidence of intraneural compression to indicate removal of the lesion. If no neural compression is identified after complete exploration of any proximal or distal compression, then we suggest avoiding resection of the malformation and simply decompressing the median nerve.

In summary, surgeons undertaking release of the carpal tunnel should be aware of anomalous anatomy that may complicate decompression. Knowledge of these anatomical variants and associated pathological features can aid the surgeon in intraoperative decision making.

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Intraoperative Finding of Flexor Carpi Radialis Avulsion During Closed Distal Radius Fracture: A Case Report

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Informed Consent The patient was informed that the data concerning his case would be submitted for publication, and he provided verbal consent.

ABSTRACT
Distal radius fractures are a common reason for orthopaedic consultations in emergency departments and outpatient orthopaedic clinics. Ruptures of the extensor pollicis longus tendon have been regularly described in conjunction with distal radius fractures, whereas only five cases of flexor tendon injuries have been reported. We describe a patient with acute rupture of the flexor tendon identified during operative fixation of the distal radius fracture. The tendon avulsion was repaired at the same time as fracture fixation; unfortunately, the patient was lost to follow-up. This case highlights the importance of a careful physical examination in treating high-energy traumatic injuries and the need to be aware of potential tendon injuries in the operating room.

Keywords Radius Fracture, Wrist Injury, Tendon Injury

INTRODUCTION
Distal radius fractures are common traumatic injuries treated by orthopaedic surgeons. The fractures can be associated with injuries of the carpal bones, including scaphoid fractures (prevalence, 0.5-6%), wrist ligament injuries, and tendon ruptures. Ruptures of the extensor pollicis longus (EPL) tendon are also common, with a reported incidence of 0.4% with closed treatment of distal radius fractures. Flexor tendon irritation, or rupture, has been extensively described in association with fixation techniques using volar locking plates. Five studies have reported ruptures of the flexor tendons with closed treatment of distal radius fractures. However, no study has reported avulsion of flexor tendons associated with closed treatment of distal radius fractures. In the past decade, open fixation using volar locking plates has gained popularity for treating distal radius fractures. In 2007, surgeons reported using open surgical approaches to stabilize distal radius fractures in 81% of cases. Owing to the increased use of volar locking plates, perhaps more surgeons will identify injury of the flexor carpi radialis (FCR) tendon. We describe an uncommon finding of an FCR tendon avulsion associated with closed treatment of a distal radius fracture caused by high-energy trauma.

CASE REPORT
A 52-year-old man (right-hand dominant) was involved in a motor vehicle crash. He was an unrestrained driver and sustained high-energy, traumatic injuries. These included aortic injury, pelvic fractures, and rib fractures. The findings of his left wrist radiograph revealed comminuted and displaced intraarticular fractures of the distal radius (Figures 1A and 1B). Physical examination revealed no laceration, an intact sensation in the median nerve territory, a capillary refill of less than 3 seconds, and normal range of motion in the fingers and wrist. In the emergency department, the patient underwent closed reduction of his distal radius fracture and splinting with a long arm cast. Radiographic findings of his hand showed no fracture. Initial radiographic findings were suggestive of carpal instability, but further imaging did not support this diagnosis. In the medical history description, no arthritic or inflammatory conditions were noted except for asthma.

Thirteen days after his initial injury, the patient underwent treatment of his distal radius fracture using a volar locking plate. The delay in operative fixation was due to his respiratory status. The extended FCR approach was used to expose the distal radius. The FCR tendon was noted to be redundant during the exposure. After further exploration, the tendon appeared to be avulsed from its insertion, which was an unexpected finding (Figures 2A and 2B). After fracture reduction and fixation using a volar locking plate, the FCR tendon was sutured to the deep FCR sheath under appropriate tension (Figure 3). This technique was used because there was no distal FCR stump that could be identified or used for repair. The patient was then placed in a
Figure 1. Right wrist radiograph on the day of injury, showing an intraarticular comminuted and displaced distal radius fracture and ulnar styloid fracture. A) Anteroposterior view. B) Lateral view. Note the most distal fracture fragment with volar displacement on the lateral view.

Figure 2. Intraoperative finding of avulsion of the flexor carpi radialis (FCR) tendon. A) Forceps holding the distal aspect of the avulsed FCR tendon; note the redundant aspect of the tendon. B) Forceps holding the avulsed FCR tendon under tension to recreate normal appearance of the tendon as naturally encountered during surgical approach.

In the immediate postoperative period, the patient was advised to perform range of motion of all fingers within the constraint of his dorsal blocking splint. Gentle wrist range of motion was permitted 4 weeks postoperatively.

DISCUSSION

Distal radius fractures are common and caused by different degrees of force. Studies have described rupture of flexor tendons with distal radius fractures caused by high-energy trauma. However, in most cases, FCR tendon ruptures may have resulted from the sharp bony edge produced by displacement of the apex volar fracture. In comparison to the EPL tendon, the FCR tendon rupture remains an uncommon finding because of volar protection provided by the pronator quadratus muscle, less constraint in the flexor canal, and a higher tensile strength compared to the EPL tendon. In the current case, however, an acute FCR tendon rupture was found intraoperatively during surgical treatment of a distal radius fracture.

In distal radius fractures, flexor tendon ruptures may occur under strain by a hyperextension force. In this setting, the tendon will rupture at its insertion, musculotendinous junction, or within the muscle substance; however, rupture of the tendon substance almost never occurs. Before rupture occurs, half of the tendon substance must be divided, even under extreme stress. The findings of this study support the theory that a combination of a sharp edge at the fracture site and hyperextension force will eventually lead to a FCR tendon rupture. The FCR tendon has three known distal insertion sites: the trapezius, the base of the second metacarpal, and the third metacarpal. Regarding our patient, one could hypothesize that the high-energy
trauma led to the avulsion of the tendon at one of its insertions. Another hypothesis is that there was no weakening of the tendon substance due to bony prominence; therefore, the point of failure was at the insertion of the tendon instead of at its substance.

Techniques used to repair FCR tendon avulsions have been infrequently described. Therefore, an intraoperative decision was made to repair the FCR tendon by suturing it to the deep FCR sheath. It can be argued that the tendon could have been positioned in its anatomical location with the use of a suture anchor. However, at its most distal location, the deep FCR sheath is a non-mobile structure and thus can be used as a proxy to the trapezium. Furthermore, a suture anchor placed on one of the metacarpal bases would have required further dissection distally compared to the exposure obtained using the FCR extended approach.

In treating distal radius fractures using volar plating, the senior author (DM) uses custom-made volar resting splints with the wrist in neutral to slight extension (10°-20°). Patients are encouraged to start with a range of motion of the fingers on postoperative day 1 to prevent stiffness. With the help of a hand therapist, patients will start a gentle range of motion at the wrist 2 weeks postoperatively. In the current case, the flexor tendon repair required the application of a splint with slight wrist flexion to protect the tendon. The standard rehabilitation protocol was also delayed, with range of motion at the wrist starting at 4 weeks postoperatively. Furthermore, the FCR tendon was tensioned tightly when repaired. These factors could place the patient at risk of stiffness, especially decreased wrist extension. However, rehabilitation protocol varies widely and some surgeons prefer to defer range of motion at the wrist at 4 to 6 weeks postoperatively when treating severely comminuted fracture patterns.

In all five case reports and in the current case, FCR tendon rupture was an incidental intraoperative finding. Thus, physicians should be suspicious of tendon ruptures when treating patients with injuries due to high-energy trauma and considerably displaced distal radius fractures. Owing to the limited reports, flexor tendon injuries due to closed distal radius fractures could be further studied to elucidate incidence, improve diagnosis, and enhance treatment.

REFERENCES
Chronic Volar Lunate Dislocation Resulting in Carpal Tunnel Syndrome: A Case Report

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Informed Consent The patient was informed that the data concerning his case would be submitted for publication, and he provided verbal consent.

ABSTRACT

Lunate dislocations are rare injuries caused by high-energy trauma disrupting the ligamentous restraints that connect the lunate to the carpus. We describe a case of missed volar lunate dislocation 10 years after the initial injury. The patient presented to our clinic with symptoms of carpal tunnel syndrome after falling on an outstretched arm. He had increasing paresthesias in his median nerve territory and underwent a proximal row carpectomy with release of the transverse carpal ligament. At 2 years postoperatively, successful outcomes were noted with an 80° arc of motion of the carpus and complete resolution of carpal tunnel symptoms. Although rare, chronic lunate dislocations should be considered as a cause of carpal tunnel syndrome in patients with considerable traumatic injuries of the wrist. Careful inspection is essential to ensure this diagnosis is not missed.

Keywords: Lunate Bone Dislocation, Volar Wrist Dislocation, Carpal Tunnel Syndrome

INTRODUCTION

Lunate dislocations are rare injuries caused by high-energy mechanisms such as motor vehicle accidents, falls from height, and sporting accidents. The classic mechanisms of injury are forceful wrist extension, ulnar deviation, and carpal supination. In the original Mayfield classification of progressive lunate instability, lunate dislocations are classified as stage IV injuries with complete disruption of the scapholunate complex and dorsal radiocarpal ligament. This allows the lunate to freely rotate into the carpal tunnel. Patients with an acute lunate dislocation commonly present with pain and swelling of the affected wrist after a high-energy traumatic injury. Carpal tunnel syndrome after an acute lunate dislocation has been reported in up to 50% of cases; however, it is estimated that up to 25% of acute lunate dislocations may be misdiagnosed on initial presentation. These injuries are later identified because patients usually have persistent pain.

Patients with a lunate dislocation may present later with chronic wrist pain, decreased range of motion, and symptoms of carpal tunnel syndrome. We report a patient with a chronic lunate dislocation who presented with worsening signs and symptoms of carpal tunnel syndrome. He subsequently underwent a proximal row carpectomy owing to chronic changes of the lunate, and a carpal tunnel release. The findings of this case differ from previous reports in the duration from original injury until diagnosis and the gross anatomy of the carpal bones at the time of operative treatment. The gross anatomy at the time of operative treatment ultimately guided our surgical management.

CASE REPORT

A 38-year-old man presented to the emergency department 2 weeks after falling on an outstretched hand. The patient noted pain in the wrist, especially when gripping items, and worsening paresthesias in the index finger, middle finger, and radial aspect of the ring finger. The patient had injured the same wrist 10 years earlier in a motor vehicle accident, but no imaging was obtained at the time.

During physical examination, the patient had minimal swelling and no deformity of the wrist. There was tenderness over the volar wrist in the area of the carpal tunnel, with decreased range of motion caused by pain. Full strength was noted in all extrinsic and intrinsic muscles of the hand, with decreased grip strength owing to pain. The patient noted altered sensation in the distal aspect of the index and middle fingers. Findings of Tinel, Durkan, and compression tests at the carpal tunnel were positive indicating the patient had signs of carpal tunnel syndrome. Pulses were equal to the uninjured side. Radiographs showed a chronic volar
dislocation of the lunate with arthritic changes (Figures 1A and 1B).

After discussing the injury diagnosis and chronicity with the patient, we performed proximal row carpectomy using dorsal and volar approaches for carpal tunnel release. Intraoperatively, there was no indication of an acute injury to the lunate or carpus. On gross examination of the lunate, there was significant cartilage loss and a groove within the bone caused by the flexor tendons (Figures 2A and 2B). The cartilage findings of the capitale and the radius both appeared normal. The median nerve appeared healthy, without any notable compression. Because of the arthritic condition of the lunate, the patient underwent proximal row carpectomy and transverse carpal ligament release using volar and dorsal approaches (Figures 3A and 3B). At 2 years postoperatively, the patient noted resolution of symptoms of carpal tunnel syndrome and wrist pain. He achieved 40° wrist flexion and extension (80° arc of motion).

**DISCUSSION**

Carpal tunnel syndrome is the most common compressive neuropathy of the upper extremity and occurs in about 5% to 16% of the general population.\(^4\,5\) The diagnosis is made clinically, with patients reporting nighttime symptoms of burning pain with associated tingling and numbness of the thumb, index, and middle fingers. Symptoms arise from microvascular compromise owing to compression that disrupts normal axonal transport and nerve function.\(^5\,7\) In our patient, the acute fall likely resulted in edema within the carpal tunnel adjacent to the chronic lunate dislocation. This caused him to have an acute worsening of a chronic, indolent carpal tunnel syndrome.

Carpal tunnel syndrome after a missed lunate injury has been reported in only a few cases. Chen\(^8\) analyzed 10 patients in Taiwan with chronic volar lunate dislocations who presented with symptoms of carpal tunnel syndrome. Three of the patients were identified after unsuccessful carpal tunnel release, while the other patients underwent electrodiagnostic studies that identified the location of the compression, confirmed...
by radiographic findings showing a history of trauma. The time to diagnosis was on average 21 months. Four of the 10 patients underwent PRC, although the other six underwent isolated lunate excision because the authors felt that PRC may be too aggressive. Similarly, Ott et al diagnosed a chronic volar dislocation of the lunate after unsuccessful carpal tunnel release. At the time of diagnosis, there was evidence of scapholunate advanced collapse but management of the dislocated lunate was not discussed.

Our patient presented in a similar manner after a low-energy fall with worsening symptoms of carpal tunnel syndrome. Imaging obtained at the time of presentation identified a volar lunate dislocation and associated arthritic changes, with considerable erosion within the lunate from the flexor tendons. Studies on treatment of chronic lunate dislocation are limited. Some authors have argued that simple lunate excision and transverse carpal ligament release can treat the disorder. Oka et al identified chronic dislocation of the lunate in a patient with rheumatoid arthritis. Excellent outcomes were noted after performing lunate excision and the Sauvé-Kapandji procedure for treating radioulnar joint instability. Stabilization of missed lunate dislocations have reported good outcomes if identified within 45 days of injury. In 2015, Cansu et al described a neglected lunate dislocation discovered 5 months after injury stabilization. Repair was performed using two-incision approach, which resulted in notable improvement in wrist range of motion and resolution of carpal tunnel symptoms. However, further delay may warrant salvage procedures. Owing to the altered shape of the lunate, stabilization alone was not felt to be an option in our patient. Based on radiographic appearance of the lunate and the chronicity of the dislocation, we discussed the option of proximal row carpectomy with our patient preoperatively. When deciding between a repair, reconstruction, or a salvage procedure, we believe the decision should be based on both the condition of the radiolunate articulation and the midcarpal joints with respect to arthritic changes. If the capitulate and radial cartilages are disrupted, then a wrist fusion may be considered.

Although rare, acute and chronic lunate dislocations are risk factors for the development of carpal tunnel syndrome. It is important that physicians consider missed lunate dislocations as a cause of carpal tunnel syndrome in patients who underwent unsuccessful carpal tunnel release or had a history of high-energy traumatic injuries to the affected wrist. In this subset of patients, we favor obtaining a radiograph or ultrasound to identify a lunate dislocation that may be causing the symptoms of carpal tunnel. Management of these injuries should be on a case-by-case basis. As seen in the findings of the current case, prolonged dislocation may result in considerable degeneration of the lunate and symptoms may resolve after proximal row carpectomy.

REFERENCES


An Uncommon Presentation of Coxa Saltans: A Case Report

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ABSTRACT
Coxa saltans, or “snapping hip,” refers to various conditions that produce a palpable or audible snapping of the hip after movement. We present an uncommon case of coxa saltans in a patient with a snapping proximal hamstring tendon. Findings of dynamic ultrasound evaluation were used to confirm the source of snapping, characterized by a lateral subluxation of the conjoint tendon over the ischial tuberosity. Our patient was treated nonoperatively, and we observed mild improvement of her symptoms. Few cases of similar pathological findings have been described, with varying causes of tendon instability. The results of the current case may help physicians in diagnosing and treating this condition.

Keywords: Coxa Saltans, Snapping Hip, Musculoskeletal Ultrasound

INTRODUCTION
Various studies have documented causes of coxa saltans, also known as “snapping hip.” The most common sources of extraarticular snapping hip include the iliotibial band and iliopsoas tendon, which may be physically sensed by the patient.1 On physical examination, the iliotibial band and iliopsoas tendon can be palpated over the lateral or anterior hip, respectively.2 However, a less commonly identified cause of coxa saltans involves dynamic instability of the proximal hamstring tendon at the ischial tuberosity.1-3 We describe the diagnosis of posterior coxa saltans using magnetic resonance imaging (MRI) and dynamic ultrasound.

CASE REPORT
A 59-year-old woman presented to the sports medicine clinic with a snapping sensation around her left buttocks. In the past year, she had noticed considerable snapping during hip flexion, most noticeable while bending over during certain yoga positions. The patient recalled an event before the onset of symptoms, in which she was pushing a vehicle with her left leg while seated inside. She then developed a sharp pain around her left gluteal region. This pain spontaneously resolved, although she did subsequently develop some pain over her left greater trochanter. She was referred to physical therapy, which resulted in minimal relief of symptoms. The patient experienced modest improvement of symptoms after multiple visits to a chiropractor and continued practice of yoga.

Findings of a focused examination of her left lower extremity revealed no gross asymmetry or swelling when compared to the right side. There was moderate tenderness to palpation over the greater trochanter but not the ischial tuberosity. We noted symmetric range of motion and strength in the left and right lower extremities. Provocative maneuvers including FADIR (flex the hip to 90°, adduct, and internally rotate), FABER (flex the hip to 90°, abduct, and externally rotate), scour test, resisted hip abduction, resisted knee flexion, and reverse plank did not result in pain or apprehension. However, active flexion of the left hip resulted in a visible, audible, and palpable “clunk” about the ischial tuberosity.

Findings of plain radiographs of the left hip and pelvis revealed mild hip osteoarthritis, without any evidence of a cam-type impingement or pincer deformity (Figure 1). Findings of dynamic ultrasound, obtained with the patient standing and forward flexing at the waist, revealed dynamic instability of the
Figure 1. Plain radiograph showing mild osteoarthritis of the left hip.

Figure 2. Dynamic ultrasound of the hip. A) Before hip flexion, which shows the conjoint tendon (CT) superficial and medial to the semimembranosus (SM) tendon. The SM tendon is superficial relative to the ischial tuberosity (IT). B) After hip flexion, which shows CT lateral to the SM tendon after subluxation off the IT.

Figure 3. Magnetic resonance imaging of the left hip, which shows A) partial tearing of semimembranosus tendon near its insertion at the ischial tuberosity (IT) and B) insertion of the conjoint tendon to the sacrotuberous ligament instead of the IT as typically seen.

proximal hamstring tendon characterized by a lateral subluxation of the conjoint tendon over the ischial tuberosity (Figures 2A and 2B). MRI findings revealed partial tearing of the proximal semimembranosus tendon (Figure 3A) and an abnormal insertion of the conjoint tendon to the sacrotuberous ligament, without attachment to the ischial tuberosity (Figure 3B). Owing to the patient’s history and results of physical examination, it was believed that this aberration resulted in the observed lateral subluxation of the conjoint tendon over the ischial tuberosity.

DISCUSSION
Extraarticular snapping hip most commonly localizes to the anterior or lateral hip, as the result of subluxation of the iliotibial band over the greater trochanter or iliopsoas tendon over the ilipectineal eminence, respectively. We described an uncommon case of coxa saltans of the posterior hip, which was due to proximal hamstring tendon subluxation over the ischial tuberosity. The diagnosis of posterior coxa saltans was confirmed
from findings of dynamic ultrasound; subsequently, this imaging modality may be useful in the evaluation of snapping hip.

The conjoint tendon comprises the proximal biceps femoris and semitendinosus tendon, originating at the inferomedial aspect of the ischial tuberosity. Connections of the conjoint tendon to the sacrotuberosus ligament have also been described in a subset of individuals. In the current study, the MRI findings revealed an atypical insertion of the conjoint tendon on the sacrotuberosus ligament without a clear attachment to the ischial tuberosity, or without evidence of current or previous injury to the conjoint tendon. A similar configuration has been described; however, it occurred after a previous injury that resulted in avulsion of the conjoint tendon from the ischial tuberosity but with residual connection to the sacrotuberosus ligament. In the current study, there was no radiographic or clinical evidence of an acute injury involving the conjoint tendon. Furthermore, we found no radiographic evidence of visible avulsion from the ischial tuberosity, making a congenital defect more likely to explain the patient’s anatomy. An isolated insertion of the conjoint tendon on the sacrotuberosus ligament yields a mechanical pull away from the ischial tuberosity and in turn potentiates lateral subluxation of the tendon over the ischial tuberosity with dynamic maneuvers. The current study is the first to describe lateral subluxation of the conjoint tendon without a history of injury or avulsion.

Other reported cases of snapping proximal hamstring tendon described limited success with an initial period of conservative care, including activity modification, physical therapy, pain medications, and corticosteroid injections. Unfortunately, all patients ultimately underwent surgical intervention. Most cases described surgical release of the tendon with tenotomy. However, in a patient with conjoint tendon avulsion described by Spencer-Gardner et al., the authors advocated restoration of the native anatomy with anatomical tendon repair. Because our patient experienced modest yet steady resolution of symptoms with only nonoperative care (eg, chiropractic treatment and yoga), she declined surgical repair. Although the ultimate outcome is not yet known, this case illustrates a rare finding of proximal hamstring subluxation and the clinical utility of dynamic bedside ultrasound in evaluating and accurately diagnosing snapping hip related to tendon instability.

REFERENCES
Leukocytoclastic Vasculitis in a 66-Year-Old Woman After Fusion of the Second Right Metatarsocuneiform Joint Using Titanium Plate and Screws: A Case Report

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ABSTRACT
Metallic orthopaedic implants are known to instigate cutaneous reactions; however, the mechanism by which this occurs is not fully understood. Contact dermatitis after implantation of stainless steel fracture plates was first described in 1966, and similar reactions to various implants have been documented subsequently. Leukocytoclastic vasculitis (LCV) is an inflammatory condition of small dermal blood vessels resulting from neutrophil invasion, degranulation, and cell death caused by a type III hypersensitivity reaction. No studies have reported use of titanium orthopaedic implants resulting in LCV. We describe a 66-year-old woman who developed LCV after the fusion of her second right metatarsocuneiform joint with a titanium plate and screws. At 4 months after removal of the titanium plate and screws, the LCV symptoms had resolved without further intervention. Although this rash might be a rare complication associated with orthopaedic implants, it is an important differential diagnosis for orthopaedic surgeons to consider when assessing and treating postoperative rashes.

Keywords: Leukocytoclastic Vasculitis, Titanium Implant, Rash

INTRODUCTION
Leukocytoclastic vasculitis (LCV), also known as small vessel vasculitis or hypersensitivity vasculitis, is a skin condition characterized by palpable, non-blanching, purpuric papules on the lower extremities and occasionally on the back and buttocks (Figure 1A and 1B). The condition typically involves the lower extremities; however, it can affect any region of the body. LCV may present as vesicles, skin ulcerations, and areas of necrosis. Although uncommon, systemic symptoms can include pruritus, malaise, fevers, lower-extremity edema, arthralgias, and myalgias. LCV is a type III hypersensitivity reaction resulting in inflammation and vasculitis, typically caused by neutrophil invasion, degranulation, and cell death. Type III hypersensitivity reactions trigger the production of immune complexes that stimulate circulating neutrophils to release proteolytic enzymes, resulting in inflammation and damage of adjacent vessel walls. LCV is usually idiopathic; however, the condition is also associated with many chronic diseases, medications, and infections. We were unable to find evidence to support titanium or other metallic orthopaedic implants mediating LCV reactions, but orthopaedic implants have been shown to instigate hypersensitivity reactions including dermatitis and lymphocytic vasculitis. If the instigating cause is removed, most patients with LCV experience spontaneous resolution of their skin lesions within weeks or months of initial onset.

Mild cases of LCV are treated with elevation, rest, and antihistamine therapy. In patients with more severe symptoms, corticosteroids are used to prevent further exacerbation. We describe a 66-year-old woman who developed LCV shortly after the fusion of her second right metatarsocuneiform joint with the use of a titanium plate and screws.
The joint surface of the second metatarsocuneiform joint was prepared for fusion. While the joint was held compressed, the titanium plate was placed dorsally and filled with titanium screws. The wound was irrigated and closed. The procedure resulted in successful bony contact and stable fixation of the joint (Figures 2A through 2C). Postoperatively, no complications were noted and the patient described feeling well.

At 2 months after the initial operation, the patient developed a pruritic rash on her right lower extremity, sparing the toes. She was evaluated by The University of New Mexico Department of Dermatology 1 month later. At that time, she had a pruritic rash on the right ankle and distal right lower leg, with minimal involvement of the left lower leg. About 36 hours before the onset of the rash, she described herself as feeling “under the weather.” It was noted during physical examination that the patient had non-blanching, palpable, purpuric papules on both legs, sparing the toes. Findings of two separate punch biopsies of the rash indicated neutrophil fragments, extravasated...

CASE REPORT

A 66-year-old woman presented to the orthopaedic clinic with chronic pain and degenerative joint disease in the second and third tarsometatarsal joints of the right foot. The patient had a history of tenderness and bossing over the second and third tarsometatarsal joints, thus requiring her to use a walking boot due to chronic pain. Nonsurgical interventions were attempted without resolution of pain (ie, various shoe wear, bracing, and fluoroscopically guided injections). Her medical history revealed non-localized allergic concerns to stainless steel and certain metallic jewelry; however, she could not characterize the type of allergic reaction she experienced. Because of her unknown allergy status to stainless steel, the decision was made to proceed with surgical intervention using a titanium plate and screws. The patient underwent fusion of the second right metatarsocuneiform joint, and arthrotomy and debridement of the third metatarsocuneiform joint.

Figure 1. Representative photograph of leukocytoclastic vasculitis. A) Left foot. B) Both legs. Photographs reprinted with permission from James Heilman, MD, https://commons.wikimedia.org/w/index.php?curid=11857797 and from DermNetNZ, https://knowledge.statpearls.com/chapter/0/24215?utm_source=pubmed, respectively.

Figure 2. Radiographs showing the titanium plate and screws at the second right metatarsocuneiform joint. A) Anteroposterior view. B) Oblique view. C) Lateral view.
erythrocytes with uncommon perivascular neutrophils, and granular deposition in the vessel walls consistent with LCV of unknown origin (Figures 3A through 3C). The patient was re-evaluated by a dermatologist multiple times because the rash did not resolve with treatment using triamcinolone cream and 20 mg of oral prednisone once a day for 5 days. No diagnosis was made, but it was speculated that the titanium plate and screws might be related to her condition.

At 6 months after her metatarsocuneiform fusion, the patient underwent removal of the titanium plate and screws from the joint. Stress of the joint after removal of the plate and screws showed successful arthrodesis. The implants removed showed no damage, and there were no signs of debris in the adjacent soft tissues. At 1 week postoperatively, symptoms of LCV resolved. Four months later, at the final follow-up, no reoccurrence was noted.

**DISCUSSION**

Metallic orthopaedic implants are known to instigate cutaneous reactions, but the mechanism by which this occurs is not fully understood. In 1966, contact dermatitis after implantation of stainless steel fracture plates was first described, and similar reactions to various implants have since been documented. Nickel, cobalt, and chromium are more likely to induce cutaneous and extracutaneous reactions; however, other metals can be immunogenic and produce similar effects.

Cutaneous reactions after metal exposure are relatively common, although reactions are less seen in metallic orthopaedic devices compared to other implants. There is an ongoing debate of the validity of developing cutaneous reactions from metallic orthopaedic implants, specifically because the implants are inserted deep within the tissue and away from the overlying cutaneous tissues. Metal hypersensitivity reactions typically present as contact dermatitis on the overlying skin that was exposed to the metal irritant, including both implanted metal and metal that directly contacts the skin on the surface. Typically, contact dermatitis presents as an eczematous reaction with erythematous scaling plaques and papules in the area of contact; however, it can occasionally present with microvesiculation, depending on the timing and extent of allergy. The eruptions normally occur over the site of the implant and do not spread from the site of origin or to adjacent extremities.

**Figure 3.** Tissue histological sections. A) Perivascular infiltrate composed of lymphocytes, eosinophils, and a few neutrophils. Presence of copious extravasated red blood cells (black arrows) are also noted. B) Dermal vessel with neutrophil fragments near vessel wall (black arrow). C) Dermal vessel that appears to have been damaged with fibrinoid material in vessel wall (black arrow).
Over time, metallic orthopaedic implants experience normal wear-and-tear that releases haptens (antigens), which in-turn induces a counter hypersensitivity reaction. Haptens activate lymphocytes resulting in a humoral immune response, including antibody and immune complex formation characteristic of types I to III hypersensitivity reactions. More commonly, orthopaedic implants induce type IV hypersensitivity reactions that cause inflammation through cytokine secretion and macrophage recruitment. LCV is representative of a type III hypersensitivity. We were unable to find any reports of titanium orthopaedic implants resulting in LCV. In the current case, our patient’s condition represents an atypical hypersensitivity reaction to a metallic orthopaedic plate and screws.

Currently, it is not possible to predict which patients will develop hypersensitivity reactions to metallic orthopaedic implants. Performing a patch test before the insertion of metallic implants can help determine metal hypersensitivity, but patch test results can be ineffective in predicting adverse outcomes. Additionally, patch testing is not recommended or indicated unless the patient had a previous allergic reaction to a similar implant. Furthermore, the risk of hypersensitivity reaction is the same for patients with and without a history of metal sensitivity. Although we cannot confirm that the titanium plates and screws were the cause of LCV in our patient, the timing of the rash appearance and its disappearance after removal of plate and screws makes this association suspected. It is important for orthopaedic surgeons to be aware of this possibility.

REFERENCES
Inclusion Body Myositis in a Middle-Aged Woman With Knee Pain and Weakness: A Case Report

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Conflict of Interest The authors report no conflicts of interest.

Informed Consent The patient was informed that the data concerning her case would be submitted for publication, and she provided verbal consent.

ABSTRACT

Weakness and osteoarthritis are common concerns for orthopaedic and primary care physicians when caring for aging adults. We describe a 58-year-old woman with a history of Sjogren syndrome and knee osteoarthritis. She presented to our clinic for injection of viscosupplementation in her left knee, and review of her medical records revealed right hand weakness at 7 years after the onset of symptoms. Findings of muscle biopsy and multiple electromyograms revealed inclusion body myositis, primarily affecting the deep finger flexors and quadriceps muscles. On the basis of this diagnosis, physical therapy and supportive care were recommended. The results of the current case show the difficulty of diagnosing inclusion body myositis and why it often remains undiagnosed.

Keywords: Inclusion Body Myositis, Inflammatory, Myopathy

INTRODUCTION

Inclusion body myositis (IBM) is an idiopathic inflammatory myopathy (IIM) found more often in men than women and commonly acquired after age 50. Data regarding causes of IBM are scarce; however, the prevalence is estimated to be between 5 and 25 of 1,000,000 patients, with some studies reporting rates as high as 45 of 1,000,000 patients. Studies have suggested an association between primary Sjogren syndrome and IBM, but significance has not been determined.

Patients with IBM typically present with progressive asymmetric weakness in the quadriceps and finger flexors (Table 1). The average time from onset of symptoms to definitive diagnosis is about 5 years. Because of the duration, multiple muscle groups may become weak (eg, hip flexors, quadriceps, ankle dorsiflexors, forearm flexors, cricopharyngeal muscle, and orbicularis oculi muscle), whereas the oculomotor muscles typically remain unaffected. Although dysphagia is seldom the presenting symptom, it may be present. After objective muscle weakness is seen, laboratory test results may be reasonably obtained. Findings can reveal mildly elevated muscle enzymes early in the disease process; however, the enzymes usually normalize as the disease progresses. A creatine kinase (CK) level more than 15 times the normal limit is atypical, thus prompting a search for an alternative diagnosis. Typically, erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) levels are not elevated and myositis-specific antibodies are not present. Notably, autoimmune disorders such as Sjogren syndrome can be associated with IBM; however, the pathophysiology behind this is not understood and potentially an area for future research.

An electromyogram (EMG) and nerve conduction study are helpful in diagnosing IIM. Findings between IBM can be similar to those of IIM, including increased insertional activity, positive waves, fibrillations, and small-amplitude polyphasic motor unit action potentials. Fasciculations, however, are only observed with IBM. With these findings, a muscle biopsy is indicated for histological diagnosis. Biopsy reveals evidence of endomysial inflammation with invasion of non-necrotic muscle fibers (particularly CD8+ T lymphocytes and macrophages), sarcoplasmic “rimmed” vacuoles that are red-rimmed on trichrome stain and blue on hematoxylin and eosin, and immunostaining that is positive for p62 and TDP-43 labeled protein aggregates. Electron microscopy findings may show inclusions that contain 15 nm to 18 nm tubulofilaments within the sarcoplasm and myonuclei. Proposed diagnostic criteria for IBM are
Table 1. Comparison of inclusion body myositis and polymyositis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Inclusion body myositis</th>
<th>Polymyositis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Uncommon before 50 years</td>
<td>Common before 50 years</td>
</tr>
<tr>
<td>Sex</td>
<td>Male &gt; female</td>
<td>Female &gt; male</td>
</tr>
<tr>
<td>Onset</td>
<td>Insidious</td>
<td>Acute or subacute</td>
</tr>
<tr>
<td>Course</td>
<td>Slowly progressive</td>
<td>More rapid</td>
</tr>
<tr>
<td>Weakness</td>
<td>Typically asymmetric finger flexors and proximal leg weakness</td>
<td>Symmetric, proximal</td>
</tr>
<tr>
<td>CK level</td>
<td>Normal or &lt; 10x normal</td>
<td>Often &gt; 10x normal</td>
</tr>
<tr>
<td>EKG findings</td>
<td>Myopathic or mixed myopathic and neurogenic</td>
<td>Myopathic</td>
</tr>
<tr>
<td>Muscle biopsy findings</td>
<td>Inflammation, rimmed vacuoles, inclusions</td>
<td>Inflammation, fiber necrosis</td>
</tr>
<tr>
<td>Response to therapy</td>
<td>Generally poor</td>
<td>Expected</td>
</tr>
</tbody>
</table>

CK, creatine kinase; EKG, electromyogram.

*Table adapted with permission from: Miller ML, Lloyd TE. Clinical manifestations and diagnosis of inclusion body myositis. In: UpToDate, Post TW (Ed), UpToDate, Waltham, MA. Accessed on January 14, 2019. Copyright © 2019 UpToDate, Inc. For more information visit www.uptodate.com.

Based on expert opinion or consensus groups, Lloyd et al’ derived possibly the most clinically useful set of criteria, including quadriceps or finger flexor weakness, endomysial inflammation, and invasion of non-necrotic muscle fibers or rimmed vacuoles. This set of criteria provided a 90% sensitivity and 96% specificity.

Recommendations for treatment include exercise, physical therapy, speech therapy, nutritional support, and fall prevention with assistive devices if needed. Data from muscular dystrophy suggest that supplementation of 3 g creatine monohydrate per day improves muscle strength and performance; however, no formal placebo-controlled trial using creatine with IBM exists. Although immunosuppressive therapy may be helpful in other inflammatory myopathies (eg, dermatomyositis, polymyositis, and necrotizing myopathy), it is generally not recommended for treating IBM. We describe a middle-aged woman with progressive muscle weakness. The findings of this case reveal the challenges in diagnosing IBM.

CASE REPORT

A 58-year-old woman with a history of osteoarthritis in both knees, Sjogren syndrome, chronic obstructive pulmonary disease, gastroesophageal reflux disease, and tobacco abuse presented to the orthopaedic sports medicine clinic for consideration of visscoseulation injection in her left knee. The patient had been receiving these injections intermittently for several years. More recently, she had undergone total knee replacement to treat her right knee osteoarthritis. At this visit, she noted difficulty when standing from a seated position in addition to her usual arthritis symptoms. Findings of a functional examination confirmed quadriceps weakness. The patient’s medical history revealed concerns of right hand grip weakness after being hospitalized for viral pneumonia 7 years earlier. Her primary care physician referred her to occupational therapy for treatment of two possible conditions that may have resulted after hospitalization: ulnar neuropathy and brachial plexus injury. When her hand weakness persisted, she was referred to a neurologist, at which time workup did not reveal a definitive cause but her EMG showed evidence of “EMG disease.” The patient did not follow-up. She eventually returned to her primary care physician with concerns of right hand weakness that affected her ability to hold her grandchild. Nerve conduction studies were performed in which a second EMG was obtained, revealing diffused electrical activity with needle insertion suggestive of “EMG disease” or myopathic process. There was no evidence of polynuropathy, mononeuropathy, radiculopathy, or denervation changes. It was suggested her condition was either diffuse myositis due to systemic involvement of Sjogren syndrome, or critical illness myopathy due to her hospitalization for pneumonia. Laboratory test results showed the following: normal complete blood count; depressed thyroid-stimulating hormone, 0.03; elevated levels of antithyroid peroxidase antibodies; normal comprehensive metabolic profile; normal B12, 247.90 pmol/L; elevated ESR, 104 mm/h; elevated CRP, 18.09 nmol/L; positive antinuclear antibody, 1:1280; elevated anti-Sjogren syndrome antigens, A and B; and normal CK levels, 1189 μkat/L. Findings of brain magnetic resonance imaging (MRI) revealed no evidence of neoplasm, multiple sclerosis, cerebrovascular accident, or other intracranial process.

The patient was referred back to a neurologist for further evaluation. During this time, she had a fair amount of weakness and atrophy in her interosseous muscles, abductor pollicis brevis, and flexor mass. Additionally, she had mild weakness of both quadriceps. A third EMG was obtained, which revealed evidence of an irritable myopathy. Findings of a biceps biopsy
test were suggestive of IBM and revealed the following: presence of rimmed vacuoles with Gomori trichrome staining and an immunostaining pattern with p62, ubiquitin, and TDP-43. Definitive diagnosis of inclusion body myositis was made 7 years after onset of symptoms. Recommendations were given for supportive care and continued physical therapy. Weakness continued to progress very slowly during the next 6 to 12 months; however, she was able to continue her activities of daily living with physical therapy.

**DISCUSSION**

IBM is a rare type of IIM, which should be considered to occur more frequently in middle-aged adults presenting with insidious onset muscle weakness of the quadriceps and finger flexors. The findings of our case show the difficulty in diagnosing IBM and why it often goes undiagnosed for an extended time. The diagnostic findings in this case support those of other published data regarding this condition, including the patient’s insidious presentation, normal CK levels, and normal imaging and biopsy findings. Using the diagnostic criteria proposed by Lloyd et al7 (ie, quadriceps or finger flexor weakness, endomysial inflammation, and invasion of non-necrotic muscle fibers or rimmed vacuoles) would have led to the diagnosis of IBM as well.

Some methods may help in diagnosing and treating IBM. The time to definitive diagnosis could be decreased by maintaining a high clinical suspicion of patients presenting with quadriceps and finger flexor weaknesses, and also pursuing appropriate workup (eg, repeat EMG, MRI, and laboratory tests). Because IBM is uncommon, it is often an overlooked diagnosis; thus, by increasing awareness of this condition, the time to diagnosis may be improved. Practitioners caring for musculoskeletal conditions are uniquely positioned to recognize IBM. The findings of our case add to the relatively small amount of case reports documenting patients with IBM associated with Sjogren syndrome. More research is needed to help elucidate the connection between autoimmune disorders and IBM.

**REFERENCES**

Achilles Tendon Ruptures in Two Male Athletes in NCAA Division I: Report of Two Cases

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Informed Consent The patients were informed that the data concerning their cases would be submitted for publication, and they provided verbal consent.

ABSTRACT
Major tendon ruptures are rare, with an Achilles tendon rupture (ATR) being the most frequent type. Reported cases most commonly involve male recreational athletes who have increased body mass indexes and are between ages 30 and 50 years. We describe two male athletes in Division I of the National Collegiate Athletic Association who underwent surgical repair for treating an ATR associated with running-related activities. In contrast to other cases, both patients had normal body mass indexes. These two cases identify high-level athletes who underwent operative Achilles tendon repair and returned to their sport at a similar level or high level of post-college athletic activity with promising strength and function.

Keywords: Achilles Tendon, Collegiate Athlete, Tendon Rupture, Ankle

INTRODUCTION
Tendon ruptures rarely occur in the athletic population and most frequently involve the Achilles tendon.1 The injury incidence rate of an Achilles tendon rupture (ATR) is 12 in 10,000 (0.12%)2 and typically affects men between ages 30 and 50 years.1,3-5 Recreational athletes account for 75% of ATRs, whereas competitive athletes account for 8% to 20%.6 The activities that most commonly result in ATR include ball and racquet sports, such as basketball and racquetball.1,3 Owing to eccentric loading forces, sprinting and jumping mechanisms can also result in ATR.2 Other risk factors for ATR include previous rupture of the Achilles tendon, tendon degeneration, muscle fatigue, and increased body mass index (BMI, kg/m2).4,7,8

ATR can be treated operatively or nonoperatively. During the past 3 decades, multiple studies have reported operative treatments with lower rates of re-rupture and increased strength at 2 years, whereas nonoperative treatment results in fewer complications (eg, deep vein thrombosis and infection).9-11 In the past 5 years, studies have challenged whether any outcome difference exists between operative and nonoperative treatment. Several meta-analytic studies have noted similar re-rupture rates between the two options.12,13 However, when treating young high-level athletes, operative procedures are preferred because of the reported increased strength, lower re-rupture rate, and perceived option to perform limited active assisted ankle range of motion earlier in the postoperative period.14

Subsequently, the preference of operative treatment in athletic patients may be attributed to quicker time to return to play and a perceived early functional improvement. In a literature review of open Achilles repairs, four trials compared early ankle mobilization to immobilization.15 The authors found that early mobilization shortened the recovery time and allowed patients to return to work and sports sooner.

Despite the preference and noted benefits of operative treatment, professional athletes who have returned to play (69%) can require 2 years to return to pre-injury levels of competition.16 In collegiate athletes, this recovery time represents a considerable portion of their college career. We describe two college-aged, competitive male athletes in Division I of the National Collegiate Athletic Association (NCAA) who presented with traumatic ATR.

CASE REPORTS

Case 1
A 22-year-old male NCAA Division I long jumper (BMI, 22.4) presented with pain in his right ankle. He was competing in a track and field meet after a warmup. During the running approach to his third long jump, he felt a pop in the back of his right leg and stopped his attempt. No pain was felt at that time. He attempted the jump again and felt a much larger snap, followed by
his right leg collapsing during the running phase of the long jump. He was unable to bear weight on his right leg after this injury. The patient noted some tightness in his right Achilles after practicing for his event a few days before the meet. However, he stated that it was only a mild discomfort. There was no other significant history of risk factors including steroid injections in that leg or recent fluoroquinolone use.

On physical examination, the right ankle was hyperdorsiflexed with swelling over the posterior portion. There was a palpable gap noted a few centimeters from the calcaneal attachment of the Achilles tendon. He was unable to actively plantarflex his ankle, and the findings of the Thompson test were positive for ATR. An injury assessment of an ATR was made at this time. A limited diagnostic ultrasound revealed at least a partial full-thickness rupture of the right Achilles tendon. Radiographs showed no notable findings. Magnetic resonance imaging (MRI) was not obtained because of the timing between the injury and the surgical treatment.

At 5 days after the initial injury, an open Achilles tendon repair was performed, with intraoperative findings confirming the ATR. The open repair was performed with the patient in the prone position, using a posterior longitudinal approach. A Bunnell-type suture technique was utilized, and four Ethibond 5-0 sutures (Ethicon, Somerville, NJ) were placed into the ruptured tendon ends. All four suture ends (eight strands) were tied independently. A running 2-0 nylon epitendinous stitch was placed circumferentially around the suture line, and the leg was splinted in 10° plantar flexion for 1 week. At about 7 days postoperatively, gentle range of motion was performed to tolerance with the athletic trainer (LH) assisting and never stressing the repair. The athletic trainer actively mobilized the skin to help decrease adhesions. A heel lift was placed into a walking boot, and the patient began immediate weight bearing to tolerance. The lift was removed about 4 weeks postoperatively.

At 10 months postoperatively, the patient reported to his former athletic trainer (LH) that he had nearly full ankle motion. Additionally, he noted that the strength and speed of ankle contraction were slightly greater than those of the uninjured ankle, as measured by the physical therapist. The patient returned to full recreational running with no perceived deficit. He also played in a recreational volleyball league without any jumping concerns. However, he perceived that his vertical jump was about 3 inches less than it was before the injury. At this time, he did not return to long jumping or sprinting because his NCAA eligibility ended the season that he had the injury.

Case 2
A 19-year-old male NCAA Division I lacrosse goalie (BMI, 22) presented to our clinic with swelling and hyperdorsiflexion in the posterior right ankle.
to being a NCAA Division I lacrosse goalie without restrictions during scrimmage and game situations.

**DISCUSSION**

The current cases described two collegiate male athletes with normal BMIs who presented with ATR associated with running-related activities, with no other notable risk factors other than possible muscle fatigue. Because of their young age, our two patients now have an increased risk for additional ATRs. The rate of re-rupture is 16.6% for athletes aged 30 years or younger at the time of the first injury.15 ATR can be a career-altering injury that negatively affects an athlete’s ability to return to competitive play.16

The decision to operatively or nonoperatively treat ATR can be challenging, particularly with highly competitive athletic patients. Both of our NCAA Division I patients underwent operative repair and returned to their sport at a similar level or high level of post-college athletic activity. In our opinion, shared decision making tended to favor operative treatment, which potentially resulted in a stronger repair, decreased chance for re-tear, and opportunity to resume athletic activity. In the current cases, the certified athletic trainers were able to mobilize the patients early and institute early modalities, range of motion, and pool therapy activities without the limitations associated with casting or bracing. In conclusion, these two cases show that surgical management for treating acute ATR may return college athletes to their sport or post-graduation high level of activity, with promising strength and function, in a reasonable timeline.

**REFERENCES**


Open Lumbosacral Dislocation: A Case Report

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Conflict of Interest The authors report no conflicts of interest.

Informed Consent The patient was informed that the data concerning her case would be submitted for publication, and she provided verbal consent.

ABSTRACT
Open injuries in the lumbar spine are rare. We describe a 20-year-old woman who presented with persistent weaknesses due to an associated lumbar plexus injury. She underwent surgical treatment of lumbosacral dislocation with prompt reduction with debridement and stabilization. At 7 months postoperatively, her symptoms showed signs of recovery. We believe the immediate reduction of the dislocation prevented permanent neurological injury, and stabilization helped healing and early mobilization. In keeping with the classical teaching of open fracture treatment, prioritizing early initiation of intravenous antibiotics and prompt debridement and stabilization may have helped decrease the long-term morbidity and overall sequelae of this unique and devastating injury.

Keywords: Open Fracture, Lumbosacral, Spinopelvic, Fracture Dislocation

INTRODUCTION
Traumatic lumbosacral dislocations are uncommon injuries typically caused by high-energy mechanisms. They are often associated with open injuries to the bowel or perineal structures. These dislocations are distinct from spinopelvic dissociations that are typically associated with fractures of the sacrum, categorized by the Denis classification as type 3 fractures with U- or H-shaped patterns. It is suggested that lumbosacral dislocations are due to the extensive ligamentous and muscular anatomy in the lower lumbar region and robust soft-tissue envelope.

Notably, open injuries in the lumbar spine are exceedingly uncommon and have only been reported after projectile or blast injuries. We present the case of a crush injury resulting in open lumbosacral dislocation, in which the posterior open wound was independent from the perineum or bowel.

CASE REPORT
A 20-year-old woman presented to our level 1 trauma center after being transported directly from the field by a helicopter. She had been working under a large trailer when the supporting stand failed, which crushed and then rolled her. After about 10 to 15 minutes, her siblings were able to raise the trailer and extract her. Results of initial physical examination indicated an intra-abdominal injury and a small wound about 3 cm over her lower right lumbar spine. Initial neurological examination findings showed motor and sensory deficits consistent with right lumbar plexus injury. Presentation findings were mainly consistent with avulsion of the L4-S1 nerve roots; however, owing to bilateral innervation, she did not have any numbness in the perirectal area or any issues with sphincter tone or voiding.

Computed tomography (CT) scans of the L5-S1 level showed a fracture of the right superior facet, dislocation of left facet joint, and fractures of the L4 and L5 spinous processes. There were left lateral listhesis of L5 vertebral body on S1; however, the spinal canal appeared to remain patent on initial CT scan (Figures 1A through 1C). The soft-tissue injury was extensive, with subcutaneous air and soft-tissue zone of injury extending from the fracture to the posterior lumbar wound.

Because of the urgent nature of her bowel injury and open fracture, the patient was immediately taken to the operating room. Magnetic resonance imaging (MRI) and radiographs were thus not obtained. Laparotomy findings revealed multiple colonic injuries, which the general surgery trauma team treated expeditiously. During exploration, it was noted that the wound on her lumbar spine communicated with both the retroperitoneal space and the lower posterior laceration. The abdominal injuries were stabilized, and the laparotomy wound was closed. To explore the posterior wound and stabilize the spinal fractures, the decision was made to transport the patient to a new operating room with a sterile field.
The posterior wound was initially explored and found to communicate directly with the lumbar spine fractures. At this time, a separate midline spinal incision was made using a standard posterior approach. This involved the traumatic wound to expose the lumbar spine and proximal sacrum up to the S2 body. The paraspinal muscles appeared to be avulsed off the posterior spinal structures. The wound was thoroughly irrigated with bacitracin saline through cystoscopy tubing; additionally, all devitalized soft tissue was removed. Afterward, the spinal column was reduced and stabilized using a posterior spinal fusion construct extending from the L3 to the pelvis. Surgical fixation of the pelvis was performed by placing S2-alar-iliac screws in the sacrum and L5, L4, and L3. The L3 was chosen owing to the extensive soft-tissue injury, and the stripping of muscle from the lumbar spine on the right and transverse process fractures indicated ligamentous rupture in the lumbosacral region. When the pedicle screws were placed, two contoured rods were used to gradually reduce the dislocation and realign the spine to the pelvis. Fusion was facilitated by using a local autograft, cancellous allograft, and bone sponges (per our institution’s protocol). Vancomycin and tobramycin powders were placed into the incisional layers, followed by a standard layered closure. A small portion of the traumatic wound was unable to close owing to tissue quality; subsequently, a Hemovac drain was placed out of the zone of injury and replaced with a vacuum-assisted closure device.

After the patient awakened from anesthesia, she was transported to the surgical trauma intensive care unit. For 5 days postoperatively, the patient was kept on intravenous antibiotic therapy with Zosyn to cover any possible contamination with bowel flora. At 5 days postoperatively, neurological examination results were consistent with right-sided lumbar plexus injury. Several weeks later as an outpatient, her catheter was removed and she was able to void spontaneously. At 6 weeks postoperatively, her wound had completely healed without concern for infection. She continued to experience right-sided weakness in her L3-5 myotome yet could walk without aids. She was continent in bowel and bladder functions.

At 7 months postoperatively, the patient had mild weakness with dorsiflexion and plantar flexion on the right L4 to S1. She noted stiffness and occasional paresthesias on the right lower leg. A nerve conduction study was not pursued owing to the promising injury healing. She did not use her ankle-foot orthosis because she found it unhelpful as she gradually recovered more strength. The incision that involved the traumatic wound was healed and showed no signs of infection (Figures 2A and 2B, Figure 3).
DISCUSSION
Open fractures are common with well-documented classification systems, treatment protocols, prognoses, and outcome data. However, fractures involving the spine are rarely open injuries. Many studies exist on penetrating trauma (eg, gunshot wounds and spine fractures), but information is limited regarding non-penetrating trauma. In the past 20 years, several case reports have been published involving traumatic spondylolisthesis and open injuries, with most including the thoracic spine.

About 75% of lumbosacral dislocations can be attributed to motor vehicle accidents, falls from heights, or pedestrians struck by automobiles. Lumbosacral dislocations are often associated with life-threatening, intra-abdominal injuries that are managed before definitive operative fixation of the lumbar spine and pelvis. Our patient had promising neurologic recovery. Additionally, she had no wound or deep infection issues in her spinal fracture, which was in a setting contaminated by both bowel and external environment. We credit this to multiple factors. First, she received prompt antibiotics immediately on arrival at our facility, which has been shown to decrease infection in open fractures. Second, she was taken to the operating room shortly after initial presentation where her bowel injury was treated promptly. Lastly, her open spinal injury was addressed promptly in the same anesthesia setting.

Aihara et al developed a classification system in 1998 that best fits the injury pattern described in the current case. Their classification is based on L5 dislocation, which is differentiated by unilateral versus bilateral facet dislocation versus fracture. In the current case, the injury pattern was most consistent with type 3 fractures, with unilateral lumbosacral facet dislocation and contralateral facet fracture. This differs from the classification by Wiltse et al, which describes posttraumatic spondylolisthesis occurring in the late term (ie, weeks to months). This injury also differs from spinopelvic dissociations typically seen with Denis type 3 sacral fractures, with a U- or H-shaped pattern.

Neurological injury is common in lumbosacral dislocations. Our patient’s primary neurologic deficit was weakness with right-sided dorsiflexion and planter flexion. In a comprehensive review of 70 patient case reports and reviews, Grivas et al reported a 58% rate of neurologic deficits in these types of injuries.

Indications for open intervention included the open injury, neurologic deficits, and notable displacement of the lumbosacral junction. Early debridement and stabilization with reduction of the dislocation helped the patient recover safely and comfortably.

Conservative treatment of these injuries has shown unsuccessful results in previous case reports. Posterior spinal fusion using pedicle screws has become the standard of care for treating this injury, with some authors advocating staging procedures with subsequent anterior interbody fusion. We deferred anterior surgical treatment because the patient was young; however, she was notified about the possibility of revision procedures if signs of nonunion developed.

The goal of anatomical reduction and solid bony fusion was met for our patient, despite the open injury. The reduction technique helped ensure locked facets existed, and use of symmetric screws and rods helped successfully realign the spine.

REFERENCES


Fracture of the Ulnar Sesamoid Bone in the Thumb of a Collegiate Basketball Player: A Case Report

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ABSTRACT

Sesamoid fractures of the hand are uncommon occurrences that can lead to prolonged pain and swelling if delayed in diagnosis. This is particularly problematic in competitive athletes. We describe an ulnar sesamoid fracture of the thumb due to a blunt traumatic injury in a Division I collegiate basketball player. The 22-year-old woman injured her left thumb when kicked during a game. The patient was treated nonoperatively with promising outcomes. Sesamoid fractures of the hand can be difficult to diagnose, and any delay can lengthen the amount of time before the athlete returns to play. Radiographic findings may help healthcare providers accurately diagnose sesamoid fractures in this patient population, resulting in timely return to activity.

Keywords: Ulnar, Sesamoid, Fracture, Athlete

INTRODUCTION

In adults, there are typically 4 to 5 sesamoid bones in the hand. Two sesamoid bones are located in the metacarpophalangeal (MCP) joint of the thumb, and it is suggested that the bones stabilize and protect the flexor tendons of the joint and intrinsic muscles. Sesamoid fractures are occasionally associated with direct traumatic injuries, but more frequently with hyperextension of the MCP joint in young and active patients. Studies are limited regarding the diagnosis and management of sesamoid fractures. Delays in diagnosis become particularly problematic for high-level competitive athletes and can result in sequelae, including avascular necrosis due to poor blood supply. Thus, it is extremely important to make the correct diagnosis early. Diagnosis is typically made after evaluating posteroanterior radiographs of the hand; however, Pracon et al reported using ultrasound findings to confirm fractures when radiographs were negative.

We describe an ulnar sesamoid fracture of the thumb in a Division I collegiate basketball player. Because current studies regarding this injury are limited, our purpose is to provide further diagnostic information that may help patients quickly return to play.

CASE REPORT

A 22-year-old female basketball player (right-hand dominant) presented to the Lobos Training Room after being kicked in the left hand with subsequent bending of her left thumb. The patient was initially evaluated 1 day before presentation, during the end of her basketball game. The swelling on her left hand had worsened, and she reported no previous injuries. When asked to locate her pain, she pointed to the palmar aspect of the first MCP joint. On physical examination, she showed both edema and bruising with tenderness to
Figure 1. Radiographs obtained 1 day after injury, showing a minimally distracted fracture through the sesamoid over the first metacarpal head. A) Posteroanterior view. B) Oblique view.

palpation over the MCP joint of the thumb. The patient was reassured that the fracture was minimally displaced and encased within the flexor pollicis brevis tendon. She was informed that she could continue to play and advised to splint and tape as needed for comfort.

Six weeks later, the patient had a follow-up appointment and obtained a second radiograph. Findings showed similar alignment with ongoing healing along the mildly displaced fracture through the sesamoid of the first MCP joint (Figures 2A and 2B). At her appointment that same day, she no longer had any remaining symptoms. On physical examination, she had intact sensation and range of motion, with appropriate strength. She was encouraged to follow-up only as needed.

DISCUSSION
Sesamoid fractures are uncommon and challenging to diagnose, especially when not clearly seen on the initial radiograph. Differential diagnosis includes rupture of the joint collateral ligament, rupture of the palmar plate (results in debility of flexing the MCP joint of the pollex), fractures near the joint, and a bipartite sesamoid. They are often associated with sports-related injuries and may result from direct traumatic injuries or hyperextension. In the current case, the

Figure 2. At 6-week follow-up, radiographs show minimally displaced sesamoid fracture with similar alignment and ongoing healing of the first metacarpophalangeal joint. A) Posteroanterior view. B) Oblique view.
injury occurred due to blunt trauma, however, there may have also been a hyperextension injury that resulted. The initial diagnosis was MCP sprain, but radiographic findings showed a sesamoid fracture. Nonoperative treatment resulted in promising outcomes, which corresponds with findings of other studies. In most cases without evidence of hyperextension instability of the MCP joint, treatment is successful with analgesia and immobilization. Immobilization with the MCP joint in 30° of flexion in a splint or cast should be short—2 to 3 weeks. Thereafter, mobilization is encouraged. Usually, surgical management is only recommended for cases of open fracture with palmar plate rupture and cases of hyperextension instability.

To help illuminate the steps necessary for successful and timely diagnosis of sesamoid fractures, further studies could compare ultrasound and radiographic findings. Becciolini and Bonacchi reported a case in which sesamoid fracture diagnosis was not identified on radiographs obtained 1 week after traumatic injury. The authors suggested that musculoskeletal ultrasound findings may help show injuries to the ligaments, tendons, or volar plate that are not apparent on radiographs. A study comparing the sensitivity and specificity of radiographs to ultrasound would be useful. Accurate diagnosis is vital, as it will allow the provider to initiate proper treatment to facilitate prompt return of full functionality of the hand in non-athletes and swift return to play for competitive athletes.

REFERENCES

Traumatic Neuroma of the Median Nerve: A Case Report

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ABSTRACT
Peripheral nerve neuromas are growths that develop after nerve trauma, which can result in enlarged and painful nerve ends when severed. Treatment of neuromas that form within a continuous nerve is controversial; however, success has been reported after general neurolysis with decompression of the nerve after its isolation from the surrounding scar bed. We describe a 21-year-old man who presented with symptoms of pain and intermittent numbness in his left elbow. Findings of high-resolution magnetic resonance imaging and ultrasound confirmed the diagnosis of median nerve neuroma at the level of the forearm. He subsequently underwent neurolysis with protective nerve wrap, with complete resolution of symptoms at 6 weeks postoperatively. Surgeons may consider this surgical option in treating patients with neuromas that form within a continuous nerve.

Keywords: Traumatic Neuroma, Median Nerve, Nerve Wrap, Neuroma Surgery

INTRODUCTION
Peripheral nerve neuromas develop as a result of nerve trauma. If severed, the traumatically injured nerve will continue to grow, resulting in an enlarged nerve end that can cause pain after light stimulation. The distal nerve segment undergoes Wallerian degeneration, in which the nerve axon dies and the nerve epineurium remains. Unfortunately, treatment of neuromas is challenging. One treatment option is excising the neuroma and rerouting both the nerve ends and burying them in tissue (e.g., muscle or bone); however, this form of treatment has a high failure rate. Newer forms of treatment such as targeted muscle reinnervation and allograft nerve reconstructions have shown success in preventing recurrence.

Neuromas in continuity are a more difficult problem. In this situation, the nerve is damaged but not severed. The neuroma forms within a continuous nerve.1 This injury does have the potential to heal, particularly in young children. The management is controversial, but improved outcomes have been noted after low-risk neurolysis with decompression of the nerve followed by isolation of the nerve from the surrounding scar bed.2 We describe the case of median nerve neuroma at the level of the forearm. Diagnosis was ultimately confirmed by findings of high-resolution magnetic resonance imaging (MRI) and ultrasound.

CASE REPORT
A 21-year-old man was referred to our clinic with elbow pain that had been gradually increasing for years. The patient was employed as a mechanic and had a palpable, extremely tender, left anterior elbow mass that had grown in size during the previous 5 years. The patient had multiple congenital issues, most notably left-sided fibular hemimelia with a congenital short femur. He underwent previous amputation on the left lower extremity and proximal tibial epiphysiodesis. Other notable history included gastroschisis and a previous hernia. At 24 weeks of age, the patient underwent venous cutdown of symptomatic upper extremity in the neonatal intensive care unit. He had no history of schwannomas or peripheral nerve disease.

Upper extremity evaluation findings revealed palpable fullness in the left anterior antecubital fossa mass. He had a positive Tinel sign and reported considerable tenderness in the region. His nerve injury was classified as Seddon class II-III and Sunderland class V with complete sensation and motor function but chronic neuropathic pain. The patient had full range of motion; however, he had concerns of pain with elbow extension. Findings of low-resolution MRI found
no abnormalities. An electromyography with nerve conduction study was performed, in which findings were normal. The patient described constant pain at the elbow aggravated by lifting. Nonoperative measures to eliminate symptoms such as bracing, activity modifications, therapy, and avoidance of bothersome activities had all failed.

At this point, a high-resolution 3 Tesla MRI was obtained. Findings showed subtle abnormality of the median nerve (Figures 1A and 1B). Owing to persistent and worsening pain that failed nonoperative management, surgical nerve decompression was recommended.

Preoperatively, the anesthesia team localized the mass using ultrasound before the administration of nerve block. The median nerve was identified in the upper arm, proximal to the antecubital fossa, and traced to the distal forearm. A 15-MHz linear probe was used to image these structures. The median nerve appeared to be in continuity under ultrasound; however, there was evidence of hyperechoic tissues surrounding the median nerve at the level of the antecubital fossa, which was suggestive of dense scar formation (Figure 2).

The median nerve was explored at the antecubital fossa by an oblique incision extending distally from the transverse venous cutdown scar. When the scar was encountered, the median nerve was identified distal and proximal to the zone of injury. Outside the zone of injury, the nerve was normal in turgor, color, and girth. Careful dissection was performed through the zone of injury (Figure 3). The nerve was abnormal, encased in scar, and adherent to surrounding tissue. It did not have any glide capacity owing to the severe scarring. Neurolysis was then performed, in which the median nerve was wrapped with a nerve wrap made of decellularized porcine gut mucosa. This was done to protect the nerve from the surrounding scar bed using an AxoGuard (Axogen, Alachua, FL) to promote nerve gliding.

At 2 weeks postoperatively, he reported considerably diminished intensity of shooting pains and frequency. A negative Tinel sign was observed at the surgical incision site. At 8 weeks postoperatively, he had complete resolution of symptoms and planned to resume his automotive technician training.
DISCUSSION

Traumatic neuromas form as a result of nerve regeneration after an injury. Neuromas typically form within months of surgical procedure and have the potential to grow indefinitely. Both MRI and ultrasound findings are important to confirm diagnosis. Because a low-resolution MRI may not show the cause, it is best to utilize high-resolution MRI for evaluation of nerve injury. Treatment options include nerve stabilizing medication, therapy for desensitization of the nerve, protection of the area, and surgical decompression from the surrounding scar bed.

Surgical treatment includes neurolysis with isolation of the nerve from the surrounding scar bed. This can be accomplished with a nerve protector that surrounds the damaged nerve and minimizes nerve rescarring. Souza et al. showed that this method significantly affected patient outcomes with a decreased mean ordinal pain score of 2.6. Before nerve wraps were available, autograft vein was utilized to protect the nerve from the surrounding scar bed and to prevent nerve adherence to surrounding tissues. This method is still utilized. Both vein wraps and conduit wraps provide isolation of the nerve from the surrounding scar bed. The conduit graft has the advantage of not requiring a second surgical procedure. In the current case, findings from patient history, MRI, and ultrasound scans all led to the diagnosis of traumatic neuroma after venous cutdown at age 24 weeks. Surgical decompression and nerve wrapping successfully eliminated pain. Notably, the problem in this case was most likely the inability of the nerve to glide due to adherence to surrounding scar tissue. The symptoms were most severe with elbow extension.

In patients with neuropathic pain yet fully functioning nerves, early decompression of the nerve with isolation from surrounding scar tissue may lead to resolution of the pain. In the current case, the patient had symptoms since age 7 years (per the patient’s recollection) and was finally treated for this problem at age 21. Once treated, he had complete resolution of symptoms by 8 weeks postoperatively. Surgeons should consider the benefits of high-resolution MRI and this technique in treating patients with traumatic neuroma.

REFERENCES

Diagnosis of Leprosy Using Sural Nerve Biopsy Findings: A Case Report

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ABSTRACT

Leprosy, also known as Hansen disease, is an uncommon chronic disease caused by the slowly growing acid-fast bacilli, *Mycobacterium leprae*. Leprosy has tropism for peripheral nerves and skin and can also be found in the upper respiratory tract, eyes, and nasal mucosa. When left untreated, there can be considerable nerve damage resulting in paralysis, blindness, and the crippling of hands and feet. Although infrequent in the United States, leprosy has been diagnosed in patients exposed to armadillos, an animal reservoir. We describe an 80-year-old man who presented with a 6-year history of chronic erythematous, macular rash, and progressive symmetric sensory motor neuropathy. Initially, it was thought that the patient had an eczematous rash; however, he was later diagnosed with polar lepromatous disease owing to findings from a sural nerve biopsy. When results of clinical examination and skin biopsy are inconclusive, use of a peripheral nerve biopsy may help confirm leprosy.

Keywords: Leprosy, Hansen Disease, Sural Nerve Biopsy

INTRODUCTION

Leprosy, also known as Hansen disease, is caused by the slowly growing acid-fast bacilli, *Mycobacterium leprae*, infecting the skin and peripheral nerves. Most leprosy cases occur in developing countries. Countries with high incidence rates include India, Brazil, Indonesia, Bangladesh, and Nigeria. In the United States (US), a few hundred new diagnoses are reported each year. About 75% of affected patients immigrated to the US or have traveled to endemic countries. It is suggested that leprosy is spread through the respiratory route, although the means of transmission are not fully understood. In the US, leprosy is also a zoonotic disease, passed between humans and armadillos.1 Other risk factors include old age, genetic predisposition, immunosuppression, and close contact with known cases.2

Leprosy is classified into the following categories: tuberculoid, borderline tuberculoid, mid-borderline, borderline lepromatous, lepromatous, and indeterminate. Patients with a high degree of cell-mediated immunity and delayed hypersensitivity present as tuberculoid with relatively few well-demarcated lesions. Patients with no apparent resistance to *Mycobacterium leprae* present as lepromatous with many poorly demarcated lesions. Patients in the other categories can present with a spectrum of symptoms between tuberculoid and lepromatous. Early physical examination findings include: hypopigmented or reddish skin patches, diminished sensation or loss of sensation in involved areas, paresthesias, painless wounds or burns, and tender enlarged peripheral nerves. Neuropathy and ophthalmic injury can also occur. The diagnosis is established when at least one of these physical findings is present, and skin biopsy findings (obtained from the leading edge of the skin lesion) confirm the presence of acid-fast bacilli in a cutaneous nerve.2 Alternatively, sural nerve biopsy findings can confirm diagnosis.

When other diagnoses have been ruled out, leprosy should be in the differential for patients who present with skin manifestations and progressive neuropathy.2 Early diagnosis and a full course of treatment are critical for preventing lifelong neuropathy and disability. Often, diagnosis is delayed owing to potentially fragmented care and unfamiliarity with the rare disease in the US. We describe an older man who was diagnosed with leprosy 6 years after onset of symptoms.
CASE REPORT

An 80-year-old Hispanic man, born and residing in the US, presented for an assessment of hand contracture. His medical history included Parkinson disease. Before retirement, he had traveled for work in South America, including Brazil and Mexico. The patient did not recall any close contacts with individuals who may have had Hansen disease, and thus he was unsure about the source.

Six years before his current presentation, the patient developed an erythematous macular rash on his extremities, which progressed to his trunk and back. He did not recall if there was hypoesthesia associated with the lesions. His skin lesions were initially diagnosed as eczema. After 3 years of failed treatment, skin biopsies were performed revealing superficial and deep perivascular lymphohistiocytic infiltrates that were suggestive of infection. Immunohistochemical stains were negative for *Treponema pallidum* but showed rod-shaped microorganisms in areas containing histiocytes. Acid-fast bacilli smear and culture were negative for mycobacterium. Fungal and routine bacterial cultures were negative. *Treponema pallidum* antibody and QuantiFERON Gold were both nonreactive. Subsequently, the diagnosis of leprosy was not considered definitive at that time. The lesions did not resolve and continued to be nonpruritic and hypoesthetic.

The patient developed numbness (associated with tingling and paresthesias) in both upper and lower extremities. At that time, electromyography findings were normal. He was seen at multiple facilities during the next few years for treatment of progressive sensorimotor neuropathy in all extremities due to unclear causes before progressing to his current level of disability. Other symptoms included the chronic rash, mild left lagophthalmos, madarosis, and a nonobstructive lesion on the left vocal fold.

He was referred to an orthopaedic surgeon (EAM) and noted the following concerns: lack of sensation in his lower extremities distal to his knees, minimal sensation in his hands to his elbows, contractures of both of his hands, and left foot drop. Findings of sural nerve biopsy using Fite staining revealed many acid-fast organisms, severe intraneuronal inflammation, destruction of axon and myelin, and involvement of the blood vessel wall with luminal narrowing but without fibrinoid necrosis. Findings of 16S ribosomal molecular testing were positive for *Mycobacterium leprae* complex; however, no *Mycobacterium tuberculosis* was detected. There were no distinct granulomas on nerve biopsy findings. Biopsy results were consistent with polar lepromatous disease (Figures 1A through 1D).

It was determined that the hand contractures were likely caused by considerable imbalance

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**Figure 1.** Various stains of the sural nerve biopsy. A) Haemotoxylin and eosin stain shows axonal and myelin destruction and blood vessel wall involvement with luminal narrowing but without fibrinoid necrosis. Axons, light blue; blood vessels, light pink; and epithelium enclosing pink-red stained lumen. B) Cluster of differentiation 68 (CD68) immunohistochemical stain shows dark brown CD68 staining of intracellular granules in monocytes, representing intraneuronal mononuclear inflammation. C) Sevier-Munger silver stain shows differentiation of histological features within the nerve tissue. Axons, black; myelin sheath, light brown; and collagen and muscle, brown. D) Fite acid-fast stain, revealing *Mycobacterium leprae* as indicated by pink clusters of bacilli.
Involving severe weakness of his intrinsic muscles. At presentation to our clinic, the patient had developed contractures of multiple fingers. After discussing treatment options with the patient, surgical treatment was not recommended because of uncertainty that the benefits would outweigh the risks. He was subsequently referred to physical therapy. Recommendations were considered for immunosuppressive therapy to prevent further nerve damage.

Shortly after definitive diagnosis, the patient was prescribed antibiotics by the infectious disease specialist (KSS). After consultation with the National Hansen’s Disease Program in Louisiana, the oral regimen was started and included 500 mg of clarithromycin extended-release tablets daily, 100 mg of minocycline daily, and 600 mg of rifampin monthly to be taken for at least 1 year. The patient was not a risk to infect others, thus he did not require decreased contact with the public.

**DISCUSSION**

Leprosy should be considered as a diagnosis in patients with skin lesions, enlarged nerves, and sensory loss. Loss of sensory perception occurs in the early stages of leprosy. Preventing or minimizing injury to peripheral nerves is a major goal of treatment; therefore, assessment of peripheral nerves is essential.\(^2\) In a prospective study of early neuropathy diagnosis in leprosy, sensory nerve conduction and warmth perception were the earliest and most frequently affected tests.\(^3\)

Nerve trunks involved include the ulnar and median nerves, common peroneal nerve, posterior tibial nerve, facial nerve, radial cutaneous nerve, and great auricular nerve. Deficits associated with the involved nerve trunks include claw hand, foot drop, claw toes, plantar insensitivity, and lagophthalmos. Nerve biopsy findings are important in confirming the diagnosis of leprosy, usually from the sural, superficial radial, or dorsal branch of the cubital nerves. Histopathological features of leprosy lesions in the skin and peripheral nerve may have discrepancies. Biopsy is also useful for evaluating the effectiveness of treatment.\(^2\)

On sural nerve biopsy, polar lepromatous leprosy is characterized by firm, cord-like thickening of the peripheral nerves, which is the result of extensive fibrosis. There is extensive loss of nerve fiber and an increase in endoneurial collagen. Infiltration with foamy macrophages and an absence of lymphocytes are prominent. The perineurium may be thick and extensively multilayered. The subperineurial area may contain a granular proteinaceous matrix and pockets of collagen. Numerous bacilli are seen in the foamy macrophages, and Schwann cells are frequently packed in clusters or bundles. In the absence of any infiltrating cells, it is common to find Schwann cells loaded with bacilli in a clinically cord-like nerve from an untreated polar lepromatous case (Figures 2).\(^4,5\) Although fibrosis in our patient’s specimen was mild to moderate and CD8 positive lymphocytes were present in numbers nearly equivalent to those of macrophages, the quantity of organisms was quite high and the histologic appearance appeared more consistent with a less inflammatory category of disease.

Our patient presented with symptoms of chronic lepromatous leprosy. He had notable physical deficits because of the delay in diagnosis due to fragmented care and the rareness of this disease. His skin lesions and neuropathy did not have a conclusive diagnosis until the findings of a sural nerve biopsy. Although risks of sural nerve biopsies include infection and increased pain, the biopsy is recommended in patients with considerably progressive symptoms, dense sensory loss in the associated nerve territory, and inconclusive findings from less invasive testing such as skin biopsies.\(^6\) Notably, obtaining a skin biopsy presents minimal risk to the patient and should thus be obtained early. However, findings of sural nerve biopsy can prove helpful when skin biopsy results are inconclusive in patients with progressive neurological deficits.
REFERENCES
Ipsilateral Femoral Neck and Shaft Fractures with a Floating Knee Injury: A Case Report

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Informed Consent The patient was informed that the data concerning his case would be submitted for publication, and he provided verbal consent.

ABSTRACT
Isolated ipsilateral fractures of the femoral neck and shaft are rare injuries. Similarly, a floating knee (ie, ipsilateral fractures of the femur and tibia) is uncommon. We describe a 34-year-old man with ipsilateral fractures of the femoral neck and shaft with an ipsilateral floating knee after a motorcycle collision. He was treated with operative fixation, and was walking without assistive devices at his most recent follow-up appointment in February 2019. We believe this to be a unique combination of injuries not yet described in studies.

Keywords: Ipsilateral Neck Shaft, Floating Knee, Femoral Neck, Femoral Shaft, Tibial Shaft

INTRODUCTION
Ipsilateral femoral neck and shaft fractures are typically associated with high-energy polytrauma.1,2 The ipsilateral femoral neck and shaft fracture combination was originally described by Delaney and Street.3 Femoral neck fractures accompany femoral shaft fractures 6% of the time4 and are most commonly vertically-oriented bascervical, whereas femoral shaft fractures are most commonly transverse and butterfly fractures.5,6 To decrease the frequency of misdiagnosis, various protocols such as pre- and postoperative computed tomography scans and intraoperative stress examinations have been recommended.7 Although these injuries are typically treated surgically, no consensus exists on the order of fixation techniques or most effective fixation strategy.

Ipsilateral tibia fractures, also called floating knee injuries, are similarly difficult to treat. They were originally classified by Blake and McBryde8 in 1975 as Type I (extraarticular) or Type II (articular). Subsequently, Fraser et al9 added subclassifications to Type II fractures to indicate tibial plateau injury (IIa), distal femur (IIb), or articular involvement of both sides of the knee (IIc). Floating knee injuries are associated with open injuries with soft-tissue damage, occurring in 54% to 62% of patients. Amputation is performed 1% to 3% of patients.1,9-11

In isolation, both ipsilateral femoral neck and shaft fractures and floating knee injuries present various treatment considerations that surgeons must take into account; yet, reports of patients presenting with both injuries are rare. We describe a patient who underwent surgical fixation for treating ipsilateral femoral neck and shaft fractures as well as a floating knee injury.

CASE REPORT
A 34-year-old man was transported directly to the emergency department after a motorcycle collision. On admission, he was given cefazolin and gentamycin and Advanced Trauma Life Support protocol was initiated. At that time, the patient had a Glasgow Coma Scale of 15. Subsequent imaging revealed a displaced fracture about the right vertical basicervical femoral neck (Figure 1), a right femoral shaft fracture (Figure 2), and a right tibial shaft fracture (Figure 3). The patient sustained a comminuted right patella fracture, right tibial shaft and fibula fractures, left distal radius fracture, left patella fracture, and a grade IIIA open left tibial plateau fracture. A thoracostomy tube was placed to treat his right-sided hemopneumothorax and intraventricular and subarachnoid hemorrhages.

About 12 hours after presentation, the patient was cleared by the neurosurgical team and taken back to the operating room by the orthopaedic trauma team. The patient was placed in supine position on a radiolucent table. First, the open left tibial plateau fracture was irrigated and debrided. The wound was then closed, and a knee spanning external fixator was placed. The right femoral neck fracture was treated with open reduction using a lateral approach to the proximal femur. A capsulotomy was performed along the anterior neck, and the fracture was then reduced
with use of a Cobb and Schanz pin in the lateral femur. Reduction was verified by digital palpation and fluoroscopy findings, which was held provisionally with multiple K-wires. Next, a sliding screw was placed at a 130° angle into a four-hole side plate, with use of 4-mm antirotation screws placed proximal to the side plate. In a transpatellar manner, a retrograde intramedullary nail was placed in the femur. The distal two holes of the dynamic hip screw with a plate were placed around the femoral nail. Reduction was confirmed with findings of fluoroscopic images (Figures 4 and 5). To treat the tibia fracture, a suprapatellar intramedullary nail was placed normally. After fixation, fluoroscopic views were obtained to verify reduction and hardware placement (Figures 6 through 8). At the conclusion of the procedure, no instability or laxity was noted after examining the full ligamentous knee.

After being admitted to the hospital, the patient subsequently returned to the operating room on days 5 and 7 for definitive treatment of his other injuries. These included operative fixation of the left tibial plateau, operative fixation of the left distal radius, and partial patellectomies of both patellas. The patient was positioned to avoid weight bearing on the right and left
Figure 4. (Left) intraoperative anteroposterior view and (right) lateral fluoroscopic image of the right hip confirming reduction femoral neck fracture with appropriate placement of hip screw with side plate and antirotation screw.

Figure 5. Intraoperative fluoroscopic image of the right femoral shaft confirming adequate reduction and intramedullary placement of nail.

Figure 6. (Left) intraoperative anteroposterior view and (right) lateral fluoroscopic image of right knee confirming appropriate placement of femoral and tibial nails.

Figure 7. (Left) intraoperative anteroposterior view and (right) lateral fluoroscopic image of right tibia confirming adequate reduction and intramedullary placement of nail.
Figure 8. (Left) intraoperative anteroposterior view and (right) lateral fluoroscopic image of right ankle displaying appropriate placement of intramedullary nail and distal locking screws.

Figure 9. Radiographs at 5 months postoperatively. A) (Left) anteroposterior view and (right) lateral right hip. B) (Left) anteroposterior view and (right) lateral femur. C) (Left) anteroposterior view and (right) lateral tibia and fibula.
lower extremities, with the knees maintained in extension for the partial patellectomies. Additionally, he was positioned to avoid weight bearing on the left upper extremity, with weight bearing allowed through the elbow.

At 10 days postoperatively, the patient was given enoxaparin to treat venous thrombosis prophylaxis and was discharged to a skilled nursing facility. At 8 weeks postoperatively, knee range of motion was initiated and the patient was advised to bear weight as tolerated on the right lower and left upper extremities. At 12 weeks postoperatively, the patient could bear weight on the left lower extremity as tolerated.

At the most recent follow-up 5 months postoperatively, he could walk without assistive devices. The range of motion of both knees was 0° to 90°. The patient continued to undergo physical therapy to increase the range of motion and strength of his knees. At this time, radiographs showed healing of the femoral neck and shaft fractures as well as the tibia fracture. Additionally, no loss of reduction was observed in the femoral neck fracture (Figures 9A through 9C).

**DISCUSSION**

Ipsilateral femoral neck and shaft fractures, as well as floating knee injuries, are rare. In the current case, the femoral neck fracture was first approached using a sliding hip screw. We then used a retrograde intramedullary nail for the femoral shaft fracture followed by the use of a suprapatellar intramedullary nail for the tibia fracture. Initial stabilization of the femur allowed for easy manipulation of the tibia fracture for reduction and fixation. There is currently no validated consensus on the optimal strategy for treating ipsilateral femoral neck and shaft fractures or floating knee injuries.

Many authors have advocated to first fixate the femoral neck fracture with either three cannulated screws or a sliding hip screw to avoid high risk of complications (eg, avascular necrosis of the femoral head, nonunion, and varus deformity). Some authors have suggested to first fixate the femoral shaft fracture, which allows for improved control of the distal fragment while addressing the more technically demanding femoral neck fracture. Further debate exists regarding use of a single cephalomedullary device versus two separate implants with treating each fracture. Bedi et al found a significantly higher rate of femoral malreduction after using a single cephalomedullary device to treat ipsilateral femoral neck and shaft fractures. Subsequently, the authors concluded that using two implants was preferable owing to improved fixation outcomes with a sliding hip screw or three cannulated screws. In the current case, we utilized two implants while first addressing the femoral neck: a sliding hip screw and a derotational screw. Shortly after, we used a retrograde intramedullary nail in the femoral shaft.

Regarding treatment of floating knee injuries, fixation strategies should be tailored to each individual patient’s fracture pattern because no standard method exists. Type I floating knee injuries have been treated using intramedullary nails in both femur and tibia fractures, with promising results. It is recommended that the femur undergo fixation before the tibia. This is because of a concern that further soft-tissue injury might happen in the unstable femur fracture when reducing and stabilizing the tibia fracture. Additionally, stabilization of the femur allows for a more stable position to approach the tibia fracture and allows access to the starting point.

Femoral neck and shaft fractures as well as floating knee injuries result from high-energy trauma, and they often include various associated injuries that affect treatment outcomes. In the current case, we described treatment of a unique injury pattern that has not yet been reported. Ultimately, because no standard method exists, surgical management should be tailored to patients’ injury patterns and surgeons’ preference and experience.

**REFERENCES**


Multiple Pterygium Syndrome With Severe Knee Flexion Contracture: A Case Report

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Informed Consent The patient’s parents were informed that the data concerning her case would be submitted for publication, and they provided verbal consent.

ABSTRACT

Multiple pterygium syndrome, a subgroup of arthrogryposis multiplex congenita, is characterized by the webbing of different parts of the body. We describe a child who developed 140° flexion contractures of the popliteal fossa, which complicated mobility, skin care, and general hygiene. After seeking multiple opinions, the parents elected to proceed with through-knee amputation of both knees. At 6 month follow-up, the child had been fitted with bilateral prostheses and was able to ambulate with assistance. The findings of the current case suggest that in extreme cases of multiple pterygium syndrome, through-knee amputations may represent a predictable and functional treatment option that should be considered.

Keywords: Multiple Pterygium Syndrome, Contracture, Prosthesis and Implants, Amputation

INTRODUCTION

Multiple pterygium syndrome is a clinically heterogeneous disorder described as the pterygia (ie, webbing) of various parts of the body and associated craniofacial anomalies. This syndrome is a subgroup of arthrogryposis multiplex congenita, characterized as multiple joint contractures across different parts of the body. Other subgroups include amyoplasia, distal arthrogryposis, fetal crowding, and systemic tissue disorder. In multiple pterygium syndrome, the most commonly affected areas include the neck, axilla, antecubital, and popliteal. Patients with this syndrome can present with various features such as short stature, syndactyly and camptodactyly of the fingers, foot deformities, facial abnormalities, scoliosis, and neurologic dysfunction.1-5

Multiple pterygium syndrome is an uncommon condition with few documented cases. Usually, the syndrome is initially seen in utero with decreased fetal movement noticed in ultrasound and reported by mothers.6 It is suspected that multiple pterygium syndrome is a multifactorial condition resulting from gene defects or problems with the intrauterine environment; however, specific genetic abnormality for multiple pterygium syndrome has not been detected yet. Fetal akinesia produces maldevelopment of the joints and excessive connective tissue. The resulting flexion contractures present extreme challenges for patients and their providers. We describe a patient who underwent through-knee amputation of both knees to treat multiple pterygium syndrome that was diagnosed in utero.

CASE REPORT

Our patient first presented as a 3-week-old female newborn with severe pterygoid contractures since birth. Flexion contractures of both elbows and radial longitudinal deficiency (ie, radial club hand) of the right hand were diagnosed. Initially, the elbow contractures were treated with extension splinting. At that time, it was thought that functional outcome of the upper extremities was achieved.

At 3 years of age, the patient returned to the clinic. She lived at home with her mother, older brother, and maternal grandmother. She still had considerable contractures of both elbows; however, they remained functional. Unfortunately, the flexion contractures of her knees had progressed to 140° with little motion (Figures 1A and 1B). The patient’s mother reported difficulty with performing her daughter’s daily hygiene routine, concerns about the developing skin breakdown that was in the popliteal fossa of both knees, and challenges regarding wheelchair transportation. At this time, through-knee amputations were discussed. It was felt that this option would provide the best functional outcome, but the family was encouraged to seek a second opinion because of the magnitude of the treatment. Additionally, arrangements were made for the mother to meet with two different occupational
therapy specialists to ascertain whether the patient could use the proposed prosthetics owing to upper extremity limitations.

Two years later, at age 5, the patient returned to the clinic. Her mother reported that the large referral center they went to for a second opinion had agreed with our plan. The patient primarily used a wheelchair and otherwise had to crawl for mobility. Her skin breakdown continued to be an issue and no improvements had been seen. Her mother wished to proceed with through-knee amputation of both knees, with the goals of preventing further skin breakdown, improving balance while sitting, and potential ambulation with prosthetics. The orthotics and prosthetics specialist visited with the family again to discuss prosthetic options.

The surgical procedure was performed without complication, and the patient was discharged from the hospital 2 days postoperatively (Figure 2). The patient was noted to have promising healing of her surgical wounds but was thought to have developed phantom pains that were then controlled with a low dose of gabapentin.

At 5 months postoperatively, the patient had been fitted with prostheses for both knees (Figure 3). She began once-a-week sessions with a physical therapist. At 6 months postoperatively, her physical therapist reported that she was able to ambulate about 91.4 m (300 ft) with moderate assistance (Figures 4A and 4B). Overall, the mother had no concerns and was happy with the outcome.

DISCUSSION

Multiple pterygium syndrome is an uncommon condition for which little has been published regarding treatment and outcomes. To our knowledge, this is first report detailing 140° flexion contractures of the right and left knees. Our patient had popliteal skin breakdown, could only crawl for mobility, and had poor sitting balance and wheelchair fit. Our options were continued observation, dynamic splinting, soft-tissue releases, or amputations. Owing to the lack of published data on treating such severe contractures, our team felt that through-knee amputation of both knees would provide the most predictable outcome. Her
mother was present at all clinic visits and was intimately involved with this decision.

Other techniques have been described for treating less severe knee contractures. One technique uses a Z-plasty to lengthen the soft tissues. This option can only be used for small contractures and when the sciatic nerve and vessels are not displaced into the webbing. One patient with a 45° contracture was treated with soft-tissue releases and gradual lengthening using an Ilizarov external fixator. Although initially successful, 15° to 30° of contracture recurred postoperatively. In the current case, soft-tissue releases were not believed to provide a functional outcome. Although it was not confirmed with advanced imaging findings, the sciatic nerve and vessels commonly adhere to the pterygium.

In the current case, we had the benefit of being involved from the beginning. Early in the patient’s life, her mother had been counselled about the potential of amputations. Her mother returned to the clinic with a clear understanding of what she was agreeing to after receiving a second opinion, meeting with several therapists and prosthetics specialists, and having multiple visits with our orthopaedic team. Although not a common surgical solution, having our team ready and on the same page helped ease the transition for the family. Furthermore, the surgical procedure was successful, without any complications, and the patient continued to progress with physical therapy. At 6 months postoperatively, she was standing and walking up to 91.4 m (300 ft) with moderate assistance using knee prosthetics and handheld support at the elbow and forearm.

When carefully planned and tailored to the individual case, through-knee amputation may provide a predictable and functional solution for young patients with severe knee flexion contractures associated with multiple pterygium syndrome. In the current case, no risk of further reoccurrence has been observed and physical therapy was started immediately after the procedure. Through-knee amputation should be discussed as a surgical option in these uncommon circumstances.

REFERENCES
Use of Titanium Mesh Cage in Treating a Subtrochanteric Defect: A Case Report

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Informed Consent The patient was informed that the data concerning his case would be submitted for publication, and he provided verbal consent.

Abstract
Titanium mesh cages have been used during fixation of segmental defects in long bones; however, use in the subtrochanteric region of the proximal femur is a novel application. We describe a 38-year-old, 330-lb man with a highly comminuted fracture about the right femur after a gunshot wound. Immediate treatment involved use of a cement spacer. Findings of follow-up imaging showed about 26° external rotational deformity and 2-cm limb shortening. To correct the rotational abnormality and limb length discrepancy, a cylindrical titanium mesh cage and custom-made femur locking plate with a cancellous bone autograft were used. Subsequently, successful bridging was obtained across the defect. Titanium mesh cages may be potential alternative devices to use in treating segmental femoral bone defects in the subtrochanteric region of the femur.

Keywords: Hip Fracture, Revision Surgery, Surgical Mesh

Introduction
Several treatment options exist for posttraumatic segmental defects in long bones, including vascularized bone grafts, the Masquelet technique, and distraction osteogenesis.1–8 Cylindrical mesh cages packed with a cancellous bone allograft or autograft were first reported by Cobos et al9 in 2000. Multiple studies on cages have reported improved incorporation of the graft into the defect, shorter times to limb function recovery, and fewer additional procedures.9–13 In 2006, a canine study reported histological findings that indicated significantly more healing in the femoral diaphysis group using cages than in the control group.14 Use of cylindrical mesh cages in human long bones has mostly been reported in the humerus, tibia, and mid-femur.9–13 To our knowledge, there are no reports of using the cages in the subtrochanteric femur, where biomechanical stresses exerted on the implant are especially high. We describe successful application of a cylindrical titanium mesh cage after a considerable subtrochanteric defect.

Case Report
A 38-year-old, 330-lb man presented to the emergency department with multiple gunshot wounds to his left forearm, upper chest, abdomen, and right groin. The resulting injuries included a highly comminuted proximal fracture about the right femur with segmental bone loss (Figure 1), and a left-radius fracture with a grade IIIA Gustilo-Anderson classification.

Figure 1. Anteroposterior view of the right hip, obtained in the emergency department.

After overnight resuscitation in the trauma intensive care unit, a fellowship-trained trauma orthopaedic surgeon (RG) performed open reduction and internal fixation (ORIF) using a custom-made locking plate for treating the right-proximal femur fracture. A lateral approach to the hip was used. Fully stripped bone fragments were removed, revealing 5 to 7 cm of bone loss. Owing to the extent of the injuries, a temporary antibiotic cement spacer was used to fill the defect (Figure 2). ORIF for treating the left radial shaft fracture...
was completed 5 days later. The patient was discharged 28 days after admission to an inpatient skilled nursing facility, with a touchdown weight-bearing restriction of his right leg.

His right femur was clinically noted to be short and externally rotated. At 11 weeks after injury, the results of a computed tomography scan confirmed these findings. More specifically, the right femur was 27° externally rotated and 2.4-cm short, relative to the left side. Deformity correction and definitive fixation were planned, including adjunct use of a titanium mesh cage to accommodate the size of the defect and the patient’s weight of more than 330 lb. Although technically possible to perform within 4 to 12 weeks after placing a cement spacer, second-stage definitive fixation was delayed for our patient. This was decided so that the patient could spend 5 months in a dedicated rehabilitation facility to optimize his medical fitness and psychosocial readiness.

During the second-stage definitive fixation, a sterile goniometer and fully threaded Steinman pins were used to mark the rotational correction. The existing plate, screws, and cement spacer were all removed. The healing bone that was preventing deformity correction was excised. When the fracture site was adequately mobile, reamer irrigator aspirator was passed once to obtain about 30 cm³ of autograft. A 68-mm cylindrical titanium mesh cage was packed with autograft and placed into the defect. A new custom-made proximal femur locking plate was secured, achieving both deformity correction and fixation (Figure 3). A touchdown weight-bearing restriction was again implemented. The patient was discharged to inpatient rehabilitation 6 days postoperatively.

At 6 weeks postoperatively, the patient was actively involved in a physical rehabilitation program and was advanced to weight bearing as tolerated. At 3 months postoperatively, the patient was primarily using a walker for ambulation but was able to bear full weight on his right-lower extremity without pain. He was able to flex and extend his right hip through a functional range of motion with complete strength. Radiographic imaging findings of the right femur revealed considerable interval healing and bridging bone with some heterotopic ossifications in the area (Figure 4).
DISCUSSION
Management of large segmental bone defects can be a challenging endeavor. Common treatment options include use of vascularized bone grafts, the Masquelet technique, and distraction osteogenesis. Each option is associated with complications. Use of vascularized bone grafts for treating segmental bone defects was first described in 1975. Although this option has a high consolidation rate, it involves a highly complex procedure that typically requires surgeons with specialized training to both harvest and transfer the graft. Potential negative outcomes include fracture at the site of the graft, failure of fixation of the graft, and the need for reconstruction of the anastomoses due to poor limb perfusion.

Masquelet et al described filling a segmental defect with a cement spacer, inducing the formation of an overlying pseudosynovial membrane. After cement spacer removal, the encapsulating membrane is filled with a bone autograft. Although this technique can take several months to achieve the desired result, it has been shown to be successful in the humerus, tibia, and femur. Wong et al reported a mean interval of 43.5 days between placement of the spacer and the second surgical procedure to apply the autograft. Aparid et al reported decreasing the time required for complete weight bearing after the second stage by fixation using an intramedullary nail, but mean time was still 4 months.

Another option for treating large segmental defects is distraction osteogenesis, also known as bone transport, with an Ilizarov apparatus. This involves slowly separating two distracted bones, during the course of months, as new bone forms in between the segments. Bone transport is an effective method for reconstructing large bone defects; however, there are numerous potential complications such as implant site sepsis, instability at the docking site, and joint contractures. Furthermore, time to healing is proportional to the size of the defects. Green reported an average fixation time of 1.9 months per 1 cm of bone loss. Thus, a 6-cm defect might require almost 1 year to address using distraction osteogenesis, whereas using a titanium mesh cage could result in consolidated bone healing around 3 months.

Titanium mesh cages are an attractive alternative with an increasingly reliable track record after emerging in the early 2000s. Use of them has resulted in shorter time to unencumbered limb function in comparison to the Masquelet technique and distraction osteogenesis. Cobos et al initially reported 3 months of full weight bearing function after fixation of fibular defects; this timing is consistent with that of other case studies. Additionally, the application is a straightforward procedure, employs the use of readily available implants, and provides immediate limb stability, putting it at an advantage compared to the vascularized bone transplant. Compared to idiopathic membranous nephropathy, which is typically not

Figure 5. At 15 months after revision open reduction and internal fixation, radiographs of the right hip show the titanium mesh cage and proximal femur locking plate. A) Anteroposterior view. B) Lateral view.

During the last follow-up at 15 months postoperatively, the patient remained clinically functional with only mild pain reported at the hip with range of motion. On visual inspection of his alignment, the right- and left-lower extremities appeared symmetric. Findings of radiographs continued to show healed bone with interval increase in callus formation medially (Figures 5A and 5B). No hardware failure or loosening were noted despite the patient’s weight gain of more than 100 lb since definitive surgical fixation.
used for management of critical bone defects, use of titanium mesh cages easily allows implantation of a larger quantity of contained bone graft. A theoretical disadvantage of the application of these cages includes risk of infection when treating an open fracture. Although Reynder et al. reported promising bridging bone after application about the femur, no osseous continuity was found within the mesh cage. Owing to the practical advantages, titanium mesh cages should be considered as a viable method for the fixation of large segmental bone defects, even in high-stress areas such as the subtrochanteric femur.

REFERENCES

The American-British-Canadian Travelling Fellowship in Albuquerque

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In May 2018, The University of New Mexico (UNM) in Albuquerque hosted the American-British-Canadian (ABC) Travelling Fellowship. The visiting fellows comprised seven orthopaedic surgeons from the United Kingdom, Australia, New Zealand, and South Africa. As the first stop on their 5-week tour, the fellows arrived in Albuquerque with a sense of trepidation and uncertainty, as the whole experience of this academic grand tour was actually underway, with new colleagues that each had never really met before. They need not have worried, as they were warmly welcomed into their hosts’ homes, and were treated to an excellent academic, social, and professional experience that set a high bar for the remainder of their tour.

In 2018, the ABC Travelling Fellowship celebrated its 70th anniversary. The fellowship originated in 1948 as an innovation by Professor R. I. Harris, Chief of Orthopaedics in Toronto and then President of the American Orthopaedic Association. World War II was a time of innovation in orthopaedic surgery, due to the volume and complexity of the casualties seen. After the war ended, the first ABC Travelling Fellowship tour was convened to maintain links between allied orthopaedic associations and give a group of promising young surgeons the opportunity to travel to North America to exchange knowledge, ideas, and experiences. Seventy years later, the ABC Travelling Fellowship exists “to identify, develop, engage, and recognize leadership and to further the art and science of orthopaedics.”

The ABC tour is a considerable undertaking and involves spending more than a month away from home. The effect on families, friends, and colleagues is considerable and requires commitment and personal sacrifice from the fellows selected by their respective orthopaedic associations. However, it represents a unique opportunity for self-reflection and discovery, giving the fellows time to think critically about their practice and career, evaluate their individual and shared goals, and develop collaborations and friendships that will support them during their future careers.

The 2018 tour party comprised seven surgeons with various subspecialist practices. These included four United Kingdom surgeons: Paul Baker (arthroplasty), Phil Walmsley (knee), Amir Sandiford (arthroplasty), and Arul Ramasamy (foot and ankle); one surgeon from Australia, Luke Johnson (tumour); one surgeon from New Zealand, Michael Rosenfeldt (sports, knee, and shoulder); and one surgeon from South Africa, Michael Held (knee).

Albuquerque was the first stop in America, serving as the launch pad for their travels across the Southwest and West Coast of America before they travelled to Canada. Overall, the tour comprised seven institutional visits in the United States (Albuquerque, Phoenix, Los Angeles, San Francisco, San Diego, Salt Lake
City, and Denver), two in Canada (Edmonton and Winnipeg), and two academic meetings (Canadian Orthopaedic Association in Victoria, Canada, and the American Orthopaedic Association meeting in Boston, Massachusetts).

Weary and tired after a full day of travel, the tour party arrived in Albuquerque on 29th May 2018. The early arrivals were greeted with the warmest of welcomes, with Robert (Bob) C. Schenck Jr having memorised our names from the images sent in advance. This small touch did not go unnoticed and set the tone for the level of preparation and hospitality we came to enjoy during our time in New Mexico. The group were accommodated the homes of Bob, Daniel Wascher, and Kevin McGee, which was an ideal start for a group that had been complete strangers only 24 hours ago. The relaxed and informal atmosphere allowed the fellows to make friends and feel at ease while they chatted with the hosts and wider UNM faculty.

The following day, a full social program had been arranged and commenced with a breakfast burrito (a new concept for all the fellows) followed by a walking trip to Tent Rocks (Figure 1). An afternoon spa at Ten Thousand Waves in Santa Fe reinvigorated us after the previous day of travel and allowed us to get over any residual jetlag. Cocktails and dinner led back to some heated discussions as the fellows and the local faculty started to get the measure of one another. Our second day was spent observing clinical care in either out-patients or operating theatre, depending on subspecialty interest, followed by a small symposium where some of the party gave their first talks. The day was rounded off with a barbeque hosted by Dustin Richter and his family.

The final full day proved to be one of the highlights of the entire tour. During the day, we attended the Annual UNM Orthopaedic Alumni Conference organised and hosted by Eric Benson (Director), Dustin Richter, and Deana Mercer. The local residents presented their research before the rest of the tour party gave their talks. Invited speakers presented on the delivery of community trauma care, providing the fellows with insight and understanding about the way trauma services are delivered in the United States and how these differ from our own countries. In the evening, we were guests of honour at the chief residents’ graduation party, a unique experience that celebrated their achievements and recognised the sacrifices and hard work that they, their families, and their trainers had made during their training. What struck many of us was the sense of togetherness and pride expressed throughout the evening. The experience gave us food for thought and an example that we should strive to replicate in our own graduation ceremonies.

As Bob Schenck told us on a number of occasions, “culture eats strategy for lunch.” This refers to the concept that if the environment is not right and the people around you do not buy into your concept and direction of travel, then your planned development and evolution is unlikely to succeed. What we witnessed in Albuquerque was a department that has created a culture that should allow strategy to flourish. A department that functioned more like an extended family, led admirably by the father figure of “Papa” Schenck, than a group of colleagues. Their warmth and welcome left a lasting impression on the ABC tour. It gave us all a working culture to aspire to and provided an experience that will live long in not only our minds but also our hearts (Figure 2).

Figure 1. The American-British-Canadian travelling fellows exploring the Kasha-Katuwe Tent Rocks National Monument in the New Mexico sun.

REFERENCE

Reflections on Sports Medicine Fellowship Applications

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When I started the process of applying to sports medicine fellowships, I wanted to pick the “best” fellowship; that is a natural desire for most of us in this field. We are all inherently competitive and want to position ourselves to be the best possible orthopaedic surgeons, with as many work opportunities as possible. That is normal. The challenge is that there really is not a “best” sports medicine fellowship. By rule of the Accreditation Council for Graduate Medical Education and the American Orthopaedic Society for Sports Medicine, all fellowships meet the same general requirements.1 There are programs that offer more operative volume or greater surgical complexity than others, some that are more well rounded, and some that are less balanced. Some are academic (ie, heavy focus on research and didactic time), some are not. Some have lots of sports coverage, and others basically have none. And then there is the name (we will get to that later). The key is to try to get the best combination of all of these attributes.

MENTORSHIP
The personal relationship with mentors cannot be overstated and is arguably the most important piece of this puzzle. Fellowship is a long year to learn. But the truth is, we continue learning substantially throughout practice. Even if you want to slam through 500 anterior cruciate ligament (ACL) reconstructions a year, some patients will return with a problem and not every case will be straightforward. For challenging cases, and more importantly challenging life choices, it is helpful to have your mentors a phone call or text away.

DIVERSE TRAINING
With nearly 100 programs to choose from, there is no excuse to sacrifice an area of training. Ideally, we would all learn how to perform an ulnar collateral ligament reconstruction from Tommy John or be taught the iliotibial band ACL reconstruction technique from Dr. Lyle J. Micheli himself. But realistically this isn’t possible. After completing a sports medicine fellowship, surgeons should be comfortable with the following core disciplines: hip arthroscopy, open shoulder (instability and arthroplasty), superior capsule reconstruction, and revision ACL. When graduating from a sports medicine fellowship, you need a unique, marketable skill. No practice, academic or private, is looking to hire a young surgeon to scoop up their young, healthy patients waiting for ACL reconstruction. Whether you love or hate hip scopes, you should have a niche skill until you build up the practice you want.

SPORTS COVERAGE
Sports coverage is an important element of fellowship training, so much so that it is in the name of the specialty. Each program provides various coverage opportunities, ranging from high school football Friday nights to National Football League games every Sunday. It is helpful to understand the role a team physician plays if you would like to make that a part of your practice; and certainly dropping the Michigan football block “M” on your resume does not hurt either. But keep in mind the return on your investment is fairly capped. The hours spent on the sideline evaluating players are not drastically different than those spent in clinic. Although coverage may be a valuable experience, trading 8 hours with the team Saturday for 8 hours reading literature or operating may in fact be more worthwhile to your development as a surgeon.

RESEARCH
Lastly, some programs have a heavier focus on academic training than others. Academic fellowships tend to draw more complexity and breadth, which are key elements to fellowship training. To be an appealing applicant, it helps to demonstrate a common ground in research. Truthfully, most residents find research challenging because the associated labor is not particularly exciting. However, research is valuable in that you become an expert in a subspecialized aspect of your field. With this research comes connections, and with connections come opportunity.
PROGRAM LOCATION
The location of a fellowship is important to consider, but falls fairly low on the priority totem pole. Although the location of an institution is ideally comfortable and affordable, you could live anywhere for a year. Perhaps more importantly, one should consider job interests after fellowship. Finding a job in an unfamiliar location can be challenging; there is value in having “boots on the ground” in an area that you want to live and understand the local demand for a sports-trained orthopaedic surgeon and market saturation.

REPUTATION AND MATCHING
A former graduate of my residency program urged us to blind ourselves to the name of a program and “pick a program that suits your needs, instead of choosing one that you can simply tolerate but employs someone famous.” While I agree, I also acknowledge that everyone wants to go to an institution with a good reputation—it just makes sense. Thus, I would like to expand on his point and suggest that it is important to consider to whom the name is important. Although the layperson may care that you trained at Mayo Clinic instead of South Central Louisiana State University, the mention of “Mayo” among some academic-based sports medicine surgeons has resulted in skeptical looks on more than one occasion. Ultimately, relying on the reputation to train you to be a competent, thoughtful surgeon is dangerous. If your goal is to capture the patient population that values an institution’s reputation above all else, then you should pursue those fellowship programs. However, do not let the name of a fellowship come at the cost of mentorship, surgical volume, surgical complexity, and research opportunity.

The great news about sports medicine fellowships and the San Francisco Match is that the ball is firmly in the applicant’s court. A recent study published in the Orthopaedic Journal of Sports Medicine found that nearly 50% of applicants matched their first choice and 70% matched their top two. This pales in comparison to the 30% of programs matching their top applicants. The 2017-2018 San Francisco Match saw a near equal number of applicants to number of positions offered. These statistics are a welcome change to the stresses we faced in residency matching.

IDEAL FELLOWSHIP
The ideal sports medicine fellowship—for me—is academic without heavy pressure in research. It has every possible subfield of sports covered (shoulder, elbow, hip, knee, ankle, pediatrics). It should be run by experienced, well-published mentors and experts; it facilitates your learning by a combination of both observing and doing. It is in a comfortable, affordable location and covers enough athletics to build a CV and experience without standing shadow on the sideline or sacrificing every Saturday, Sunday, and weeknight.

I have decided that a fellowship with Drs. John Tokish, Ned Amendola, Asheesh Bedi, Marc Philipon, Christopher Harner, and Robert LaPrade located in Coeur d’Alene, Idaho covering college hockey would probably cover those bases. Unfortunately, I have yet to see that fellowship advertised on the San Francisco Match.

At the end of the day, there is no objective criteria to claim that one fellowship is better than another. To my surprise, institutions that I have left excited about have left other applicants underwhelmed and vice-versa. This speaks to the subjectivity of the community’s value of a “good” fellowship. Fortunately, there are many great fellowships out there, and the definition of great deeply depends on your career goals. The overwhelming majority of applicants whom I interacted with along the trail have echoed the sentiment that they would be happy to match at nearly any of the programs interviewed. It is a prosperous time to be a sports medicine fellowship applicant.

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The University of New Mexico Department of Orthopaedics & Rehabilitation: Alumni in Each State

Number of alumni in each state. Map reprinted with permission from Vexels (https://goo.gl/QtSLq5).

**Hand Surgery Fellows**

<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
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<tr>
<td>Damon Adamany</td>
<td>2007</td>
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<td>Ahmed Affifi</td>
<td>2008</td>
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Ronald Tegtmeyer (KS) 1976
Kenneth Teter (KS) 1993
Norfleet Thompson (TN) 2015
Erik Torkelson* 1964
James Trussell (WI) 1973
Gregory Voit* 1996
Catherine Walsh (CA) 2011
Howard Weinberg 1978
InSok Yi (CO) 1998
Robert Yoo (MA) 1977
Steven Young (LA) 2001
Eimer Yu 1979
Sports Medicine Fellows
Roy Abraham (NM) 2006
Tamas Bardos (HUNGARY) 2015
Brandee Black (CT) 2016
Todd Bradshaw (TX) 2014
Blake Clifton (CO) 2015
Lindsey Dietrich (TX) 2014
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Trauma Fellows
Stephen Becher (CA) 2014
Shahram Bozorgnia (CA) 2008
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Seth Criner (CA) 2016
Fabio Figueiredo (CO) 2007
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Residents
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