The University of New Mexico Orthopaedics Research Journal

2018

The University of New Mexico Orthopaedics Research Journal 2018

Volume VII

The University of New Mexico Orthopaedics Research Journal

2018

Volume VII

Published by the Regents of The University of New Mexico

ISSN 2167-4760

Department of Orthopaedics & Rehabilitation
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MSC10 5600
1 University of New Mexico
Albuquerque, NM 87131
505.272.4107

Printed by Starline Printing
7111 Pan American West Freeway N.E.
Albuquerque, NM 87109
505.345.8900
www.starlineprinting.com

With thanks to
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We thank them for their generous support of *UNMORJ.*

THANK YOU ALL

The Co-Editors and editorial board of *The University of New Mexico Orthopaedics Research Journal* express sincere thanks to the following peer reviewers, whose volunteered time and effort continually enhance the Journal's scientific quality and relevance of content. As a team, we continue to move forward in our path toward official indexing in PubMed.

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ISSN 2167–4760

SHORT INSTRUCTIONS FOR AUTHORS

The University of New Mexico Orthopaedics Research Journal

The University of *New Mexico Orthopaedics Research Journal (UNMORJ)* is a peer-reviewed (double blinded) publication of UNM Department of Orthopaedics & Rehabilitation. *UNMORJ* highlights original research relevant to orthopaedic-focused surgery and engineering, with the goal of MEDLINE indexing.

The submission deadline for UNMORJ volume 8 is November 1, 2018 by 11:59 PM (Mountain Time). Manuscripts submitted afterward will be considered for volume 9. Email questions to UNMORJ@salud.unm.edu.

Submit the Title Page, Blinded Manuscript, each table, and each figure as separate files to UNMORJ@salud.unm.edu.

General Formatting Title Pages and Blinded Manuscripts must be submitted as Microsoft Word documents. *UNMORJ* follows the style and format of the AMA Manual of Style (10th ed). Use Times New Roman, 12-point typeface and 1-inch margins. Use continuous line numbering, continuous page numbering in the upper-right corner, and double spacing. Spell out numbers less than 10 except measurements (eg, "4 days"). Use SI metric units. Only include up to 2 significant digits (eg, $P = 0.05$, $P < 0.01$).

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Blinded Manuscript Excluding the references, abstract, tables, and figure legends, we will accept ≤3200 words for reviews; ≤2500 for scientific articles, pilot studies, and education articles; ≤1200 for case reports, technical notes, and new technology; and ≤1000 for reflections. All papers (except reflections) must include headings of Abstract, Introduction, Discussion*, References, and Figure Legends if figures are used. Variations are as follows: scientific and education articles include Methods and Results; *reviews and new technology articles use Conclusion instead of Discussion; new technology articles include Design; case reports include Case Report; pilot studies include Progress and Future Goals; and technical notes include Technique. Subheadings may vary but are generally not included in Introduction, Discussion, and Conclusion sections.

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References List in order of appearance (not alphabetically) and present in the text by superscript numbers. Format all references in *AMA Manual of Style* (10th ed). All listed references must be cited in the text and vice-versa.

Tables/Figures Place each table on a separate Word document. Create tables using only the Word table function. Number each table and provide a descriptive title, with added footnotes as applicable (eg, to spell out abbreviations). Remove any images from the text, and save each one separately in 300 DPI as an EPS, TIFF, PPT, or JPEG file. Provide a brief descriptive legend for each figure in the last page of the Blinded Manuscript. In the figures, add markers (eg, asterisk) to identify noted parts. When submitting an image published elsewhere, provide information about the obtained permission. All figures and tables must be cited in the text.

We welcome all relevant orthopaedic and engineering submissions. We encourage manuscripts from faculty, fellows, residents, alumni, and colleagues. **For detailed instructions, view http://orthopaedics.unm.edu/research/research-journal.html.**

Thank you for considering *UNMORJ* as an avenue to feature your research.

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TECHNICAL NOTE

CASE REPORTS

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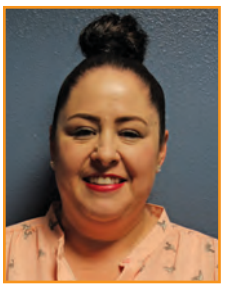

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Letter from the Chair

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 seventh volume of *The University of New Mexico Orthopaedics Research Journal (UNMORJ)*. This volume marks a period of transition to our goal of becoming a peer-reviewed orthopaedic journal with citations in PubMed. This is our second 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 2017 and 2018 volumes, including the following individuals:

UNMORJ 2017—Adam Adler, MD, Eric Benson, MD, Jenni Buckley, PhD, Shane Cass, DO, Tahseen Cheema, MD, James Clark, MD, Thomas DeCoster, MD, Rebecca Dutton, MD, Fabio Figueiredo, MD, David Grow, PhD, Daniel Hoopes, MD, Andrea Lese, MD, James Love, MSME, Christopher McGrew, MD, Moheb Moneim, MD, Patrick Mulkey, MD, Jorge Orbay, MD, John Phillips, MD, Ashkan Pourkand, MSME. Jeffrey Racca, MD, Dustin Richter, MD, John Ruth, MD, Andrew Schannen, MD, Jordan Smith, MD, Daniel Stewart, MD, Mahmoud Reda Taha, PhD, Ahmed Thabet-Hagag, MD, Lauren Vernon, PhD, and Jason Wild, MD.

UNMORJ 2018—Stephen Becher, MD, David Burk, MD, Gregory DeSilva, MD, Michael Decker, MD, Fabio Figueiredo, MD, Katherine Gavin, MD, Jenna Godfrey, MD, J. Speight Grimes, MD, David Grow, PhD, Bryon Hobby, MD, Andrea Lese, MD, Heather Menzer, MD, Nathan Morrell, MD, Drew Newhoff, MD, Blake Obrock, DO, Jorge Orbay, MD, Matthew Rush, MS, Selina Silva, MD, Ahmed Thabet-Hagag, MD, Lauren Vernon, PhD, John Wiemann, MD, and Zhiqing Xing, MD.

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 seventh volume, and my personal thanks to the many others responsible for the continued expansion of research at UNM Orthopaedics, including 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 5 years. 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 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.

Robert C. Schenck Jr, MD
Professor and Chair
Department of Orthopaedics & Rehabilitation

Letter from the Co-Editors

Deana M. Mercer, MD; Christina Salas, PhD

Greetings! We welcome you to the seventh volume of The *University of New Mexico Orthopaedics Research Journal (UNMORJ),* featuring research and educational efforts of faculty, alumni, fellows, residents, and students from The University of New Mexico and beyond.

This is the second volume to feature an external peer-review process for *UNMORJ*. We are pleased to announce the addition of a second phase in the review process, allowing enhanced communication between authors and reviewers. 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 for our reviewers who lent their expertise, efforts, and time to make our seventh volume a successful, peer-reviewed publication. We sincerely thank all the contributors to this production—as well as Gail Case, Department Administrator; Sahar Freedman, Managing Editor and Copy Editor; and Joni Roberts, Managing Editor—whose work and dedication were instrumental in bringing the journal to fruition. We are similarly grateful to the help of our 2018 editorial interns Skylar Griego and John Ngo, as well as our layout editor Jana Fothergill.

We invite you to explore our recent department publications, listed below. These are in addition to the 30 articles published in last year's *UNMORJ*. 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.)

- Ansari MH, Claes S, **Wascher DC**, Neyret P, Stuart MJ, Krych AJ. International perspective on revision anterior cruciate ligament reconstruction: what have we been missing? Instr Course Lect. 2017;66:543-556.
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- Campbell RA, Gorman SA, Thoma RJ, Annett RD, **McGrew CA,** Yeo RA, Mayer AR, King JH, Rowland AS. Risk of concussion during sports versus physical education among New Mexico middle and high school students. Am J Public Health. 2018 Jan;108(1):93-95. doi:10.2105/AJPH.2017.304107.
- **Clifton B, Richter DL**, Tandberg D, **Ferguson M, Treme G.** Evaluation of the tibial tubercle to posterior cruciate ligament distance in a pediatric patient population. J Pediatr Orthop. 2017;37(6):e388-e393. doi: 10.1097/BPO.0000000000001035.
- Eberly L, **Richter D**, Comerci G, Ocksrider J, **Mercer D,** Mlady G, **Wascher D**, **Schenck R**. Psychosocial and demographic factors influencing pain scores of patients with knee osteoarthritis. PLoS One. 2018 Apr 9;13(4):e0195075. doi: 10.1371/journal.pone.0195075.
- Freeman K, Michalson J, Anderson D, Brown T, **DeCoster TA** , Dirschl D, Karam M, Marsh JL. Correlating tibial plateau fracture severity and reduction quality with outcomes using a new rank ordering method. Iowa Orthop J. 2017;37:57-63.
- Lynch AD, Chmielewski T, Bailey L, Stuart M, Cooper J, Coady C, Sgroi T, Owens J, **Schenck R**, Whelan D, Musahl V, Irrgang J; STaR Trial Investigators. Current concepts and controversies in rehabilitation after surgery for multiple ligament knee injury. Curr Rev Musculoskelet Med. 2017;10(3):328-345. doi: 10.1007/s12178-017-9425-4.
- **McGrew CA**. Active voice: in the Winter Olympics, "citius, altius, fortius" sometimes translates to "concussion." Sports Med Bull. 2018. http://www.multibriefs.com/briefs/acsm/active022018.htm. Accessed February 22, 2018.
- **McGrew CA**, Crum A, Toldi J. Expert comment on: [Mullally WJ. Concussion. Am J Med. 2017;130(8):885-892. doi: 10.1016/j.amjmed.2017.04.016]. PracticeUpdate.

http://www.practiceupdate.com/journalscan/37347/1/6?elsca1=emc_enews_expert-insight&elsca2=email&elsca3=practiceupdateprimary&elsca4=primarycare&elsca5=newsletter&rid=NTU2MjE3OTAyNTYS1&lid=10332481. Accessed June 16, 2017.

- **McGrew CA**, Pusateri M, Hockenberry B. Expert comment on: [Mez J, Daneshvar DH, Kiernan PT, et al. Clinicopathological evaluation of chronic traumatic encephalopathy in players of American football. JAMA. 2017;318(4):360–370. doi:10.1001/jama.2017.8334]. PracticeUpdate. http://www.practiceupdate.com/content/chronic-traumatic-encephalopathy-in-players-of-american-football/56238/62#commentarea. Accessed August 7, 2017.
- **Moneim MS, Salas C, Lese AB, Thompson NB, Mercer DM**. Long-term outcomes of partial trapeziectomy with capsular interposition arthroplasty for osteoarthritis of the thumb basal joint. Orthopedics. 2018;41(2):e228-e233. doi: 10.3928/01477447-20180123-03.
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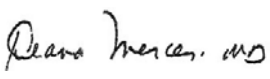
*UNMORJ i*s proud of its past and current accomplishments in highlighting original research relevant to orthopaedic surgery and engineering. We look forward to continue spreading knowledge to help improve care for patients on local, regional, national, and international levels.

Sincerely,



Deana M. Mercer, MD
Associate Professor

Christina Salas, PhD
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Department of Orthopaedics & Rehabilitation

Letter from the Chief of the Division of Physical Therapy

Burke Gurney, PT, PhD, OCS

The University of New Mexico (UNM) Physical Therapy Program admitted its 44th class in Fall 2017. Since its inception in 1974, our program has accepted and educated nearly 1000 students. We are pleased to expand our program to utilize newer UNM Health Sciences Center (HSC) facilities for education and research, incorporate study abroad opportunities, and establish future collaborative efforts within and beyond the university. In my final year as division chief, I am proud and honored to have worked alongside such a hardworking, passionate group of professionals and students alike—and I am excited to see the continued growth of our program in the years to come.

UNM Physical Therapy continues to prosper with the recent growth in UNM HSC facilities. Thanks to our larger classrooms in the new Domenici Building, we increased enrollment from 30 to 34 students. Additionally, we currently utilize the newly constructed Wellness Center in Domenici West Wing to offer UNM HSC employees a fitness screening program. The screening has been a huge success, and we are booked for months in advance! Furthermore, we completed our second year of service at the Service Learning Student Physical Therapy Clinic (also known as REACH Clinic). We expanded our service to 12 patients per week, including adults and children with orthopaedic- and neurologic-related injuries. Finally, our motion analysis laboratory is in full swing, with about eight active research projects. I am pleased to note that we secured several small grants to help fund our expanding research endeavors.

In addition to investing in our local campus, UNM Physical Therapy is dedicated to encouraging students to grow professionally and personally while studying abroad. This year, we are excited to continue our Guatemala program (8 years since inception) and introduce new setups in Addis Ababa, Ethiopia, and Tula, Russia. More than half of the 2019 class will volunteer in other countries to offer physical therapy services for those in need.

Future plans for UNM Physical Therapy include developing an orthopaedic and/or acute care residency program as well as developing a PT/PhD program. We have entered into discussions with Lovelace Rehabilitation to be part of the exciting Physical Medicine and Rehabilitation Department, including creating a faculty practice clinic to double as a new home for our REACH clinic.

On a more personal note, we have some announcements regarding current and future faculty. Both Kathy Dieruf, PT, PhD, and Fred Carey, PT, PhD, retired last year. Kathy kindly stayed on to help train our new neurologic faculty members Rose Vallejo, PT, DPT, who started in January and Sue Leach, PT, PhD, who will be joining us in June. Fred has relocated with his wife to southern Arizona. I will be stepping down as division chief at the end of September 2018. It has been my honor to be a faculty member at UNM HSC since 1995, and the division chief for the past 5 years. After over 25 years as a faculty member and program director, Ron Andrews, PT, PhD, will also be retiring in September. We are currently searching for the next division chief and program director, and we look forward to finding individuals whose goals align with and invigorate our fantastic team of staff, students, faculty, and allied healthcare professionals.

The UNM Division of Physical Therapy is proud of the many accomplishments of our students, faculty members, and collaborators. Every year, we improve the ways in which we serve our institution, students, profession, and state—with the shared goal of providing high-quality care to the patients of New Mexico and beyond.

Sincerely,

Burke Gurney, PT, PhD, OCS

Burke Gurney, PT, PhD, OCS
Professor and Chief
Division of Physical Therapy

Letter from the Residency Director

Gehron P. Treme, MD

As another academic year comes to a close, congratulations are due to our five graduating chief residents Erika Garbrecht, Brett Mulawka, Brielle Payne Plost, Tony Pedri, and Alex Telis as they conclude this important stage in their training. It has been an honor to participate in their journey, along with all of the other members of our team here at The University of New Mexico (UNM), and to witness their growth personally and professionally the last 5 years.

As it is every year, this season of change brings in another class of residents to take the place of our graduates in the long line of orthopaedic surgeons who have trained here. A special welcome to our new group of interns Aamir Ahmad (The University of Arizona-Tucson), Bryce Clinger (Virginia Commonwealth University), Allicia Imada (University of Vermont), Jordan Kump (University of Utah), and Kate Yeager (Oregon Health & Science University) as they join the UNM family. We are excited to have you with us.

Completing residency at all requires grit, determination, perseverance, and compassion along with physical and intellectual fortitude—all of which our graduates possess in spades. But there's always more to the story. All great accomplishments are the sum total of many interactions that challenge, support, guide, and push us on to the final goal. As Malcom Gladwell writes in his book *Outliers: The Story of Success:*

> *"The tallest oak in the forest is the tallest not just because it grew from the hardiest acorn; it is the tallest also because no other trees blocked its sunlight, the soil around it was deep and rich, no rabbit chewed through its bark as a sapling, and no lumberjack cut it down before it matured."*

So as we congratulate this graduating class of residents, it would be a good time to reflect on those experiences and individuals that have, in their own unique and peculiar way, pushed, prodded, and often unknowingly allowed us to get to the place we are today. Of course, we all have our closest supporters who help us meet our daily challenges and keep us going when we need it most. Without this group, there could be no success at all. Peel back more layers, though, and there is a story we could all tell. The tale might involve a grandparent, high-school English teacher, farmer, or cranky construction-site foreman (those are all mine, and there are many more) who intentionally or unintentionally showed us the way, put up obstacles, or lent advice that shaped who we became. And looking even deeper, opportunities and situations experienced by those far back on our family trees set us up for this success, often in hidden and fascinating ways.

We are, none of us, self-made and what a good opportunity to think about how our individual stories have taken shape. Great work Erika, Brett, Brielle, Tony, and Alex. We are so proud to call you graduates of our program. It has been a true pleasure and honor to have you on our team the last 5 years.

Sincerely,

Gehron P. Treme, MD
Associate Professor and Residency Program Director
Department of Orthopaedics & Rehabilitation

Below-Knee Amputations: A Review

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Funding The author received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The author reports no conflicts of interest.

ABSTRACT

At our institution, physicians from the orthopaedic department perform a considerable proportion of below-knee amputations. These amputations are performed to treat non-traumatic and traumatic injuries. However, the outcomes of amputation are not discussed as often in our educational experience as those of other procedures. The current review examines the current and relevant studies for indications and outcomes of patients with non-traumatic and traumatic conditions treated with below-knee amputations.

Keywords: Diabetes Mellitus, Vascular System Injuries, Traumatic Amputation, Amputation

INTRODUCTION

Amputations have long been performed to definitively treat lower-extremity wounds, infections, and injuries. Amputations were performed as early as 43,000 BCE, and prostheses were used as early as 1500 BCE, according to Padula and Friedman.[1] As numerous surgical and medical advancements have been made, especially in the past 20 years, the indications for and outcomes of amputations are much different than in ancient times.

Currently, nearly 2 million people live with limb loss in the United States.[2] Among those, the main causes are vascular disease (54%)—including diabetes and peripheral arterial disease—trauma (45%), and cancer (< 2%).[2] About 185,000 amputations occur in the United States annually.[3] In 2009, hospital costs associated with amputations totaled more than $8.3 billion.[4] African-American patients are up to four times more likely to undergo an amputation than white Americans.[5] Nearly half of the individuals who undergo amputations owing to vascular disease will die within 5 years. This is higher than the 5-year mortality rates for breast cancer, colon cancer, and prostate cancer.[6] Of persons with diabetes who undergo lower-extremity amputations, up to 55% will undergo amputation of the second leg within 2 to 3 years.[7] The current study will review the indications and outcomes of non-traumatic and traumatic amputations.

NON-TRAUMATIC AMPUTATIONS: PATHOLOGICAL FEATURES AND INDICATIONS

Most non-traumatic below-knee amputations are performed for non-healing wounds, with or without underlying infection. Lower-extremity ischemia appears to be the main determinant in development of the wounds. Many patients with ischemia to the lower extremity also have diabetes, which complicates the ischemia. Lepäntalo et al[8] found many factors that mask the severity of the present vascular pathological features and tissue injury occurring in patients with diabetes. In particular, there are both macro- and microvascular changes that can complicate the clinician evaluation of lower-extremity perfusion.

In patients with diabetes, macrovascular changes have been noted to be more extensive in the crural arteries compared to the pedal arteries. Therefore, clinicians who palpate the dorsal pedis artery may incorrectly assume that the limb is adequately perfused. Microvascular changes in patients with diabetes can result in thickening of the capillary basement membrane, which does not impede oxygen delivery but does impede delivery of nutrients and cellular materials. The lack of nutrients and cellular material play a considerable role in inhibiting tissue repair. It is common to falsely assume that if the limb receives oxygen, it also receives these key nutrients and cellular building blocks for tissue repair. Because oxygen saturation is more easily measured now, clinicians should be careful to assume that oxygenated tissue has sufficient nutrients and cellular material for wound healing. Knowing these complicating factors, Lepäntalo et al[8] proposed that clinicians should never amputate a limb for treating non-traumatic reasons without work-up and consultation from a vascular surgeon.

Many investigations have tried to evaluate the quality of blood flow to extremities and possibly predict wound healing of slow-healing wounds and at specific amputation levels. Recently, Wang et al[9] performed a systematic review and meta-analysis of various tests to predict wound healing. They analyzed 37 studies and evaluated various vascular studies regarding prediction of wound healing. Examined tests included ankle-brachial index (ABI), toe-brachial index,

transcutaneous oxygen measurement ($TcPO^2$), toe systolic blood pressure, ankle peak systolic velocity, skin perfusion pressure, microvascular oxygen saturation, and hyperspectral imaging. Most studies focused on ABI and $TcPO^2$. The authors concluded that overall quality of evidence was low to suggest that any of these tests could differentiate between a limb that could heal a wound versus one that could not. Many of the reviewed studies stated that clinical judgement plays a considerable role in whether to amputate and at what level.

NON-TRAUMATIC AMPUTATIONS: OUTCOMES

Many studies have described outcomes of below-knee amputation for treating non-traumatic indications.[10-15] Overall, the mortality rate is high. In 2016, a systematic review noted 53% to 100% of patients died in a 5-year study on non-traumatic amputation.[10] Specifically, 40% to 82% of patients died who underwent below-knee amputation for treating non-traumatic injuries. Noted risk factors for death were increased age, renal disease, proximal amputation, and peripheral vascular disease.

Reported ambulation rates are relatively low. At 1-year postoperatively, studies have described 23% to 65% of patients ambulating after below-knee amputation.[11-13] One study evaluated the 30-day unplanned re-admission rates of patients undergoing major lower-extremity amputation. A total of 739 patients who underwent amputation at one of two large centers in the United States were evaluated. The overall re-admission was 28.8%, with stump complications accounting for 28.6%. Most other re-admissions were owing to nonsurgical site infections. Table 1 includes the unplanned re-admission diagnosis within 30 days of below- and above-knee amputation and percentages. During the 30 days, 8.8% of patients died. Of the patients undergoing below-knee amputation, 34.1% were converted to an above-knee amputation.[14] Because of these poor outcomes and risk of complications, some authors have suggested that patients with considerable risk factors for poor outcomes may be better served with an above-knee amputation.[15]

Table 1. Diagnosis made at unplanned patient re-admission within 30 days after below-knee or above-knee amputations, reported in 2017 by Phair et al[14]

Diagnosis	*Total patient re-admissions (n = 213)*	*BKA patient re-admissions, (n = 134)*	*AKA patient re-admissions, (n = 79)*
Stump Complications, %	28.6	35.8	16.5
Nonsurgical site infection, %[a]	33.8	28.4	43.0
CHF, %	7	8.2	5.1
Cardiac complication, %	5.2	4.5	6.3
Diabetes-related complication, %	6.1	5.2	7.6
Other, %	23.5	21.6	26.6

BKA, below knee amputation; AKA, above knee amputation; CHF, congestive heart failure.
[a]Nonsurgical site infections include urinary tract infection, pressure ulcer, pneumonia, clostridium difficile colitis, unspecified.

TRAUMATIC AMPUTATIONS: INDICATIONS

After major trauma to the lower extremity, whether to choose limb salvage versus amputation becomes a treatment dilemma. Different factors indicate early and later amputations for treating traumatic injuries. Early amputation is clearly indicated if salvage is not possible and if functional result might be improved; however, both are difficult to determine preoperatively.

Scoring systems have been proposed to help determine indications for immediate amputation, including the Mangled Extremity Severity Score (MESS); Predictive Salvage Index (PSI); Limb Salvage Index (LSI); and Nerve, Ischemia, Soft-Tissue, Skeletal, Shock and Age of Patient (NISSSA). The MESS is the most well-known and researched scoring system.[16] It was developed in 1990 after retrospective and prospective evaluation on 51 patients with major extremity traumatic injuries, excluding those with major nerve transections.[16] The authors suggested that after using this scoring system to evaluate energy of trauma, ischemia, presence of shock, and age of the patient, clinicians would have a specific number guiding the salvageability of the limb.

Recent studies have challenged the reliability of this scoring system. The authors of the original paper published a follow-up article stating the advancements of medical care have made this scoring system less relevant in today's world.[17] The authors also stated that there is no reliable scoring system currently that can quickly predict the benefit of limb salvage versus early amputation. This was confirmed by a systematic review evaluating the current available scoring systems of major extremity trauma (ie, MESS, PSI, LSI, and NISSSA).[18] No specific scores were reliable enough to be used as the only criteria to proceed with either limb salvage or early amputation. Furthermore, none of the scoring systems considered the functional recovery of the patient after a specific treatment.

No scoring system is widely used to determine late amputation after initial attempt at salvage. Some relative indications include chronic recalcitrant infected non-unions, persistent un-reconstructable soft-tissue wounds, and painful non-functional limb. Similar to non-traumatic amputations, indications for early and late amputation to treat traumatic injuries depend on

the surgeon's overall assessment of the potential for salvage. Calculating an injury index may be useful to help make that assessment.

TRAUMATIC AMPUTATIONS: OUTCOMES

For patients with traumatic injuries treated with amputation, the mortality rate is much lower than that of non-traumatic injuries. Patients with a traumatic injury or non-traumatic injury treated with amputation have a 5% and 15% early mortality rate, respectively. For traumatic injuries treated with amputation, patients that survive 90 days postoperatively have a 5-year mortality rate of about 2%. Owing to much higher survival rates after traumatic amputations, studies have focused on functional and psychosocial outcomes.[19-21]

In 2002, a benchmark study from the Lower Extremity Assessment Project (LEAP) group presented valuable information on outcomes in patients undergoing limb salvage versus early amputation. The Sickness Impact Profile (SIP), a multidimensional measure of self-reported health status, was used to measure and quantify the outcome of 569 patients with severe lower-extremity trauma who underwent limb salvage or amputation. After 2 years postoperatively, the SIP scores were similar in the limb salvage group compared with the amputation group; however, both groups had considerable disability as measured by the SIP compared to age-matched controls. The disability was found to be physical and psychosocial. Low educational levels, people of color, lack of private insurance, poor social-support network, low self-efficacy, and involvement of disability-compensation ligation were predictive of a poor outcome.[22] A follow-up study of these patients at 7 years postoperatively revealed that both physical and psychosocial functioning deteriorate between 24 months and 84 months after the injury.[23]

Although the LEAP group found relatively poor outcomes after major lower-limb trauma, another study reported promising outcomes with similar injuries. A retrospective study from the United Kingdom on military-patients evaluated the physical and mental outcomes after immediate amputation, delayed amputation, and limb salvage to treat major trauma.[24] Regarding the immediate and delayed unilateral amputation groups, a total of 86% of patients were able to walk distances comparable to age-matched controls in 6-minute walk test. A total of 50% of these patients were able to run independently. Interestingly, patients undergoing amputation or limb salvage had the same rates of the general population regarding major anxiety and depression rates. All patients did have full access to a multidisciplinary team trained to work with persons who experienced severe limb trauma.

CONCLUSION

Below-knee amputations are life-changing procedures for patients, whether for treating non-traumatic or traumatic injuries. Regarding non-traumatic amputations, the primary indication may be a non-healing ulcer with or without concurrent infection. The pre-amputation health status of patients plays a main role in the outcome. Many of these patients undergoing non-traumatic below-knee amputations have a complex medical history and are best served with a multidisciplinary team for pre- and postoperative treatment. Thorough work-up before the procedure should be conducted. In some cases, a patient with poor preoperative health status may be more successfully treated with an above-knee amputation because of the higher risk of wound complication and low likelihood of ambulation postoperatively.[15]

In traumatic-related amputations, MESS has been shown to provide an adequate assessment for determining whether to perform an early amputation. Surgeons may use this as a tool to help develop an overall assessment of indication for early amputation in treating patients with traumatic injuries. Attempted salvage should be considered first, with early amputation performed only when salvage is clearly impossible. Salvage is typically performed for treating patients who are healthier than those undergoing amputations for treating non-traumatic injuries. In healthy patients, an amputation is life changing, especially regarding mental health. Patients who have severe lower-extremity injuries requiring amputation may function well postoperatively depending on adequate access to both physical and mental health care.

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Primary Fusion for Treating High-Energy Intraarticular Fractures of the Distal Tibia: A Review

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Funding The author received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The author reports no conflicts of interest.

ABSTRACT

Orthopaedic surgeons on-call often see patients with fractures of the distal tibia involving the articular surface, with extension proximal into the metaphysis, or intraarticular distal tibia fractures. These injuries pose unique challenges owing to the typical high-energy mechanism, articular-surface involvement, high degree of comminution, and typically large soft-tissue injury. Treatment has evolved greatly with the advent of modern fracture-fixation techniques and implants. However, a large percentage of patients continue to report poor subjective outcomes. Nearly all of these patients develop posttraumatic arthritis, with the most severe often requiring further reconstructive or fusion procedures once healed to treat the symptoms. Recent studies have described promising outcomes after treating certain fractures (eg, Lisfranc and subtalar) with primary fusion of the affected joints as the definitive method of fixation. Subsequently, there is increased interest in treating severe intraarticular distal tibia fractures with primary fusion of the tibiotalar joint. Few studies have reported on this topic, yet several case reports and small series of patients found successful outcomes with primary fusion. The purpose of this paper is to provide a brief review of intraarticular distal tibia fractures and primary fusion, covering reported treatment methods and outcomes. Although primary fusion may be a viable option in improving patient outcomes in certain fracture patterns and patients, more long-term studies comparing methods are needed to help surgeons decide definitive treatment.

Keywords Tibial Fractures, Intra-Articular Fractures, Fracture Fixation, Review Literature

INTRODUCTION

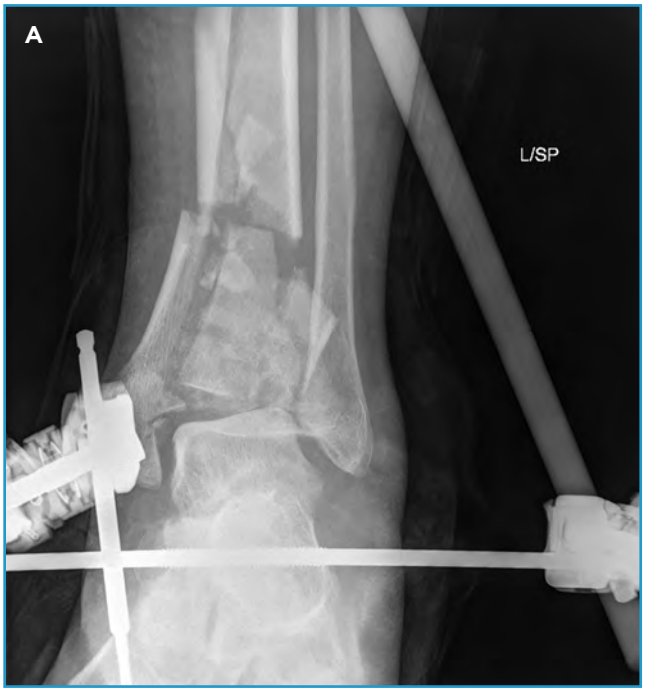
Distal tibia fractures involving the articular surface, with extension into the metaphysis, are common and comprise 1% and 10% of lower-extremity fractures and tibia fractures, respectively.[1] They are frequently associated in patients with multi-organ injuries, and up to a third are open injuries.[1] These fractures typically result from either a low-energy torsional type injury (eg, ski boot) or, more commonly, a high-energy axial load (eg, automobile accident). Treatment is challenging owing to the high levels of comminution, joint involvement, and soft-tissue injury.

Many strategies have been attempted to treat these specific fractures, including nonoperative treatment, external fixation, and open reduction and internal fixation (ORIF). Recently, studies have discussed primary tibiotalar joint fusion for the most severe acute fractures, which tend to have worse clinical- and patient-reported outcomes.[2-7] The purpose of this paper is to review intraarticular distal tibia fractures, including historical and current treatment and outcomes, and recent studies examining primary fusion as a method for treating severe acute fractures (Figures 1A and 1B).

DEFINITIONS AND DEMOGRAPHICS

Distal tibia fractures involving the articular surface, with extension into the metaphysis, are different from more proximal tibial shaft fractures and ankle fractures. Those involving the articular surface are commonly referred to as tibial plafond or tibial pilon fractures, with some debate regarding origin and correct nomenclature.[8,9] The term “plafond” stems from the French word used to describe decorative ceilings or roofs often found in cathedrals. In orthopaedics, the word subsequently describes the anatomical region of the distal tibia articular surface, which is the roof or ceiling of the tibiotalar joint.[9] The other term, “pilon,” describes not only the anatomical region but the type of fracture and mechanism of injury to help differentiate from fractures with less comminution, impaction, and proximal extension such as medial malleoli fractures.[8]

Intraarticular distal tibia fractures typically occur in younger men aged 20-40 years as the result of low-energy, torsional-type injuries (eg, ski boot) or, more commonly, high-energy axial loads such as automobile crashes or falls.[1] This fracture type comprises roughly



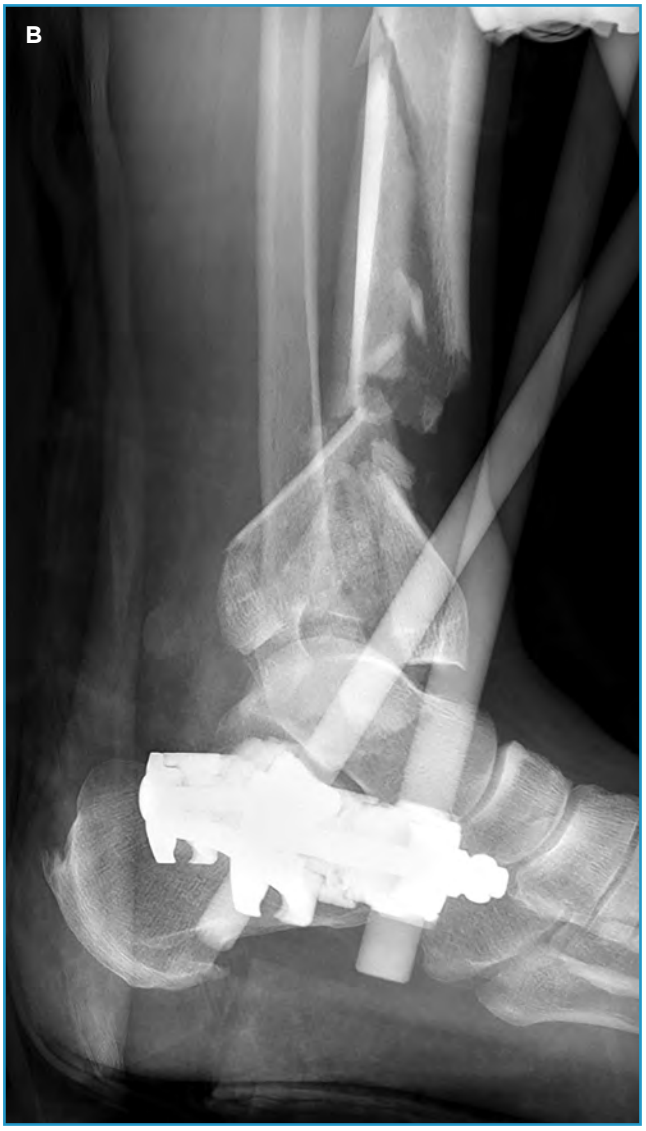


Figure 1. AO classification of a 43-C type distal tibia fracture, seen in a plain radiograph that shows greater than 50% communication of the articular surface. A) Anteroposterior view. B) Lateral view.

1% of lower-extremity fractures and less than 10% of tibia fractures.[1] Patients with multiple injuries or open injuries (one-third of patients for open injuries) often present with intraarticular distal tibia fractures.[10]

The fracture was initially reported in skiers who presented with lower-energy, torsional-type injuries. Currently, it is more commonly seen after high-energy crashes in which an axial load force forces the dome of the talus into the articular surface of the tibia, resulting in considerable comminution, impaction of the articular surface, possible necrosis of articular cartilage as a result of the pressure, and extension of fracture lines proximal into the metaphysis of the tibia.[1]

DIAGNOSIS

Diagnosis of intraarticular distal tibia fractures includes typical workup and treatment of traumatic orthopaedic injuries. Because of the association with multiple injuries, patients with these fractures should undergo a thorough evaluation of medical history and physical examination to rule out other injuries.[10,11] Initial diagnosis begins with plain radiographs of the intraarticular distal tibia, entire tibia, and foot to help differentiate from more common bi- or trimaleolar ankle fractures.

Historically, multiple orthogonal radiographs (eg, internal and external ankle radiographs) were obtained to help characterize the fracture fragments. Computed tomography (CT) scans and 3D reconstructions from the CT scan have become more commonly used for diagnosis and preoperative planning. Cole et al[12] showed that after CT scans were obtained in addition to radiographs, extra information was obtained in 80% of cases and change in surgical plans occurred in 60%. Typically, advanced imagining such as CT scans are obtained after initial reduction has been performed, including placement of a temporary external fixator to assist with regaining bone length and alignment.

Intraarticular distal tibia fractures have several predictable fragments that should be identified preoperatively to determine the methods of surgical approach and fixation. Traditionally, three fragments have been described and associated with their ligamentous attachments to surrounding structures. These include the medial fragment and associated deltoid ligament, anterolateral or Chaput fragment, anterior- and posterior-inferior tibiofibular ligaments, and posterolateral or Volkman fragment. A central compacted fragment or "die punch" may also be associated, which cannot be easily detected as

appreciating on plain radiographs but must be addressed at the time of surgical treatment to achieve adequate reduction of the articular surface.

CLASSIFICATION

Several classification systems describe intraarticular distal tibia fractures. Historically, the most commonly used system is the Rüedi and Allgöwer[13] classification scheme that involves three types based on the amount of articular comminution and displacement. More recently, the AO/OTA classification of fractures has become commonly used especially with research on types 43-B and 43-C fractures, representing intraarticular distal tibia fractures with metaphyseal extension (Figure 2).[14]

TREATMENT AND OUTCOMES

Treatment of intraarticular distal tibia fractures has evolved owing to use of several different algorithms and techniques. The indications for fixating intraarticular distal tibia fractures has remained relatively constant. Rüedi and Allgöwer[13] published one of the first reports on operative fixation, describing the goals as achieving restoration of limb length, less than 5° of angular malalignment in any plane, and less than 2 mm of joint incongruity. Recent publications have discussed less stringent criteria but emphasized reduction of the articular surface and reconstruction of the metaphysis to the diaphysis. Nonoperative management is typically reserved for treating fractures with minimal displacement or for patients too ill or frail to undergo surgery. In general, most intraarticular distal tibia fractures are treated operatively.

Techniques

Many techniques have been described to achieve reduction and fixation of intraarticular distal tibia fractures, including as follows: immediate versus delayed fixation, ORIF, ring fixator fixation, and hybrid fixation (eg, partial open reduction and ring fixation, or partial open reduction and internal fixation). The specifics of each method are beyond the scope of this paper, but overall treatment outcomes will be discussed.

Open Reduction and Internal Fixation

Historically, operative treatment included immediate ORIF. In an earlier study by Rüedi,[15] greater than 70% of "good to excellent" results were reported with less than 10% complications (eg, infections) and most patients returned to work. Studied fractures were mostly low energy, and outcomes were clinical rather than patient specific. Other reported outcomes using immediate ORIF were less promising, with more than 50% infection, 10% skin sloughing, and 36% nonunion or malunions.[16,17]

Owing to advancements in modern fixation techniques, the cause of these failures was linked to soft-tissue envelope at the time of operation. Sirkin et al[18] described a protocol for treating patients with severe intraarticular distal tibia fractures. The study recommended temporary fixation with either a splint or spanning external fixation, followed by definitive fixation when appropriate depending on the soft tissue. The authors performed definitive fixation at an average of 14 days from the injury and observed lower infection rates (< 5%), only one amputation, and no secondary skin coverage procedures. Similar studies have noted current average infections between 1% and 2% for closed injuries and 8% to 10% for open injuries treated with delayed fixation.[1]

Quantification of Outcomes

Owing to the absence of a standard validated system that encompasses all injury aspects, it is difficult to quantify clinical outcomes of intraarticular distal tibia fractures. Several criteria and scoring systems have attempted to quantify outcomes, which typically include radiographic healing parameters, physical function assessment (subjective and objective), functional variables, and pain.[19-21] Many systems are adapted from ankle outcome scores, yet the different nature between injuries make the crossover unreliable.

Several studies have described clinical outcomes with relatively similar results. Teeny and Wiss[20] reported 71% of patients with "good to excellent" outcomes after undergoing anatomical reduction (vs 37% after non-anatomical reductions, of which 32% required ankle

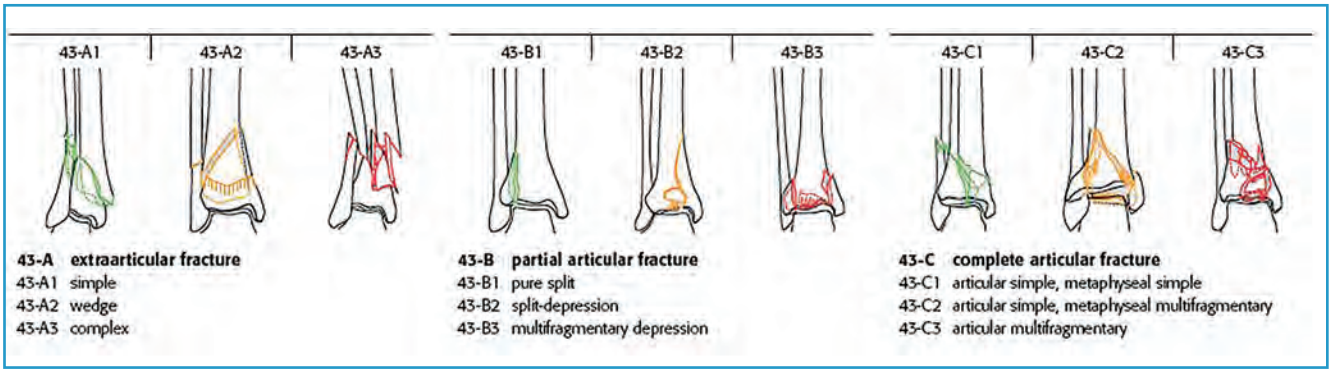


Figure 2. AO/OTA classification of 43-A, 43-B, and 4-C types of fractures, showing extraarticular, partial articular, and complete articular fractures of the tibia, respectively. Figure reprinted with permission from the Orthopaedic Trauma Association.

fusion). Barbieri et al[22] found similar results on patients with AO/OTA type 43-C1 fractures, with 100% of those patients having "excellent results" whereas only 45% of patients with type 43-C2/3 fractures had "excellent results." Watson et al[23] noted that 60% of patients with type 43-C fractures had "excellent results" when treated with use of mostly ringed fixator techniques. Regarding the percentage of patients who can expect promising outcomes, a number often quoted is 70%, which decreases when associated with more severe fractures.

Patient-Reported Outcomes

Recently, more studies have been interested in patient-reported outcomes and individual patient outcomes. This focus may be because more patients are healing in positions deemed appropriate without the need for secondary procedures and with decreased complications. The Medical Outcomes Study 36-item Short-Form General Health Survey (SF36, or SF12 with 12 items) has been used by several authors to note patient-reported outcomes and compare the scores to other disease processes.[24,25]

Pollak et al[24] reported on 80 patients with AO/OTA type 43-B/C fractures who underwent surgical fixation at two main trauma centers in the United States. They reported that SF36 physical health sub-scores were 36 points below population-based norms, and physical function scores were 21 points lower than matched norms. A total of 43% of patients no longer walked, and 13% of those who could walk used an assistive device. Study data were compared with available SF36 scores of patients with other chronic diseases; results showed that patients with intraarticular distal tibia fractures reported considerably lower scores than not only the general health population but also patients with pelvic fractures, migraines, asthma, hypertension, acquired immune deficiency syndrome, acute myocardial infarction, and diabetes. Similar scores were noted between patients with spinal injuries and only slightly better scores than patients on hemodialysis. Bonato et al[26] used SF12 to measure outcomes among Australian patients and found similar results, with scores at 38.2 on the physical health portion and 49.7 on the average population norm. Only 57% of patients had returned to work at 1 year, and 26% still reported severe pain in the extremity.

Recent studies have tried to determine prognostic factors associated with patient-reported outcomes after intraarticular distal tibia fractures.[25] De-las-Heras-Romero et al[25] examined demographic factors, social factors, fracture severity, postoperative complications, postoperative function, and radiographic findings. At 5 years, patients reported notably lower scores on both physical and mental portions of the SF36, with lower scores on both correlating with fracture severity, quality of reduction, and arthrosis at time of follow-up. Method of fixation, time of immobilization, and final range of motion correlated with lower physical scores but not mental scores.

PRIMARY FUSION

To prevent complications, reduce the need for future operations, and improve patient outcomes in the most severe distal tibia intraarticular fractures, primary fusion of the tibiotalar joint has been suggested. Because of new fusion techniques and implants, primary fusion of fractures has become a more accepted procedure. Nearly all severe fractures lead to posttraumatic arthrosis and patient-reported outcomes correlating with quality of reduction and severe arthrosis; subsequently, one method to prevent this outcome is primary fusion at the time of injury.[10,25] This greatly simplifies the need for reduction of the articular surface and theoretically prevents the possibility of posttraumatic arthrosis. Fusion may lead to loss of motion at the fused joint, although promising outcomes have been found in patients undergoing ankle fusion.[27-29]

No specific guidelines exist on which fracture types and patients should be treated with primary fusion or what defines an unreconstructable distal tibia fracture. Generally, unreconstructable fractures are described when less than 50% of the joint surface is involved with small fragments and delamination of the articular surface.[2-7]

Several techniques have been used with primary fusion.[2-7] Bozic et al[2] used a standard staged protocol for treating 15 patients with AO/OTA type 43-C fractures by primary fusion using a posterior blade plate. Of the 15 patients, seven had open injuries and 13 were initially placed in an external fixator for soft-tissue management. At 38 weeks, all patients healed and could walk. No patient-reported outcomes were noted.

Zelle et al[3] also described use of a posterior blade plate in treating 20 patients with AO/OTA types 43-C2 and 43-C3 fractures. At 2 years, the follow-up rate of patients was 85%, with 100% of patients walking and SF36 scores similar to those reported for patients undergoing ORIF. One patient developed an aseptic nonunion treated with a revision procedure, and another patient had a clinically significant leg-length discrepancy. Otherwise, all patients had healed incisions and wounds without need for secondary procedures.

Beaman and Gellman[5] used a specifically designed plate for anterior ankle fusion to perform primary fusion in treating distal tibia intraarticular fractures. The study also used a hybrid construct equipped with a ringed fixator to help maintain reduction and alignment in constructs deemed unstable. At an average of 4.5 months, they reported 100% union rate with no revisions or malunions. Patients scored an average of 83 on the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score. One patient developed a nonunion, and another patient had a malunion treated before fracture

healing with adjustment of frame. One patient had a superficial wound treated with skin grafting. All patients had at least one pin-site infection treated with oral antibiotics only. Several patients required removal of hardware after healing to treat related symptoms.

Ho and Ketz[6] described a technique involving a limited ORIF posteriorly, followed by anterior tibiotalar joint fusion. The method was used to treat fractures deemed "unreconstructable." No outcomes were reported.

Hsu and Szatkowski[7] reported one patient with an AO/OTA type 43-C severe open fracture and limited vascular flow to the extremity, diabetes, and a low socioeconomic status. A hindfoot fusion nail was used with tibiotalocalcaneal arthrodesis as the definitive treatment of the injury. The patient healed without complication, with an AOFAS hindfoot score of 79 at 17 months. Although the described protocol called for no weight bearing, it was noted that the patient likely was bearing weight almost immediately.

CONCLUSION

Distal tibia intraarticular fractures are complex and pose many treatment challenges. Historically, these fractures have been difficult to treat, with numerous complications resulting in unsuccessful outcomes. Because of new treatment procedures, protocols, and fixation techniques (eg, staged fixation), most fractures heal with minimal complications. However, treatment of more severe fractures continues to pose challenges because, despite reliably healing, patient-reported outcome scores are low.

The role of primary fusion for treating distal tibia intraarticular fractures has not been entirely established. Short-term follow-up studies on small groups of patients have shown that similar outcomes between severe and fractures treated by other means.[2-7] Fusion may be a viable option for treating unreconstructable fractures, especially when performed by surgeons with expertise in the procedure. Primary fusion may also benefit patients who have physiological or psychosocial factors that make traditional fixation methods less ideal, which includes patients with limited healing potential (ie, those with diabetes, peripheral neuropathological features, tobacco use, and psychological comorbidities). Fusion, although not a simple procedure, can simplify the need for articular reduction of the fracture; as such, there may be less risk of loss of reduction when patients weight bear after undergoing fusion compared to after undergoing articular reduction.

Because most patients develop posttraumatic arthrosis, few studies have been able to quantify the number of patients who develop symptoms caused specifically by arthrosis and require further procedures such as fusion or replacement. More studies are needed to quantify the number of delayed fusions performed and the postoperative function of patients treated with fusion after undergoing initial ORIF. Performing fusion at the initial procedure may help patients avoid secondary or revision procedures.

In summary, primary fusion of intraarticular distal tibia fractures is a viable treatment option and may improve patient outcomes in certain fracture patterns and patients. However, more procedures must be performed with more follow-up to further determine the role of primary fusion of distal tibia intraarticular fractures.

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Controversies in Treatment of Pediatric Supracondylar Humerus Fractures: A Review

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Funding The author received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The author reports no conflicts of interest.

ABSTRACT

Although supracondylar humerus fractures are one of the most common fractures in children, there remains notable controversy regarding several treatment aspects. Controversial topics include fixation of ipsilateral forearm fractures, treatment of type II supracondylar humerus fractures, pin configuration, timing of operative intervention, and treatment of supracondylar humerus fractures with a vascular injury. Studies have supported both closed and open reduction for treating ipsilateral forearm fractures associated with supracondylar humerus fractures. For type II supracondylar humerus fractures, some studies support nonoperative treatment owing to risks associated with operative treatment such as pin-site infections. However, other studies support operative fixation because of the risk of loss of reduction or malunion with nonoperatively treated fractures. Pin configuration can affect the stability of fracture fixation. Biomechanically, the strongest configuration has been shown to be a crossed-pin fixation; however, placement of a medial pin increases the risk of iatrogenic nerve injury. Therefore, an ideal pin configuration must balance stability with safety. Which fractures should be treated emergently and which can safely be delayed until the next morning is also controversial. The definition of adequate perfusion of the arm with a supracondylar fracture is debated as well as how to treat patients with decreased perfusion. Although the topic is widely researched, there is still much to be learned about the ideal treatment of supracondylar humerus fractures in children.

Keywords: Elbow, Humeral Fractures, Pediatrics, Operative Treatment, Conservative Management

INTRODUCTION

Supracondylar humerus fractures are the most common type of elbow fractures in children, accounting for 50% to 70% of all elbow fractures in children. The incidence of supracondylar humerus fractures peaks from ages 5 to 7 years and is rare in children aged less than 18 months and more than 12 years. Although supracondylar humerus fractures are one of the most common fractures in children, there remains some controversy in their treatment.[1]

Concomitant fractures are common and often due to higher energy mechanisms, most commonly ipsilateral forearm fractures. Whether to fix these fractures and in what order to fix them is a controversial subject. The ideal treatment of type II supracondylar humerus fractures (those in which the anterior cortex is disrupted but the posterior cortex is intact) is also controversial as is the ideal pin configuration. Whether to take patients to the operating room in the middle of the night for emergent operation as well as the treatment of supracondylar humerus fractures with a vascular injury are also controversial. The noted controversies will be discussed in the current review.

TREATMENT OF SUPRACONDYLAR HUMERUS FRACTURES WITH IPSILATERAL FOREARM FRACTURES

When an ipsilateral forearm fracture is present with a supracondylar humerus fracture, operative versus nonoperative treatment of the forearm fracture is debated. Several studies have shown promising results with closed reduction and casting.[2-5] Blumberg et al[5] reviewed 47 cases of pediatric "floating elbows" (supracondylar humerus fractures with an ipsilateral forearm fracture), in which the supracondylar humerus fracture was treated operatively and the forearm fracture was treated nonoperatively. Of these 47 patients, a total of 17 required manipulation of the forearm fracture before placement in a noncircumferential cast or splint. No patients lost reduction or required repeat manipulation, and there were no cases of compartment syndrome.

Other studies, however, support operative fixation to treat ipsilateral forearm fractures. Several studies have shown risk of displacement with closed treatment and increased risk of compartment syndrome with circumferential casting.[3,4] Ring et al[6] studied 16 patients with supracondylar humerus fractures (nine of which were treated operatively) and an ipsilateral forearm fracture, ten of which were treated with closed reduction and immobilization of the forearm fracture.

Of the patients who underwent nonoperative treatment of the forearm fracture, two developed compartment syndrome (one of which underwent fasciotomies, and one of which was unrecognized initially and went on to develop Volkmann's contracture). Four other patients had impending compartment syndrome that resolved after splitting of the cast; three of those patients lost reduction and required re-manipulation of the forearm. Of the six patients who underwent operative fixation for treating both the supracondylar humerus fracture and forearm fractures, none developed compartment syndrome or notable complications. However, other studies have described low complication rates after operative fixation.[7,8] Therefore, some authors have supported fixation to avoid circumferential casting, allow better access to monitor neurovascular status, and facilitate wound care in patients with open fractures.[6,7]

Order of Treatment: Supracondylar Fracture or Forearm Fracture

When treating both fractures operatively, there is controversy regarding which fracture to address first. Templeton and Graham[9] suggested fixation of the supracondylar fracture first to more easily allow limb monitoring, dressing changes, and closure of open fractures. However, Tabak et al[8] recommended fixation of the forearm first because this was often already reduced in the emergency department. This would also provide a stable forearm to assist with reduction of the supracondylar humerus fracture.

OPERATIVE OR NONOPERATIVE TREATMENT OF TYPE II SUPRACONDYLAR HUMERUS FRACTURES

There is evidence both for operative as well as nonoperative treatment of some type II supracondylar humerus fractures. Hadlow et al[10] reviewed 148 patients with type II supracondylar fractures treated with closed reduction and casting. Of these patients, 23% required a second procedure owing to loss of reduction (either re-manipulation with placement of a new cast or closed reduction and pin fixation). However, 77% were treated successfully with cast immobilization. Therefore, the authors recommended an initial trial of nonoperative treatment of all type II fractures.

Similarly, Parikh et al[11] found that 28% of patients lost reduction after closed reduction and cast immobilization. Fitzgibbons et al[12] noted similar findings, with 80% of patients treated nonoperatively having successful results and a 20% failure rate. Factors that correlated with failure of closed reduction and cast immobilization included radiographic degree of fracture extension (based on the anterior humeral line) and width of the soft-tissue shadow on the upper arm after reduction (7.9 cm vs 7 cm).

In a retrospective review of 189 patients with type II supracondylar fractures treated nonoperatively, a total of 21% of patients initially treated nonoperatively eventually underwent operative treatment.[13] Fractures without rotational deformity or coronal angulation, with a shaft-condylar angle of more than 15°, and those with pure extension deformity were more likely to be treated successfully nonoperatively.

Other studies, however, have supported operative fixation of at least some type II fractures. In a retrospective review of 189 type II supracondylar fractures treated with percutaneous pin fixation, Skaggs et al[14] found no loss of reduction a 2.1% rate of pin-traction infection (0.5% of which required re-operation). In a study with long-term follow-up on 155 patients treated nonoperatively with cast immobilization, Camus et al[15] found 80% had radiographic evidence of extension deformity.

A currently well-accepted treatment algorithm includes nonoperative treatment of type II supracondylar humerus fractures, with closed reduction and cast immobilization if the anterior humeral line bisects the capitellum and there is no rotational deformity. Many of these fractures are stable after closed reduction and casting in 90° to 100° of flexion. If more than 100° of flexion is required to maintain reduction, fewer complications may be found with closed reduction and percutaneous pin fixation. Furthermore, percutaneous pin fixation is required to address rotational deformities.[1,16]

PIN CONFIGURATION

Although percutaneous pin fixation is a well-accepted method of treatment, several controversies exist regarding the details of pin placement. Use of crossed pins (one from medial to lateral and one from lateral to medial) provides the most biomechanically stable configuration; however, risk of injury to the ulnar nerve is higher (1%-12% with use of a medial pin).[17] Several studies have shown that while the crossed-pin technique might be the most stable biomechanically, there is no statistically significant difference when compared to use of three laterally placed pins.[17-20] Therefore, when increased stability is needed, use of three lateral pins is generally recommended to avoid the risk of iatrogenic ulnar nerve injury.

Kocher et al[18] compared use of lateral entry-pin fixation and crossed-pin fixation in a randomized control trial. The study found no difference in outcomes between the two groups, and ulnar nerve injuries did not occurred in either group. At follow-up, five of the eight surgeons had switched from using a crossed-pin configuration to lateral-pin configuration. In a meta-analysis, Woratanarat et al[21] found a 4.3-fold increased incidence of ulnar nerve injuries after using cross pinning compared to lateral pins, with a number needed to harm of 28. The incidence of ulnar nerve injuries decreased from 15% to 2% with use of two lateral pins as the standard treatment and use of a medial pin reserved for fractures that remained unstable after placement of

the two lateral pins. By initially placing two pins laterally and then checking for stability, surgeons can reserve use of medial pins for unstable fractures. The medial pin can also be placed with the arm in a safer (extended) position after laterally-based provisional fixation.[21] Although the ulnar nerve typically rests posterior to the medial epicondyle, some anterior displacement of the ulnar nerve can occur during passive flexion of the elbow in 31% of children. Therefore, placing a medial pin with the elbow in some extension can decrease the risk of iatrogenic ulnar nerve injury.[22]

In 2007, Zenios et al[23] described a protocol of standard fixation using two lateral pins. They assessed stability using lateral radiographs showing internal and external rotations. If unstable, a third lateral pin was placed and stability was examined again. If the fracture was still unstable, a medial pin was placed. Six revision procedures were performed in the control group (25%), whereas none were performed in the protocol group. Only 26% of fractures were unstable after placement of two pins; therefore, most fractures could be treated with two lateral pins. In 2016, Bauer et al[24] confirmed that internal rotation stress testing improved determination of the need for additional fixation.

Pin Spread

Another point of discussion is the spread of the pins. In a retrospective review of type III supracondylar humerus fractures treated with pin fixation, Livermore et al[25] found less rotational stability in laterally displaced fractures treated with all-lateral fixation. However, this was able to be overcome with a mean pin spread of 15.2 mm at the fracture site (compared to 9.2 mm in those that were less stable).

Starting Point for Pin Placement

The starting point for placing lateral pins can either be directly lateral or in the capitellum. Currently, general consensus is that the starting point for lateral pins should be in the capitellum rather than directly lateral. This provides a stiffer construct, allows greater engagement of the distal fragment, and allows more room to place a third pin.[26] However, this starting point may result in a higher risk of septic joints if the pin site becomes infected because the capitellum is intraarticular.

Medial entry-site pins are placed in the inferomost aspect of the medial epicondyle, starting as anteriorly as possible to avoid the ulnar nerve. This pin should be placed using a mini-open approach to ensure avoidance of the ulnar nerve.[16]

TIMING OF SURGICAL TREATMENT

A very common controversy regarding supracondylar humerus fractures is timing of surgical fixation. Historically, supracondylar humerus fractures were treated immediately because of concern that delayed fixation would lead to increased swelling, risk of compartment syndrome, infection, nerve injuries, and conversion to open reduction. Furthermore, early intervention may ease reduction before swelling increases and allow earlier hospital discharge.[27]

Arguments for delayed treatment (typically until the next day) include allowing adequate fasting status of the patient and optimal surgical environment. Delayed fixation can prevent fatigue of the surgeon and surgical team, especially during the middle of the night. It also allows time to select a surgical team familiar with the procedure. Furthermore, waiting until the next day may also allow the operation to be performed by a fellowship-trained pediatric orthopaedic surgeon.

Treatment of most type II supracondylar humerus fractures can safely be delayed until the morning. Several studies have shown no difference in complications after treating type II supracondylar fractures with a delay of up to 24 hours.[28,29] In a review of 399 type II supracondylar humerus fractures, no difference was found in major complications between patients treated within 24 hours and those treated after 24 hours from the time of injury.[28] Some studies have examined even greater delays. In 2011, one study compared type II supracondylar humerus fractures treated within 7 days of injury to those treated more than 7 days after injury and found satisfactory results in all patients, no conversions to open reduction, iatrogenic nerve injuries, vascular complications, or compartment syndromes. However, two patients (4.8%) of those treated 8 days after the injury developed trochlear necrosis.[29]

Several studies have evaluated time of treatment with both types II and III supracondylar humerus fractures grouped.[27,30-33] Findings have indicated that treatment delays of 8 hours to 21 hours result in no increase in complications or conversions to open reduction. Notably, these studies have been retrospective, not randomized, and included both types II and III fractures grouped. Some selection bias may have occurred because in many of these studies, treatment of type II fractures were more likely to be delayed whereas type III fractures were more likely to be early.

It is uncertain whether treatment of type III supracondylar humerus fractures can safely be delayed until the morning and whether certain factors should lead to earlier intervention. Some studies have shown no difference in outcomes of type III fractures with delayed treatment.[34-36] Iyengar et al[34] found no clinical difference and no difference in need for open reduction after delayed treatment of more than 8 hours from the time of injury. Leet et al[35] found no difference in length of operating time, need for open reduction, or unsatisfactory results after an average treatment delay of 21.3 hours from the time of injury. Aydoğmuş et al[37] compared outcomes between patients who underwent surgical treatment during the day (8 AM to 5 PM) to those at night (5 PM to 8 AM). The authors found a higher rate of unsuccessful fixation in the nighttime group and a

trend toward increased rate of open reduction, although this was not statistically significant.

However, other studies have found worse results after delayed treatment.[38,39] Walmsley et al[38] found that delays of more than 8 hours from presentation to the emergency department led to an increased rate of open reduction (33.3% versus 11.2%) and a weak correlation with increased length of operating time. In a systematic review of five non-randomized retrospective studies, Loizou et al[39] noted significantly higher rates of conversion to open reduction in the delayed treatment group (defined as 8-12 hours after injury) compared to the early treatment group (22.9% vs 11.1%).

Certain characteristics that can be seen with type III supracondylar fractures may indicate a need for more urgent intervention. Patients who have severe elbow swelling and anterior ecchymosis can experience a decline of neurovascular status over a short amount of time.[40] Severe swelling, anterior ecchymosis, and anterior skin puckering have been associated with the development of compartment syndrome.[41] Therefore, patients with these physical examination findings may be better treated with earlier surgical intervention and careful monitoring until the time of the procedure.

Generally, it is safe to delay surgical treatment of type II supracondylar humerus fractures overnight until the morning. Treatment delay of type III supracondylar humerus fractures can also be safe for fractures that are closed, result from low-energy mechanisms, and have no vascular compromise. Factors associated with a need for earlier intervention to prevent neurovascular decline and development of compartment syndrome include patients with anterior ecchymosis, severe swelling, and skin puckering.

VASCULAR COMPROMISE

There is substantial debate regarding treatment of supracondylar humerus fractures with vascular compromise. Evaluation of perfusion of the upper extremity should include examination of the color of the hand, temperature, edema, pulp turgor, and capillary refill. Palpation and Doppler evaluation of pulses should be included. Findings should also be compared to those of the uninjured side.

Poorly Perfused Pulseless Hand

In the treatment of poorly perfused hands, some studies recommend closed reduction with immobilization immediately in the emergency department.[42,43] There is little risk with an attempted reduction and this can often restore the pulse. Reduction can lead to return of perfusion in about half of patients.[42,43] The arm should then be splinted in less than 90° of flexion.

Angiography before reduction is not recommended. Reduction can often restore perfusion and if it does not, the area of injury is known. Therefore, pre-reduction angiography can delay treatment without benefit. No evidence has suggested post-reduction angiography if perfusion does not return.[44]

While reduction will often lead to return of perfusion, if perfusion does not return after reduction then open vascular exploration is indicated. Local interventions may include release of tethering, adventitial stripping, and lidocaine injection. If perfusion returns but not the pulse, there continues to be controversy regarding the correct intervention.

Unfortunately, up to 22% of patients with poorly perfused hands develop compartment syndrome, which increases to 50% if vascular reconstruction is required.[43] However, overall excellent clinical outcomes have been shown long term if circulatory failure is treated immediately.[45] Interestingly, after reconstruction, studies have noted significant rates of asymptomatic re-occlusion and residual stenosis even if the hand remains well-perfused.[46]

Perfused Pulseless Hand

Treatment of perfused pulseless hands, known as "pink pulseless hands," is challenging. Historically, there was concern that conservative treatment of patients with supracondylar fractures that had a perfused but pulseless hand could lead to progressive ischemia resulting in cold intolerance, exercise claudication, and growth discrepancy. Reduction and fixation for treating fractures without exploration can result in maintained perfusion with a return of the pulse in 50% to 100% of patients.[43,47] In 2013, Scannell et al[47] reviewed 20 patients with type III supracondylar humerus fractures and perfused pulseless hands treated with closed reduction and percutaneous pin fixation. Of these patients, five had a return of their pulse in the operating room. Fourteen of the 20 patients had a brachial artery injury seen on duplex evaluation. At follow-up, all 20 patients had a palpable radial pulse with no difference compared to the uninjured side regarding arm circumference or length, elbow motion, muscle duration, and grip strength.

Fortunately, collateral circulation often provides enough distal perfusion despite brachial artery injury. Studies have shown no significant evidence of complications such as cold intolerance or exercise claudication, although long-term studies are lacking. Only one case report has described a patient with cold intolerance but normal function at 4 years after an injury involving both a vascular and median nerve injury.[48]

Treatment of perfused but pulseless hands should be individualized. Reduction and percutaneous fixation should be performed on an urgent basis; however, controversy remains regarding how emergently. Emergent vascular exploration is not necessary; patients must be carefully monitored postoperatively to detect any decline in perfusion (Figure 1).[49]

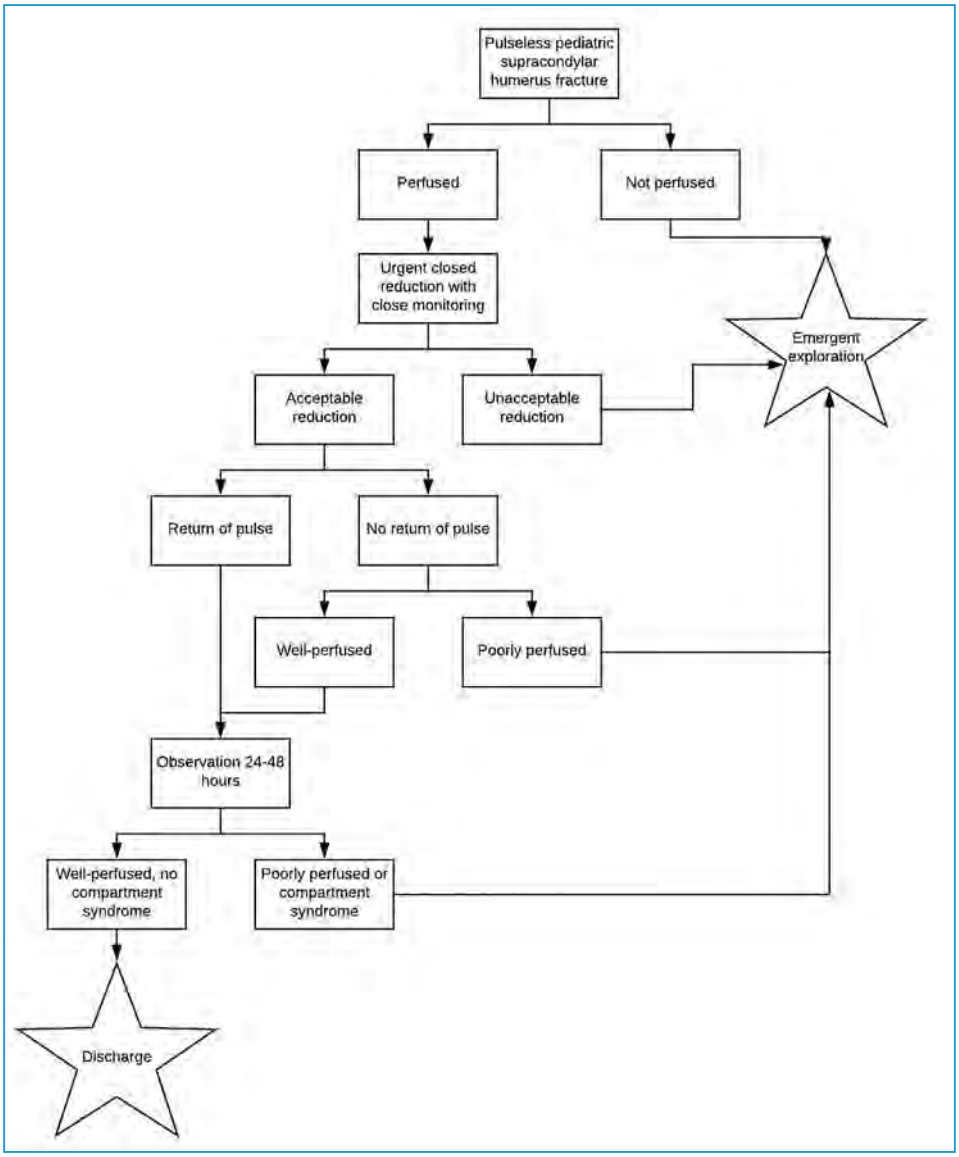

Figure 1. Algorithm for treatment of supracondylar humerus fractures without a palpable pulse.

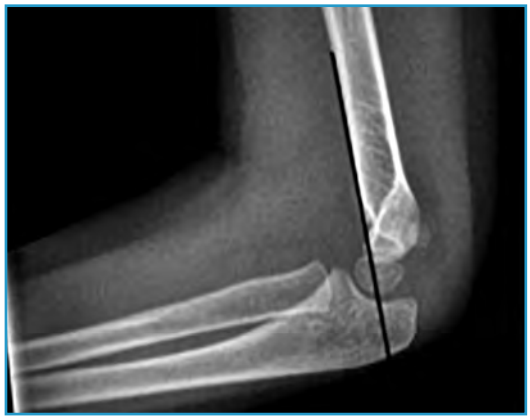

Figure 2. Radiograph of the lateral elbow, showing anterior humeral line bisecting the capitellum.

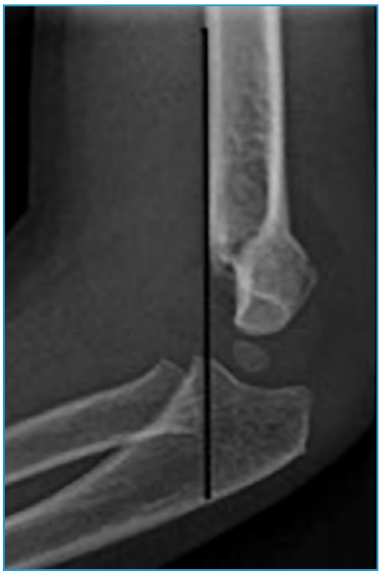

Figure 3. Radiograph of the anterior humeral line that is anterior to the capitellum, showing extension of the fracture.

CONCLUSION

Controversies in treating pediatric supracondylar humerus fractures include treatment of ipsilateral forearm fractures, treatment of type II supracondylar humerus fractures, pin configuration, timing of surgical treatment, and treatment of supracondylar humerus fractures with vascular compromise.

It is debated whether ipsilateral forearm fractures should be treated operatively or nonoperatively. Operative fixation may decrease the risk of loss of reduction of the forearm fracture and can avoid circumferential casting, provide better access to monitor neurovascular status, and facilitate wound care.

In treating type II supracondylar humerus fractures, those that are in acceptable alignment may be treated nonoperatively. Factors that indicate better results with operative treatment include the following: anterior humeral line that does not bisect the capitellum (Figures 2 and 3), rotational malalignment or instability, and more than 100° of flexion needed to maintain reduction.

Regarding pin fixation, use of a crossed-pin configuration provides the most biomechanically stable fixation; however, placement of a medially-based pin increases the risk of injury to the ulnar nerve. Therefore, use of two or three laterally-based pins are recommended, reserving use of a medially-based pin for treating fractures that remain unstable after placing lateral pins. Increased pin spread and a lateral-starting point in the capitellum result in increased stability.

In general, surgical treatment of type II supracondylar humerus fractures (and some type III) can be safely delayed until the next morning. Surgical treatment should be performed earlier in patients with fractures at risk of developing neurovascular compromise or compartment syndrome. Factors associated with increased risk of compartment syndrome include severe swelling, anterior ecchymosis, and anterior puckering. Patients with a treatment delayed overnight should be carefully monitored until the procedure.

In patients who have poorly perfused hands without a pulse, reduction should be performed on an emergent basis. Reduction can often lead to a return of perfusion. If not, vascular exploration should be performed immediately. Overall, promising clinical results have been described if vascular compromise is treated immediately. Angiography is not recommended.

In patients with a “pink pulseless hand,” treatment is more controversial. Early versus delayed operative fixation is again debated. If the hand remains well-perfused postoperatively, even without a return of the pulse, vascular exploration is not recommended. However, these patients should be carefully monitored for any decline in perfusion. If perfusion is reduced postoperatively, vascular exploration should be performed. Results of further long-term studies are needed to help clarify some of these controversies in treating supracondylar humerus fractures in children.

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Open Fractures: A Review

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Funding The author received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The author reports no conflicts of interest.

ABSTRACT

Open fractures occur most commonly in men aged more than 50 years, which may result in lifetime costs for patients and healthcare systems. In the past 5 years, high-quality evidence for direct treatment of these fractures has increased. The expedient administration of intravenous antibiotics continues to be one of the most predictive factors of infection prevention. Open fractures are complicated injuries to classify owing to multiple factors that will be reviewed in the current study: severity of fracture and soft-tissue injury, thoroughness of debridement, time to initial treatment, modality of antibiotic delivery, and timing of definitive fracture fixation and soft-tissue coverage; all of which contribute to the incidence of infection and nonunion. Appropriate evidence-based treatment can decrease morbidity of patients with open fractures.

Keywords: Open Fractures, Trauma, Antibiotic, Tibia, Review Literature

INTRODUCTION

Open fractures most commonly occur in men (70%) in their fifth decade of life. Infection rates are typically tied to fractures classified by Gustilo-Anderson grades. Grade I fractures have an infection rate of 0% to 2%; grade II fractures, 2% to 10%; and grade III, 10% to 50%.[1] The monetary cost to healthcare system owing to open fractures is high, with lifetime costs of patients with severe open tibia fractures as high as $680,000. In 2012, the incidence of open fractures was 30.7 (11.5 in 1998) per 100,000 person-years. Although heavily researched, treatment of open fractures remains a debated topic, with most studies being retrospective reviews of small case series.[1] This review will cover the historical and recent studies on open fractures and how those findings can help guide treatment decisions.

CLASSIFICATION

The Gustilo-Anderson classification system is likely the best-known classification schema for open fractures owing to its accuracy in determining infections rates. However, the system has been noted to have poor interobserver reliability. Furthermore, use of the broad system may not take into account other important aspects of open fractures such as more detailed assessment of soft-tissue injury, arterial injury, possibility of required repairs, bone loss, and wound contamination. Other classification systems help categorize specifically for open fractures; for example, the Orthopaedic Trauma Association and the Tcherne classifications are detailed and nuanced systems. However, studies have not described them as frequently as the Gustilo-Anderson system.[2]

Notably, open fractures after ballistic injuries (eg, gunshot wounds) have a different level classification from most fractures. The categories differentiate between injuries related to low and high velocities (1000-2000 feet per second). For example, rifles such as shotguns shoot at lower velocities from other guns, but the mass of the pellets or slugs imparts a considerable amount of kinetic energy upon impacting with soft tissues.

ANTIBIOTICS

The timing of the first dose of antibiotics may be one of the most predictive interventions for treating infection. In a multivariate analysis of retrospectively reviewed grade III tibia fractures, Yun et al[3] showed that antibiotics delivered after 66 minutes were independently predictive of infection.

The EAST guidelines (created in 2000) provide current recommendations for selecting the type of antibiotic delivery.[4] These recommendations are as follows:

- Level 1: gram (+) coverage as soon as possible after injury. Gram (-) coverage should be added for treating grade III fractures. Penicillin should be added to treat fecal or clostridial contamination (eg, farm-related injuries). Use of fluoroquinolones should be avoided.
- Level 2: patients with grade III fractures should receive antibiotics for 72 hours after injury or not more than 24 hours after soft tissue coverage. Daily doses of aminoglycoside are safe and effective for treating grades II and III fractures.

Although local antibiotic delivery has been studied, use of systemic antibiotics are currently the gold standard for treating infections of open fractures. There are three main delivery systems: 1) beads, either in the form of polymethyl methacrylate (PMMA) or calcium sulfate, 2) vancomycin powder directly, and

3) systems classified as "other," mostly collagen based. Although calcium sulfate is biodegradable, the exudate produced may compromise wound healing. Results of retrospective reviews have shown that combining bead pouches with systemic antibiotics significantly decreases infection rates. However, PMMA has some disadvantages: on removal, PMMA can act as a foreign body harboring infection; it may not equally distribute antibiotics across a wound; and it can cause difficulty with closing a wound if the soft tissue is not easily mobilized.[5]

Elution rates have been highly studied. After mixing PMMA antibiotic cement, the antibiotic is rapidly released in the first 24 hours. Afterward, the release decelerates rapidly, followed by a steady decline. Only very low levels of antibiotics are found at 5 weeks. When increasing the surface-area-to-volume ratio, the elution rate also increases. Therefore, if no bone defect is present, use of beads can result in a successful delivery system. For treating bone defects, using a solid spacer can help control shortening and allow use of the Masqualet technique for future grafting. When combining the two antibiotics, the elution rate of tobramycin and vancomycin increases by 68% and 103%, respectively.[6]

Orthopaedists have started using vancomycin powder to treat open fracture wounds. During a military study, a contaminated rat femur model showed decreased infection rates if local vancomycin was used within 6 hours of wound creation.[7] At 2 weeks, vancomycin was detectable in the soft tissues but not seen in rats treated with PMMA. Although not yet approved for use in humans, other delivery methods (primarily in some form of a phospholipid gel for antibiotic) have been studied.[8] In a contaminated rat femur osteotomy model, use of antibiotic-impregnated gel results in significantly fewer wounds with bacteria cultured ($P < 0.004$).

The use of negative-pressure wound therapy (NPWT, also called a wound VAC) with local antibiotic deliveries has also been studied in animal models. Large et al[9] found that the ability to close the fascia was the primary predictor of whether the eluted antibiotics stayed within the wound.

IRRIGATION AND DEBRIDEMENT

Factors that may determine the effectiveness of debridement include initial time of debridement, type of irrigation used, and quality of debridement. Much research has attempted to support safe delay of initial debridement. In 2014, Schenker et al[10] found an estimated incremental salary cost of $2.2 to $4 million annually for one surgical technician and 2 nurses. This cost reflected only open tibia fracture debridements performed after hours in the United States.

Multiple studies, which includes LEAP data, have found no difference in rates of infection after debridement performed within 24 hours.[1,11,12] Hull et al[13] argued that delay could still be detrimental because reported studies divide the time to debridement (ie, a continuous measurement) into arbitrary groups; subsequently, statistically significant relationships are difficult to identify. Results of other studies may involve surgeon bias because more severe and contaminated fractures were debrided earlier, which thereby underrepresents fractures prone to infection in the later debridement group.

In addition to timing of debridement, surgeons must also decide on type and pressure of the irrigation (Figure 1). The FLOW trial may have been the largest

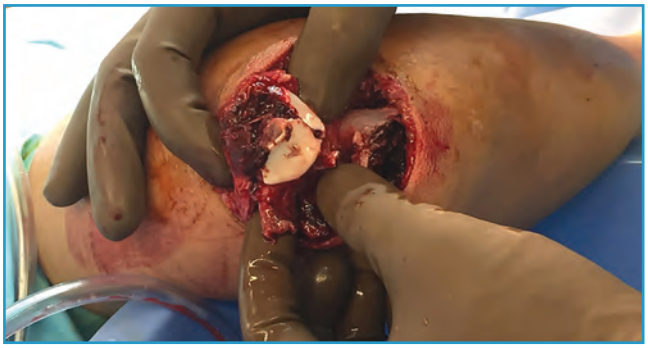

Figure 1. Intraoperative grade IIIA distal humerus fracture during the second debridement. This fracture required multiple debridements to remove all contamination, with attempted salvage despite chondral fragments lost in the field.

study to tackle these questions. It involved 41 clinical sites located around the world, used a two-by-three factorial design, and patients were randomly assigned in a 1:1:1:1:1:1 ratio into one of six groups. These were one of three irrigation pressures (high pressure, >20 psi; low pressure, 5 to 10 psi; or very low pressure, 1 to 2 psi) and one of two irrigation types (ie, castile soap or normal saline). A lower reoperation rate was found with normal saline compared to castile soap ($P = 0.01$), with no difference between pressure groups.[14]

SOFT TISSUE

Open fractures are best defined as soft-tissue injuries. The ability to safely close or cover the soft tissue affects overall infection rate, ability to regain function of the limb, and underlying healing rates of the bone. In a retrospective review, Jenkinson et al[15] noted that deep infections were common in patients who underwent delayed primary closure (4% vs 18%, $P < 0.0001$). These patients had a 14% absolute risk of reduction, with seven needing additional treatment, and an odds ratio of 11 developing deep infections. Similarly, Scharfenberger et al[16] performed a prospective cohort study at a level 1 trauma center and showed that patients treated with primary closure had fewer deep infections (4% vs 9%, $P < 0.001$) and nonunions (13% vs 29%, $P < 0.001$) compared to those treated with delayed primary closure. Patients with open fractures closed primarily were matched to a prior immediate cohort of all open fractures treated with delayed primary closure.

Negative pressure wound therapy (NPWT) has been increasingly performed to treat wounds that cannot be closed after initial debridement. Growing evidence suggests that NPWT improves wound-bed vascularity and decreases edema; however, more than 7 days of NPWT can increase risk of bacterial colonization and may diminish the flap size and need for free-flap coverage.[17-20] If the decision is made to not primarily close a wound, eventually, the wound will need to be closed or covered. To better define the timing of wound closure, serial culturing has been used. None of the protocols have indicated improved outcomes compared with earlier studies.[22,23]

There is some interest in "orthoplastic reconstruction services," combining immediate operative treatment of fractures and flap coverage. Gopal et al[23] published a landmark paper on this concept in 2000. Study results included 4% amputation rates and 3% deep infection rates at the fracture (14% deep infection rates when performed after 72 hours), although no statistical analysis was performed. Other studies have found improved outcomes of fractures covered within 7 days postoperatively.[24-27]

Interestingly, Mathews et al[28] noted improved outcomes when combining fracture fixation and flap coverage in a single operation rather than a staged approach (4% vs 35%; $P < 0.001$) in a retrospective cohort of patients with grade III tibia fractures. During the time of coverage, findings of an independent analysis of staging showed no difference in infection rates (20% at < 72 hours vs 12% at > 72 hours; $P = 0.492$).

FIXATION TIMING AND METHOD

In deciding the timing of coverage for treating open fracture wounds, the treating surgeon must also balance timing and method of definitive fracture stabilization.

Early Use of Intramedullary Nails

Regarding early placement of intramedullary nails (IMN) for treating open fractures, the original SPRINT study did not include grade III fractures.[29] Papakostidis et al[29] found that in treating open tibia fractures, use of reamed nails resulted in higher rates of earlier union in high-grade fractures than unreamed nails. Overall, no significant difference was noted in complication rates between use of reamed and unreamed nails.

Mitchell et al[31] reported that, in treating open fractures, it was safe to place tibial nails early through a semi-extended position using a suprapatellar approach. Similarly, Pandya and Edmonds[32] described immediate flexible nailing to treat pediatric open-tibia fractures. No higher rate of infection was found compared to a matched cohort of patients with closed-tibia fractures. Regardless of whether the implants were retained, provision plate fixation at the time of flexible nailing did not increase the complication rate.

External Fixators or Intramedullary Nails

Historically, the placement of an external fixator to treat every open fracture was considered advantageous. It was thought to minimize the infection rate at the fracture site and minimized disruption of the soft tissue and osseous blood supply. In a retrospective review of 42 tibia fractures initially treated using external fixators and converted to treatment using IMN, Yokoyama et al[33] analyzed factors known to contribute to infection with univariate analysis. Skin closure at more than 7 days from injury was the only significant factor that affected the rate of deep infection.

Giovannini et al[34] performed a metanalysis of randomized controlled trials, reviewing treatment outcomes between use of IMN and external fixators with grade III tibia fractures. Use of IMN was favored for lower rates of infection (0.48%) and fracture healing (0.41%) in the operating room. As stated, traditional osteosynthesis using open surgical approaches with plate and screw fixation can result in higher rates of complications such as infection, nonunion, and malunion.[2]

Depending on the patient's physiological features, IMN should be used to treat open long-bone fractures; however, the role of antibiotic-coated nails has been debated. Use of these nails can decrease infection risk when transitioning from an external fixator to a definitive metallic nail[34] and definitive treatment of open fractures.[6,36,37] For definitive treatment, one option includes use of antibiotic cement-coated IMN made by the surgeon in the operating room.[36] An Expert Tibial Nail PROtect (Depuy Synthes, Leeds, United Kingdom) may also be used, although these are only available in Europe as tibial nails.[36,37]

Segmental Bone Loss

In patients with open fractures, the presence of segmental bone loss can complicate treatment. If a critical bone defect is known, the treating surgeon could safely discard bone fragments beneath this level without risking infection by utilizing these smaller contaminated segments. Haines et al[38] examined what constituted a "critical bone defect" in a retrospective review of open tibial shaft fractures definitively treated using IMN. Findings of postoperative imaging was assessed to determine radiographic bone loss. The study suggested bone loss greater than 25 mm would be observed in open tibia fractures because the receiver operating characteristic curve indicated that less than 25 mm signified a 54% union rate (versus 0% union rate with > 25 mm).

Lin et al[39] performed a retrospective review of 16 patients with segmental bone fragments cleaned using a specific protocol. Use of the protocol resulted in only one deep-tissue infection, which necessitate removal of bone with eventual union. Additionally, one patient had delayed union at 3 months, allowing union with retention of the native bone and placement of allograft.

CONCLUSION

Open fractures occur most commonly in men aged more than 50 years, resulting in lifetime costs for both patients and healthcare systems. The most commonly used system to categorize fractures is the Gustilo-

Anderson classification, in which infection rates are tied to grade level (grade I, 0%-2%; grade II, 2%-10%; grade III, 10%-50%). Historically, high-quality evidence has been missing to guide treatment, with an increase in such evidence in the past 5 years.

The delivery of systemic antibiotics within 66 minutes of injury may decrease infection rates. These are typically directed toward Gram (+) coverage, with Gram (-) coverage used for treating grade III fracture and penicillin used in treating farm-related injuries. Local delivery of antibiotics in high-grade fractures can be done with vancomycin powder or antibiotic-impregnated cement. Surgeons should consider debridement within 24 hours using normal saline levels under low pressure. Ideally, soft tissue should be covered at the time of definitive fixation and as close as possible to the patient's initial presentation (depending on physiological features and wound-bed contamination). NPWT is another effective option for wound coverage between debridements. Immediate operative treatment using reamed intramedullary devices appears to be safe and effective. Although there is increased interest in use of antibiotic-impregnated metallic nails for treating open fractures, these are not yet commercially available in the United States.

Regarding treatment of open fractures, the most lacking research seems to be in the following areas: length and specificity of antibiotic therapy, options and efficacy of antibiotic-laden treatment, and methods to predict timing of safe closure of contaminated wound beds. Findings of further long-term clinical trials in these areas will help guide surgeons to successfully treat open fractures.

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Retrograde Nailing for Treating Femoral Shaft Fractures: A Review

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

ABSTRACT

Rigid intramedullary nailing is an effective procedure for treating fractures of the femoral shaft. Although antegrade nailing is the traditionally used technique, retrograde nailing offers various advantages. A companion article published in the seventh volume of *The University of New Mexico Orthopaedics Research Journal* addressed antegrade femoral nailing. This review will describe retrograde nailing of femoral shaft fractures, including a brief history, indications, detailed technique, outcomes, advice (or "pearls"), and common failures (or "pitfalls"). Retrograde nailing for treating femoral shaft fractures can provide successful results similar to those of antegrade nailing in general and advantages in particular situations such as more distal shaft, bilateral, and certain associated fractures.

Keywords: Intramedullary Nailing, Retrograde Nailing, Femur Shaft Fracture

INTRODUCTION

Reamed, locked, rigid intramedullary (IM) nailing is an effective treatment of most fractures of the femoral shaft. Antegrade nailing has been the traditionally standard technique,[1-4] but use of retrograde nailing offers various advantages.[5-7] Antegrade nailing was described in detail in the companion article published in the same journal.[8] An alternative technique is retrograde nailing, in which the intercondylar notch of the distal femur is used as the entry point.

Retrograde medullary nailing for treating fractures of the femoral shaft using a distal, extraarticular entry portal through the medial femoral supracondylar region was initially proposed. This required a bend in the nail and created a large stress riser. Results were improved with the development of an intraarticular intercondylar entry site in line with the medullary canal and using standard nail designs. This technique was originally advocated for the treatment of patients with ipsilateral fractures of the femoral neck and shaft.[9] Its indications were expanded to include patients with multiple injuries to facilitate the performance of simultaneous or sequential procedures.[10]

Advantages of retrograde nailing include avoiding use of a fracture table and traction, easier patient positioning and nail insertion, and shorter operating times with less blood loss.[11] The entry site is easier to access because of less soft-tissue dissection, especially in large patients. Furthermore, there is no muscle dissection and less exposure to radiation, especially to pelvic organs. Femoral shaft fractures of both thighs can be treated with the same positioning. In general, retrograde nailing may be preferable to antegrade nailing in the following situations: 1) the presence of a concomitant (possibly non-displaced) femoral neck fracture; 2) the presence of previously or simultaneously placed internal fixation of a proximal femoral fracture; and 3) the possibility of causing a femoral neck fracture by placement of an antegrade nail.

The retrograde technique can be used when proximal access to the medullary canal is blocked. Although early results with retrograde nails suggested a slightly lower union rate, the difference may have resulted from other factors such as smaller diameter nails and use of unreamed nails.[6,12-15] Use of this technique, with retrograde nails matched to the diameter of the femoral isthmus using reaming, has shown promising outcomes. Findings include healing rates and results equivalent to those of the antegrade technique, with high rates of rapid union and low complications.[6,12-15] Entry-site problems may be equivalent between retrograde (knee symptoms) and antegrade (hip symptoms) techniques.

The current article describes indications, contraindications, and current techniques associated with retrograde nailing for treating femoral shaft fractures. We will examine differences between antegrade and retrograde approaches with IM nailing. We will also review surgical techniques used in retrograde nailing, including positioning, incision, entry site, fracture reduction, reaming, nail insertion, locking screws, rod caps, wound closure, postoperative management, treatment outcomes, benefits, and complications. We will provide "pearls" (ie, advice) and "pitfalls" (ie, common failures) to assist orthopaedic surgeons with effectively implementing this method.

Table 1. Relative indications of performing retrograde (vs antegrade) nailing for treating femoral shaft fractures

Indication	*Details or reasoning*
Multisystem injury	Chest, abdomen, head
Femoral shaft fractures	Fractures distal to the isthmus, gunshot wound
Hip soft-tissue injury	--
Trauma involving multiple extremity fractures	--
Ipsilateral femoral neck and femoral shaft	Retrograde nail and hip plate
Ipsilateral acetabular and femoral shaft	Preserve surgical approach to the acetabulum
Ipsilateral pelvic ring disruption and femoral shaft	Avoid perineal post, traction, and pelvic displacement
Ipsilateral femoral supracondylar and femoral shaft	Better distal fragment fixation
Ipsilateral tibial and femoral shaft[a]	Single incision for nailing both
Bilateral femoral shaft	Obviates need for repositioning and preparation
Proximal to TKA with femoral component[b]	Improved distal fixation in distal patterns
Morbid obesity	Ease of entry point access
Pregnancy	Less radiation to pelvis
Surgeon preference	Ease of positioning, entry point access, reduction, nail placement, less operating times and blood loss

TKA, total knee arthroplasty; --, not applicable.
[a]Right femoral shaft fracture and left femoral shaft fracture.
[b]Open-box design of the femoral component.

Table 2. Relative and absolute contraindications of performing retrograde (vs antegrade) nailing for treating femoral shaft fractures

Relative contraindication	*Absolute contraindication*
Fractures located within 5 cm of the lesser trochantera	Retained implant blocking retrograde medullary access
< 45° of knee flexion[b]	Open distal femoral physis
Prior knee infection[c]	
Significant soft tissue-injury about the knee[d]	
Patella baja[e]	
Entry point may require ablation of some portion of the inferior extra-articular patella[f]	

[a]Poor proximal fragment stability.
[b]Difficult access to entry point.
[c]Risk of spreading to femur.
[d]Proximal incision may be better tolerated.
[e]Can also use medial arthrotomy approach.
[f]If using transpatellar tendon approach.

INDICATIONS AND CONTRAINDICATIONS

Table 1 shows relative indications of retrograde (versus antegrade) nailing.[2,9,16-23] In general, retrograde is preferred to antegrade in the presence of an associated condition particularly problematic for antegrade insertion.[12,21-24] Retrograde nailing is generally contraindicated in the scenarios depicted in Table 2.[11,25,26]

SURGICAL TECHNIQUE

Positioning and Incision

Place the patient on a radiolucent table in the supine position.[19] The extremity can be stabilized by a tibial traction pin, although this is not required. Manual traction or use of a femoral distractor can aid in fracture reduction, but most cases require no special equipment for traction reduction. The fluoroscope is positioned contralateral to the injured side to provide access to the medial and lateral sides of the distal femur. A 4-cm longitudinal incision is made in line with the center of the patellar tendon. The tendon can be split in line with its fibers or dissection can be performed medial to the patellar tendon.

Entry Site

The fracture should be reasonably reduced to avoid a malreduction by a malplaced entry channel. This is critically important with retrograde nailing in contrast to antegrade nailing. The entry point is located at the top of the intercondylar notch, about 1 cm anterior to the insertion of the posterior cruciate ligament (Figure 1). A guide pin is placed in this location, which is in the center of the distal femur on both the anteroposterior (AP) and lateral views of fluoroscopic projections.

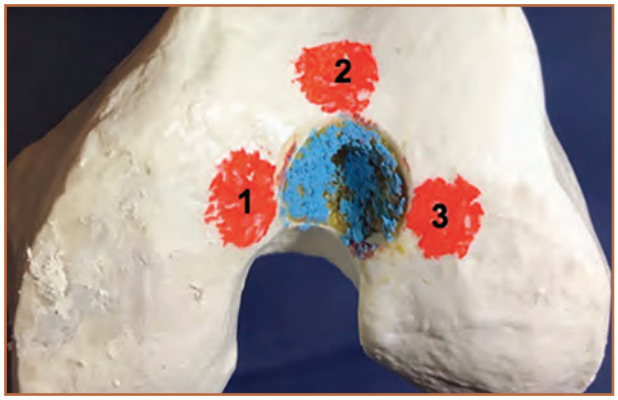


Figure 1. Distal femur sawbone, showing correct and incorrect entry points. Blue indicates correct center-center entry point for a retrograde femoral nail, whereas red indicates common errors in entry-site placement. Other marked errors include: 1) too medial, resulting in lateral translation or apex lateral deformity; 2) too anterior, resulting in postertior translation or apex posterior deformity; and 3) too lateral, resulting in medial translation or apex medial deformity.

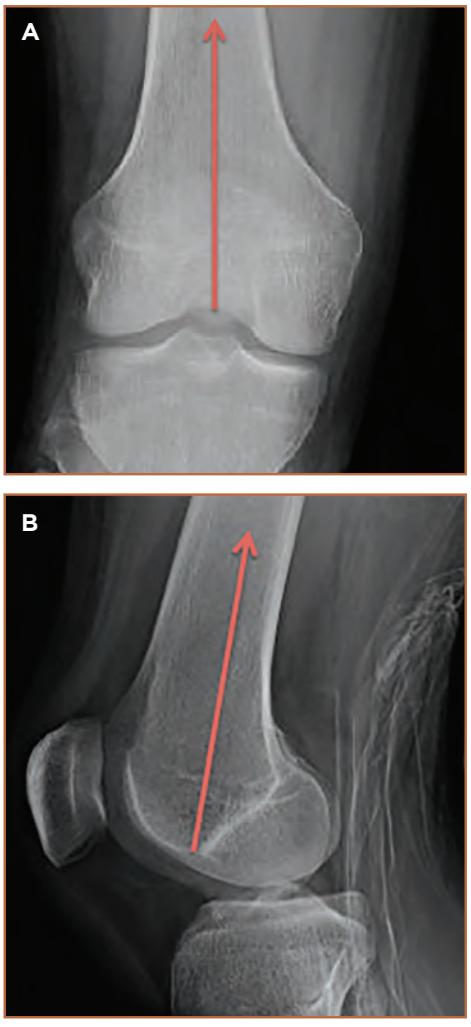


Figure 2. A) Anteroposterior and B) lateral radiographs femoral shaft fractures treated with retrograde nailing, showing recommended entry point and trajectory of guide pin (red arrow).

A guide pin is drilled 6 cm into the distal femur parallel to the medullary canal. The position of the guide pin is confirmed with biplanar fluoroscopic views, in the center on both AP and lateral projections with the fracture aligned (Figures 2A and 2B). The entry reamer is placed over the guide pin into the distal fragment. A sleeve with suction helps minimize osteochondral debris in the knee joint and minimizes trauma to the skin and patellar tendon.

Fracture Reduction and Ball-Tipped Guide Passage

The ball-tipped guide rod is inserted into the reduction tool, and both are inserted into the distal fragment of the femur. External manipulation of the thigh aligns the relatively mobile distal fragment to the relative stable proximal fragment. The guide wire is advanced across the reduced fracture into the proximal fragment. The reduction tool is removed. The ball-tipped guide is advanced to the level of the proximal edge of the lesser trochanter. The measuring sleeve is slid down until it aligns with the entry site, and nail length is measured. Care should be taken to ensure that the fracture reduction is at proper length (ie, not distracted or shortened).

After nail length measurement, the ball-tipped guide is advanced into the proximal femur so that it is not removed during reaming. Passage of the ball-tipped guide is typically easy and takes a few seconds, unlike antegrade nailing. Rotation of the limb is adjusted by comparing it with the uninjured leg, imaging the profile of the lesser trochanter in the injured leg, and matching the rotation of the distal fragment to that of the proximal fragment.

Reaming

Serial reaming of the femoral canal is started with an end-cutting reamer advanced to the level of the lesser trochanter, again using a sleeve and obturator. Fracture reduction should be maintained during reaming. Reaming can progress in 1-mm increments until cortical chatter, which is typically encountered at about 11 mm. It is recommended to use a rod diameter of 1 mm less than the largest reamer passed.[27]

Nail Insertion

The appropriately sized nail is selected and mounted onto the rod-driver assembly. The locking-screw guides are checked, and the orientation and diameter of the locking screw holes are confirmed. The nail-driver assembly is placed over the guide wire and into the femoral entry site. The nail is driven to the desired position using gentle blows while monitoring the guide wire to ensure that it does not advance with the rod. Fracture reduction is maintained during nail insertion. The nail must be seated 5 mm below the articular surface.[16] If a rod cap is planned, the rod should be seated 15 mm beneath the articular surface as confirmed on lateral views of fluoroscopic images. The tip of the nail proximally should be at the level of the lesser trochanter.

Locking

The distal interlocking screws are placed with the aid of the nail-mounted guide. It should be confirmed that the nail is recessed immediately before placing the distal locking screw.[17] An incision is made laterally where the drill sleeves meet the skin, and a longitudinal split is made in the fascia lata. The drill sleeve is seated down to bone. The specific drill bit is used to drill through to the endosteum of the far cortex and length measured. A maximum of 5 mm is added, and the far cortex is drilled. A depth gauge can be used to confirm the length of the screw. The screw is inserted through the nail with bicortical purchase. The procedure is repeated for the second screw. Oblique screws and medial-to-lateral screws using the nail-mounted guide may be used when more distal fixation is desired such as in relatively distal fractures.

The proximal AP screws can be placed freehand with fluoroscopy.[28] Correct length and rotation of the fracture should be confirmed immediately before proximal locking. A perfect circle of the hole in the proximal nail in the subtrochanteric zone is obtained using AP fluoroscopy, and the skin over the hole is marked. A 2-cm longitudinal incision is made, and the quadriceps are bluntly dissected longitudinally to periosteum with a Freer elevator (Sklar Surgical Instruments, West Chester, PA). The tip of the drill bit is centered over the hole and the drill is aligned parallel to the X-ray beam and perpendicular to the shaft of the femur. Both cortices are drilled through the hole in the nail, and the screw is placed. A 30-mm length screw is almost always used.

There is a low potential risk of injury to the femoral nerve (which has branched at this level) and the superficial femoral artery (which is far medial). The sciatic nerve could be injured with excessive penetration beyond the posterior cortex. Static and dynamic proximal interlocking options have been described.[20] Alternative techniques have been developed that are particularly helpful to the surgeon who does few nails.[29]

Rod Cap, Set Screw, and Wound Closure

Some systems have rod caps that seal the cannulation in the nail. This cap may theoretically help prevent synovial fluid from tracking into the medullary canal or medullary contents from migrating into the knee joint. Some designs purposely impinge on the distal-most interlocking screw, providing a more rigid, fixed angle device and avoiding toggle.

When rod caps are used, the effective nail length is increased; subsequently, surgeons should be certain whether the nail has been recessed sufficiently to prevent protrusion into the joint or contact with the patella in knee flexion. The tip of the screw cap must be 5 mm below the level of the articular surface. The use of a nail cap and the instrumentation necessary for its subsequent removal should be conspicuously noted in the operating dictation. The wounds and knee joint are copiously irrigated and closed in layers. Suture fixation of the split patellar tendon is usually not necessary but the senior author (TAD) routinely closes the peritendinous layer of Marshal.

POSTOPERATIVE MANAGEMENT

At the completion of the procedure, the limb is assessed for length and rotation. A ligamentous examination of the knee is performed and documented. The femoral neck should be radiographically inspected for signs of fracture with biplanar fluoroscopy. Plain radiographs are obtained of the entire femur in two planes and reviewed to assess fracture reduction, implant position, and the absence of intraoperative complications (Figures 3A and 3B; Figures 4A through 4D).

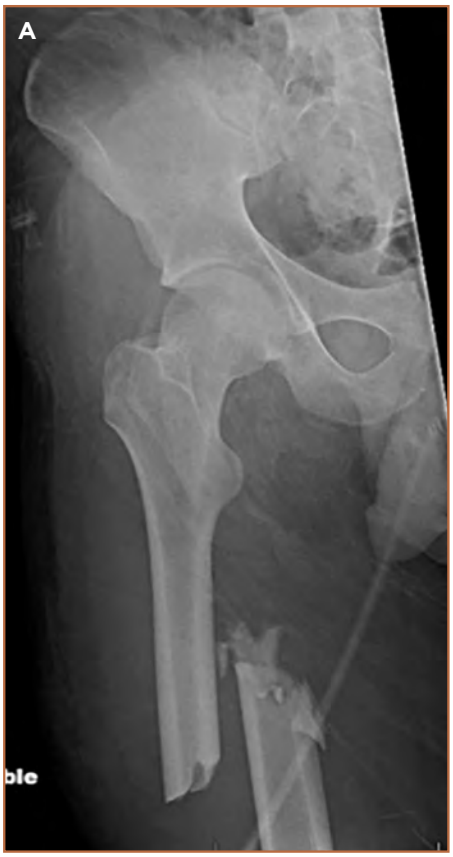
Postoperative management of femoral shaft fractures depends on the extent and severity of other injuries. Most isolated closed fractures can immediately begin treatment with weight bearing as tolerated by the patient. Crutches or a walker are used for the first 6 weeks postoperatively. Restricted weight bearing is recommended in cases of poor adherence to medical advice, extensive comminution of the fracture, or notable lower-extremity articular injuries. Limited but appropriate amounts of postoperative analgesia should be prescribed. Hip and knee range of motion and strengthening exercises are started after 2 days.

Routine follow-up consists of a 2-week clinic visit for removal of skin sutures. Subsequent follow-up should occur every 6 weeks, with a newly obtained radiograph every visit until union is observed. This typically continues for 4 to 6 months, until the patient regains full function. A final clinic visit is at 1-year after the injury (Figures 5A and 5B). Nail removal is rarely indicated. Delayed unions can be effectively managed with dynamization by removal of the proximal locking screws.[30]

POSTOPERATIVE OUTCOMES

Retrograde nailing helps restore both form and function and produces remarkably good short and long-term results with low complication rates.[11] Initial results of retrograde technique using smaller-diameter nails showed promising results but higher non-union rates than that of antegrade nailing.[31,32] When equivalent diameter (ie, 10 mm) nails were used, the reported non-union rate is the same as that of antegrade nails (< 5%).[13,14,33] Initial results have also indicated an increased rate of knee problems including knee stiffness, patella baja, heterotopic ossification, and metallosis and medullary debris in the knee joint.[28]

However, subsequent results have shown that knee stiffness is temporary and that knee motion at 3 months is the same between antegrade and retrograde nailing.[13] Furthermore, the overall incidence of knee problems after retrograde nailing is similar to that of hip problems



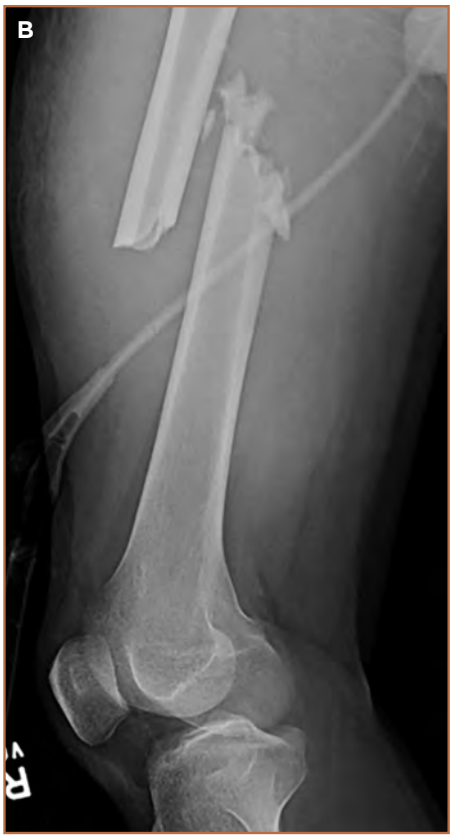


Figure 3. A) Anteroposterior and B) lateral radiographs of an acute open femoral shaft fracture.

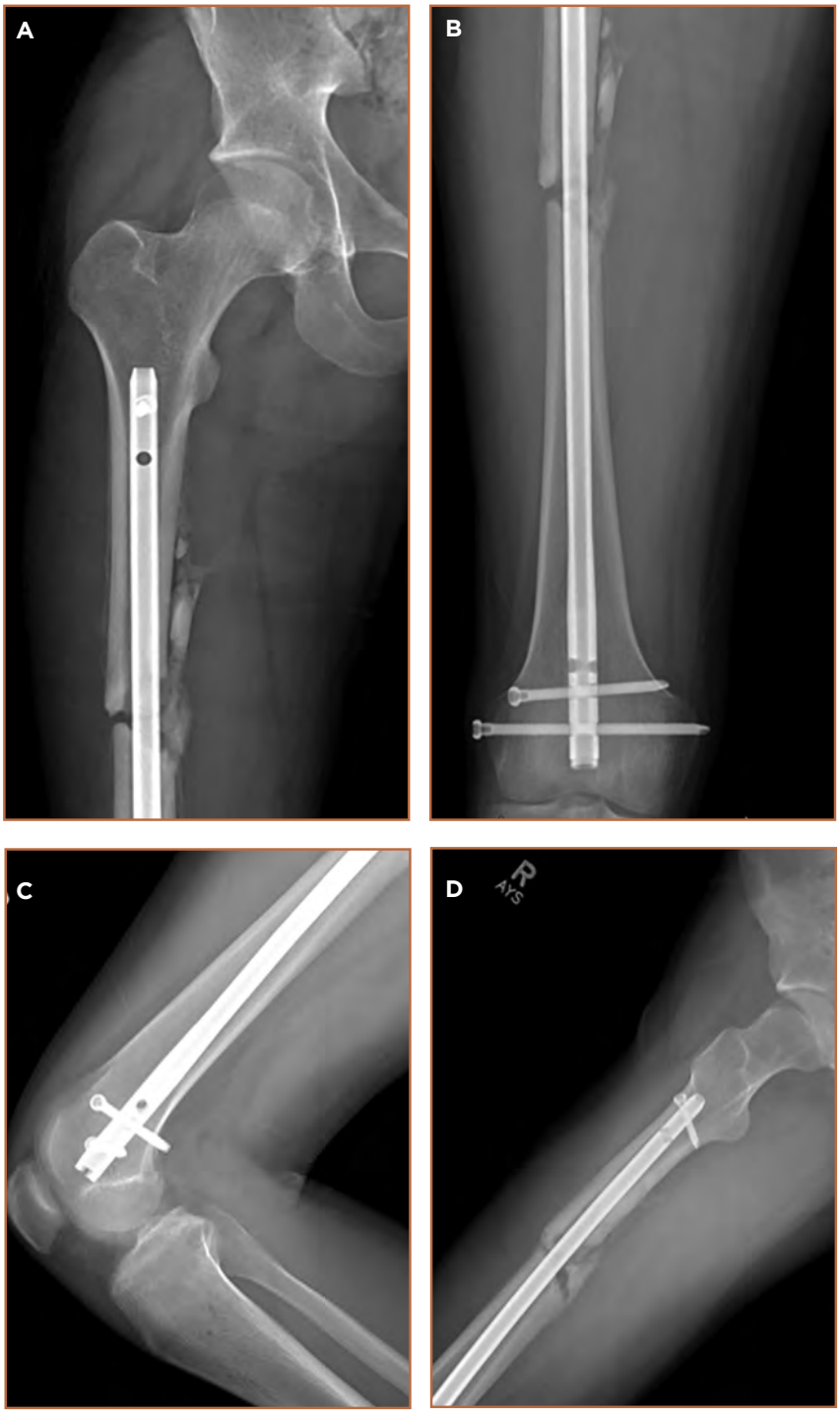
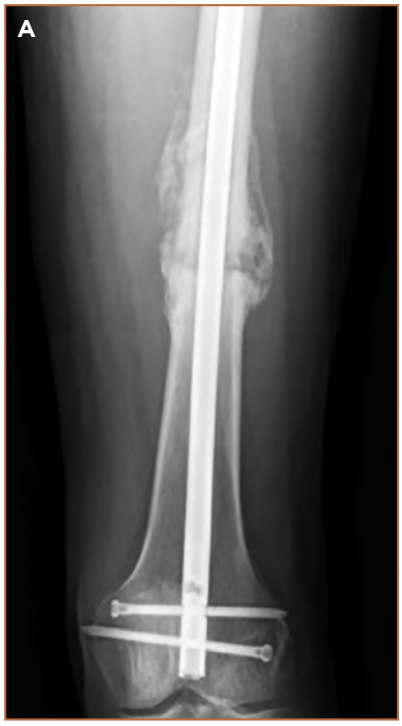


Figure 4. Radiographs of patient shown in Figure 3 after reduction of femoral shaft fracture and fixation with retrograde intramedullary nail. Anteroposterior view A) proximal and B) distal. Lateral view C) distal and D) proximal.



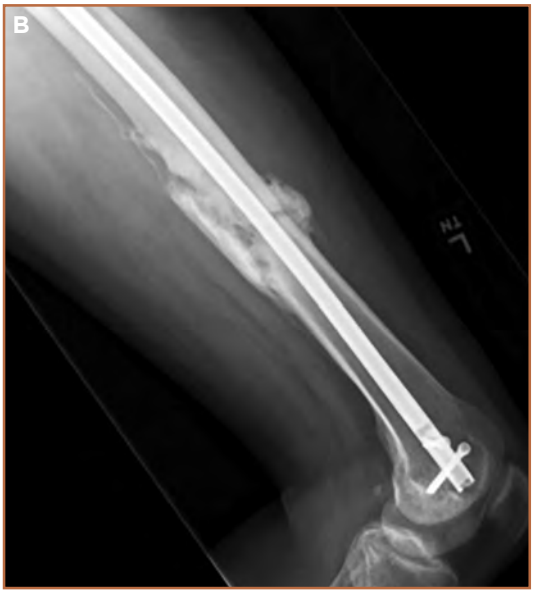


Figure 5. Radiographs of patient shown in Figure 3, showing healed femoral shaft fracture after fixation with a retrograde intramedullary nail. A) Anteroposterior and B) lateral views.

after antegrade nailing. Therefore, "entry-site problems" are equivalent between retrograde and antegrade nailing. Findings of studies have clearly shown that retrograde nailing involves easier positioning, requires less equipment, has shorter operating time, less blood loss, and less radiation than those of antegrade nailing.[4,6,23] There are specific indications in which these advantages may result in theoretical benefits to patients (Table 1). There is no indication that retrograde nailing causes more permanent loss of function and soft-tissue problems to the knee joint than antegrade nailing causes at the hip.[16]

PEARLS AND PITFALLS

When performing IM nailing using a retrograde approach, surgeons should consider the following pearls to help achieve a satisfactory radiological and functional result (Table 3). As with many surgical procedures, physicians should follow a methodical approach to pre-, intra-, and postoperative care of patients treated

Table 3. Advice, or "pearls," to consider when performing retrograde nailing to treat femoral shaft fractures

No.	*Advice*	*Details*
1	Reasonably align the fracture before entry reaming for all retrograde nails	Angular deformity will induce the same deformity after nail insertion
2	Correct angle of proximal locking screw entry site if not straight anterior	Otherwise, the nail or fracture is likely mal-rotated
3	Check for an occult femoral neck fracture after proximal interlocking	Use live fluoroscopy
4	Identify knee ligament injuries after proximal and distal interlocking	Identify by performing a full knee examination
5	Use a captured screw driver or absorbable suture looped around the screw head to avoid losing the screw in thigh soft tissue	Especially when proximally locking; the screw is difficult to retrieve otherwise
6	Use only one locking screw in the proximal fragment for distal and midshaft fractures	For more proximal fractures, use two proximal screws to prevent angular deformity
7	Identify specific implants in the operating notes, particularly special instruments	Will facilitate implant removal or revision
8	Perform aggressive IV or intramuscular pain management for 48 hours post-op	Use oral analgesia and avoid chronic narcotics after 14 days post-op

Post-op, postoperatively; IV, intravenous.

Table 4. Common failures, or "pitfalls," of nail insertion associated with retrograde nailing for treating femoral shaft fractures

Commonly failed actions	*Details*
Confirming central position of the nail within a short distal fragment	Failure results in translational or angular malunion
Maintaining reduction while reaming	--
Correctly mounting the nail on the insertion jig	--
Identifying correct orientation/diameter of the interlocking guides, holes, and drill bit before insertion	To identify, perform a drop check
Striking only the drill insertion or extraction attachment with the mallet	Avoid striking the entire drill guide with the mallet
Over-reaming by 1 mm	Avoid using a nail of larger diameter than reamed
Advancing the nail with each blow	Failure may result in complications[a]
Using appropriate force advancing the nail	Excessive force may result in complicationsa
Maintaining rotation of the nail during insertion	Failure results in oblique malpositioned locking screws and fracture malreduction through loss of anatomical anterior bow
Maintaining reduction (especially length and rotation) during nail insertion	To ensure reduction is maintained, obtain sequential imaging if necessary
Confirming proper seating of the nail at the time of locking	Failure can lead to intra-articular prominence of the nail in knee joint

--, not applicable.
[a]Complications include fracture comminution, propagation, and nail incarceration.

Table 5. Pitfalls of locking associated with retrograde nailing for treating femoral shaft fractures

No.	*Major Errors*	*No.*	*Technique Problems*
1	Not establishing a stable alignment for the limb, resulting in motion during locking screw placement and malposition of the screws	7	Allowing protrusion of screws beyond the distal femoral medial cortex, which will likely worsen symptoms
2	Improperly drilling a cortical hole near but not directly over the hole in the nail, making subsequent correct placement extremely difficult	8	Not removing the guide rod before drilling for locking screws
3	Placing screws that are too short, resulting in instability and angulation	9	Not fully seating the screw head against the near cortex, resulting in soft-tissue irritation
4	Failure to place both proximal and distal locking screws in rotationally or length unstable fracture patterns	10	Losing the screw from the screwdriver into the soft tissue during insertion[c]
5	Not assessing length, rotation, and stability at the end of the case[a]	11	Placement of locking screw in the wrong end of the dynamic slot[d]
6	Not assessing other injuries at the end of the case[b]	12	Attempting to use nail-mounted guides for distal locking, which are not reliable

[a]This is the easiest time to correct any problems.
[b]Other injuries include femoral neck fractures and knee ligament injuries. Diagnoses are best at the end of the case to determine a plan of treatment.
[c]See pearl #5 in Table 3.
[d]For dynamic effect, place the screw in the end of the slot furthest from the fracture site.

Table 6. Pitfalls of rehabilitation associated with retrograde nailing for treating femoral shaft fractures[12]

Commonly failed actions	*Details*
Recognizing abnormal length or rotation during early ambulation	Relatively easy to correct by revision of the nail
Matching activity to the achieved stability and healing	Too much activity too soon can result in loss of fixation, fracture, or bending of nail[a]
Recognizing delayed union early	Earlier on, easiest to treat by simple dynamization
Prolonged use of narcotic analgesics	Failure can result in chronic dependency problems

[a]But excessive restriction of activity can result in stiffness, weakness, and delayed union.

with retrograde nailing. Potential surgeon-related failures, or "pitfalls," associated with this approach include improper fracture choice (eg, femoral neck, intertrochanteric, and far proximal subtrochanteric fractures), incorrect entry point, malrotation, and failure to seat the nail sufficiently. Other pitfalls relating to nail insertion, locking errors, and rehabilitation are shown in Tables 4, 5, and 6, respectively.

CONCLUSION

Retrograde nailing is an effective method for treating femoral shaft fractures. The technique is easier and requires less operating time than that of antegrade nailing, with equivalent outcomes.[13] Specific indications can be identified, for which retrograde nailing is theoretically preferred. The main pearls (Table 3) and pitfalls (Tables 4-6) have been outlined to aid the surgeon in achieving a successful radiological and functional outcome and avoiding problems when using the retrograde approach for treating femoral shaft fractures.

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Correlating Patient-Specific Anthropometric Variables With Soft-Tissue Thickness at the Superolateral Arthrocentesis Entry Site to the Knee

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

ABSTRACT

Background: Irrigation for treating septic joints in adults in the emergency department is possible but requires the development of novel systems that fit all body habitus. However, varying body habitus and age of patients may affect the amount of soft tissue surrounding the knee joint capsule. We examined whether the dimensions of the soft-tissue thickness at the superolateral approach of entry to the arthrocentesis site correlated with patient anthropometric data such as age, sex, height, weight, and body mass index (BMI, kg/m^2).

Methods: Using the diagnosis code 844.2 (International Classification of Diseases, Ninth Revision), we reviewed findings of magnetic resonance imaging (MRI) of knees from 100 consecutive patients and gathered anthropometric data for each patient at the time of the MRI. We measured the soft-tissue thickness at the standard entry point for superolateral arthrocentesis.

Results: Soft-tissue thickness at the arthrocentesis site ranged from 5.5 mm to 38 mm and averaged 13.8 mm. Of the independent variables considered, BMI was the most closely correlated with joint-space size albeit poorly (R^2 = 0.46). Every unit of increase in BMI correlated with a predicted average soft-tissue thickness increase of 0.61 mm.

Conclusions: The anthropometric data obtained from this study may help create a single, universal device for use in bedside joint irrigation. The correlation between BMI and soft-tissue thickness can guide future device designs.

Keywords: Knee Joints, Infectious Arthritis, Arthrocentesis, Inventions, Body Mass Index

INTRODUCTION

Septic arthritis is a common ailment treated by orthopaedic surgeons. Treatment includes non-surgical management with antibiotics, symptomatic management, and more invasive procedures. Operative methods range from serial bedside aspirations to open or arthroscopic irrigation and debridement. Surgeons typically use irrigation and debridement in the operating room, with serial aspirations reserved for more sick or debilitated patients who cannot undergo surgical treatment or anesthesia without high risk of complications.

Recently, studies have discussed continuous bedside irrigation of septic joints.[1,2] This method allows for removal of pyogenic material from the joint space while diluting the proteolytic and lysosomal enzyme concentrations, helping prevent cartilage damage.[3] This method provides several benefits compared with current options. Because cartilage degenerates rapidly in patients with septic arthritis,[3] treating the infection is time sensitive. At most hospitals, the lack of immediately available operating rooms often delays patient care. Furthermore, these patients often have many medical comorbidities that require preoperative treatment. Performing the procedure at bedside almost immediately after diagnosis notably decreases any delays in treatment. Additionally, the amount of fluid introduced into the joint is not limited by the constraint of the time in the operating room or the need for a provider at bedside, allowing a near limitless amount of irrigation.[3]

At our institution, we are working to simplify this method of irrigation and debridement for treating septic knee arthritis. We aim to create a simple device that could be placed at bedside and allows irrigation fluid to flow through the joint, and for the fluid and

infectious material to flow back out in a continuous manner without the need for operative intervention. It is important for this device to be compact, cost efficient, easy to use, and cause minimal discomfort to patients.

We chose the superolateral entry point to the knee as the insertion site for several reasons. First, it is almost universally familiar among orthopaedic surgeons and any provider performing arthrocentesis of the knee. The site is accessed with the leg in extension to minimize patient discomfort by restricting movement. After, the leg is placed superior to the tibia and femur articulation to avoid intra-articular impingement. By exiting superior and lateral, it also avoids contact with the other leg and allows ease of access for maintenance once placed. To maximize ease of use, patient comfort, and low costs, ideally the device would be a universal size.

The purpose of this study was to determine how much variability exists in the soft-tissue thickness at the superolateral approach of entry to the arthrocentesis site of our patients and whether these measurements correlate with patient anthropometric data including age, sex, height, weight, and body mass index (BMI, kg/m^2).

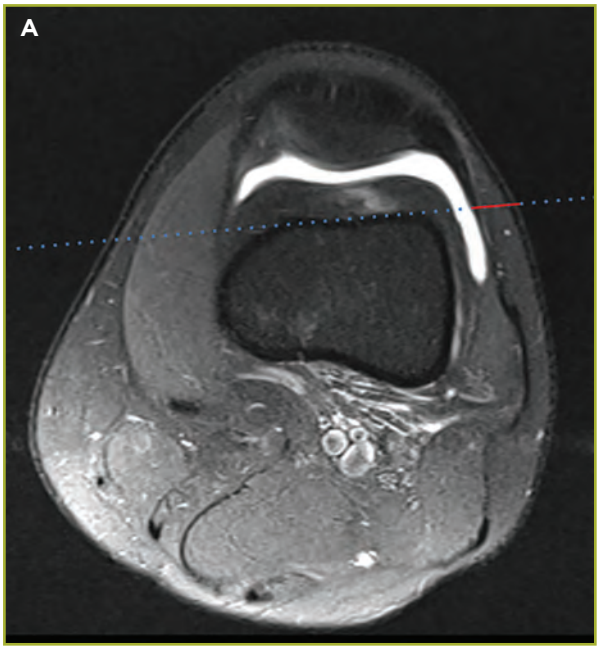
METHODS

After we received approval from our Human Research Review Committee (HRRC #16-391), we gathered magnetic resonance imaging (MRI) scans of 100 consecutive patients at our institution. We used the International Classification of Diseases, Ninth Revision (ICD-9) diagnosis code of 844.2 (sprain of cruciate ligament of knee) to produce a heterogenic group representative of our patient population.

A retrospective review of medical records was performed to obtain patient sex, age, height, weight, and BMI at the time of the MRI. We reviewed 68 MRI scans after excluding 32 patients who were either younger than 18 years or for whom anthropometric data were not available. A total of 68 patients met our inclusion criteria (34 men, 34 women).

We performed a standard method of radiographically measuring the superolateral arthrocentesis site soft-tissue thickness (SASSTT), as shown in Figure 1A. The sagittal MRI scans were used to identify the superior pole of the patella (Figure 1B). The localizing software was used to find the corresponding axial cut at the superior aspect of the patella. The soft tissue over the capsule at the SASSTT was measured, followed by a similar measurement one cut above and one cut below the initial point. Each cut progressed 3 mm through the plane imaged. The average of these was used for the statistical analysis. All measurements were performed by two senior residents (TP and PJ) and a medical student (SK).

All statistical analyses were performed using Statistical Analysis Software (SAS) version 9.4 (SAS Institute Inc, Cary, NC). Study population was stratified



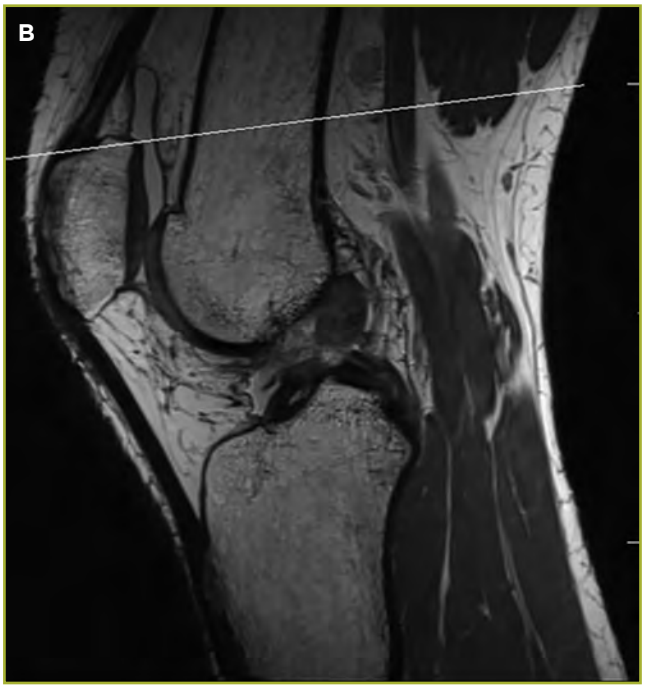


Figure 1. Magnetic resonance imaging, showing standard method of measuring the soft-tissue thickness at the superolateral approach of entry to the arthrocentesis site. A) Localizing software was used to find the corresponding axial cut at the superior aspect of the patella. The soft tissue over the capsule at the arthrocentesis site was measured, followed by a similar measurement one cut above and one cut below the initial point. Each cut progressed 3 mm through the plane imaged. B) Sagittal view used to identify the superior pole of the patella.

by sex, and demographic variables were compared using one-way analysis of variance (ANOVA). Simple linear regression was used to determine presence and strength of correlation between variables of interest and SASSTT. Multiple linear regression was used to calculate strength of association between the main outcome of interest, SASSTT, and BMI while controlling for age and sex. A post-hoc power analysis was completed based on values obtained from the final multiple linear regression model.

RESULTS

The 68 patients were aged an average of 39.1 years. The average soft-tissue thickness was 13.95 mm. Of the 34 women, the average age, BMI, and SASSTT was 40 years, 27.9, and 15.3 mm, respectively (Figure 2). Of the 34 men, the average age, BMI, and SASST was 38.2 years, 27.2, and 12.6 mm (Figure 3). For the 68 participants, the average BMI was 27.6, with an average SASSTT of 14 mm.

Post-hoc power analysis showed a power of 97.7% based on the sample size of 68, with a partial correlation of 0.46 and Alpha set at 0.05. Table 1 shows statistical analysis using ANOVA to compare age, height, weight, BMI, and SASSTT amongst men and women. Statistically significant differences were present in measurements of height ($P < 0.01$), weight ($P < 0.01$), and joint space ($P < 0.03$) between men and women. Table 2 shows correlations using linear regression relating differences in BMI, age, and sex with SASSTT. BMI was the most correlated with SASSTT ($R^2 = 0.46$). Sex and SASSTT were less correlated ($R^2 = 0.09$), and age and SASSTT were not correlated ($R^2 = 0$). Finally, analysis via multiple linear regression showed that for every unit of increase in BMI, the predicted average SASSTT measurement increased by 0.61 mm, after

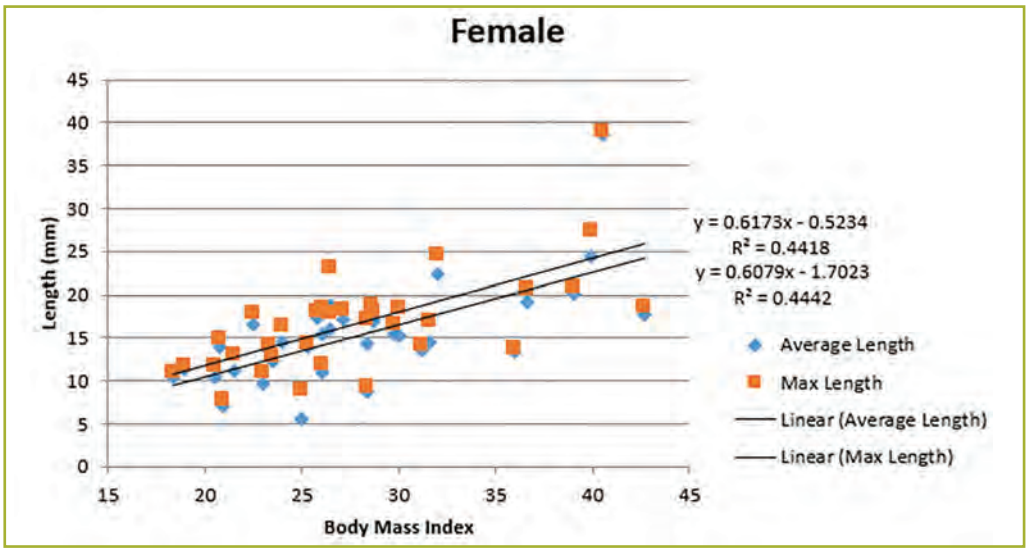


Figure 2. Female body mass index versus joint capsule length. Average lengths and maximum lengths plotted with corresponding regression lines.

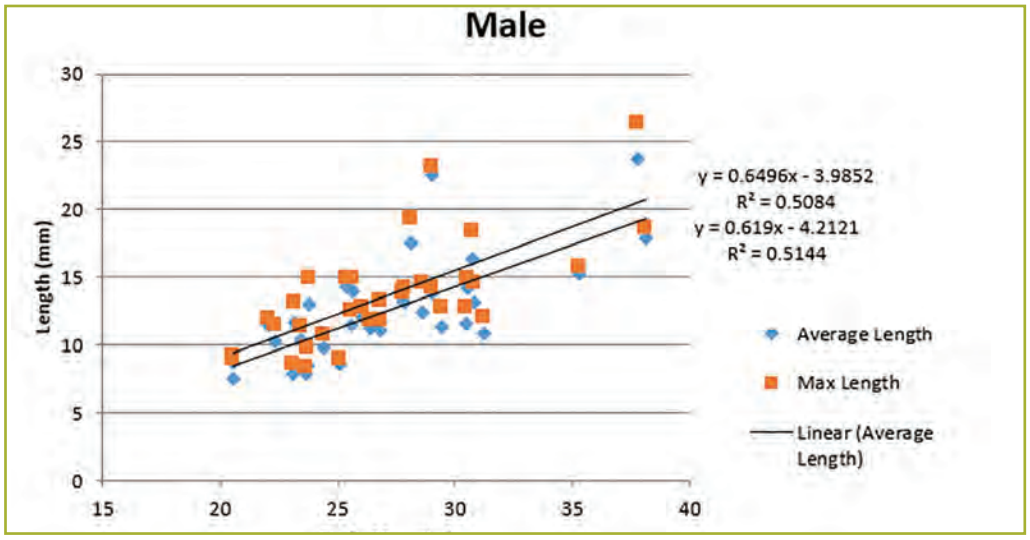


Figure 3. Male body mass index versus joint capsule length. Average lengths and maximum lengths plotted with corresponding regression lines.

Table 1. Anthropometric data of 68 patients to show the presence of significant differences in age, height, weight, body mass index, and joint space between men and women

Variable	*Men, n = 34 Mean (SD)*	*Women, n = 34 Mean (SD)*	*P value*
Age, y[a]	38.2 (15.1)	40.0 (12.6)	0.59
Height, cm	176.8 (7.9)	163.6 (6.9)	< 0.0001
Weight, kg	85.4 (14.5)	74.4 (15.0)	< 0.01
BMI, kg/m2	27.9 (4.3)	27.2 (6.4)	0.57
Joint space, mm	12.6 (3.7)	15.3 (5.8)	0.02

BMI, body mass index.
[a]Age range was 18-67 years for men and women.

Table 2. Univariate versus adjusted (multivariate) linear regression coefficients relating differences in BMI, age, and sex with SASSTT[a]

	Univariate			*Adjusted*		
Variable	*Coefficient (95% CI)*	*Pearson's Correlation*	*P value*	*Coefficient (95% CI)*	*Partial Correlation*	*P value*
BMI, kg/m^2	0.63 (0.46-0.80)	0.45	< .0001	0.61 (0.45-0.78)	0.46	< .0001
Age, y	0.04 (-0.05-0.13)	0.12	0.37	-0.002 (-0.07-0.06)	0.00	0.95
Sex	2.68 (0.31-5.06)	0.08	0.03	2.23 (0.46-4.00)	0.09	0.01

BMI, body mass index; SASSTT, superolateral arthrocentesis site soft-tissue thickness; CI, confidence interval.
[a]Dependent variable: joint space; main independent variable: BMI; adjusted model controls for age and sex.

controlling for sex and age. In addition, the average SASSTT measurement is predicted to be 2.23 mm longer in women than men, after controlling for BMI and age; however, the confidence interval was wide (CI, 0.46-4).

DISCUSSION

Septic arthritis is a common diagnosis encountered by multiple specialties within medicine and causes considerable rates of mortality and morbidity. Research has shown that if left untreated, enzymes and toxins produced by bacteria will directly damage cartilage in the joint.[4] In addition, host neutrophils can damage joint cartilage by releasing reactive oxygen species and lysosomal proteases to defend against invading organisms. Host cytokines also work to defend the body by triggering the release of matrix metalloproteinases, which may cause autodigestion of cartilage in the joint space. The purulent material alone can cause notable damage by inducing ischemia of cartilage by increasing external pressure on cartilage, decreasing the ability of nutrients to diffuse into the cartilage and restricting blood flow.[4]

Standard therapy for managing septic joint arthritis is not well defined and differs depending on the patient. Options for treatment include medical management of the infection with antibiotics, serial aspiration of infected joint fluid, arthrotomy or arthroscopy of the affected joint, and continuous irrigation and drainage of the affected joint.

Treatment of septic arthritis with antibiotics alone may be sufficient; however, it may not provide complete recovery in many cases.[5] Surgical management includes both arthrotomy and arthroscopy for drainage and debridement of an infected joint. Compared with medical management, surgical management has been shown to shorten length of hospital stay.[5] In conjunction with antibiotic therapy, surgical management is up to 95% successful in eradicating septic joint infections.[6] Patients who do not recoveroften have complications related to more severe infections at the time of diagnosis.[7] The results of arthroscopy versus arthrotomy are controversial. Some studies have shown arthroscopy to be more successful in patients requiring fewer re-operations and experiencing fewer reinfections, while showing better immediate postoperative range of motion allowing for ease of rehabilitation and mobilization.[8]

Less invasive management of septic arthritis includes needle aspiration of infected joint fluid. Some studies found no compelling evidence to recommend surgical intervention instead of serial needle aspirations, whereas other evidence suggests that needle aspiration is typically most useful in less severe infections.[9] One

limitation to the use of large bore needles includes decreased effectiveness in removing the infectious pannus and loose infectious debris that develops in many septic joints. However, in some studies, no statistically significant difference has been found between needle aspiration and surgical procedure when considering length of stay, the number of patients who recover completely, and the number of readmissions for complications.[10] Risks of iatrogenic infection from multiple arthrocentesis in a non-sterile environment and the multiple interventions required to treat the patient deter surgeons from using serial aspirations; thus, this method typically becomes reserved for patients who cannot undergo surgical treatment.

A final management option that combines strengths of operative and nonoperative interventions is continuous irrigation and drainage of the septic joint. This method is a viable option for patients who cannot otherwise undergo operative treatment and is often performed at bedside. In addition to washing out pyogenic fluid from the affected joint to decrease joint pressure, this modality also dilutes proteolytic and lysosomal enzyme concentrations, which helps prevent damage to cartilage.[3] This method can also be used to introduce intra-articular antibiotics to directly decrease bacterial load.[11] Research and development are ongoing to optimize this form of treatment. Kuo et al1[2] retrospectively analyzed patients with septic arthritis of the knee treated with arthroscopy combined with continuous closed irrigation-suction system and compared them with patients treated with arthroscopy alone. Patients with more severe infections treated with the combined method had fewer operations and shorter hospital stays. Results of recent research on complex systems with automated intermittent irrigation and suction in a cadaver model has shown promise, with an increased ability to clear joint containments compared to the described continuous irrigation-suction devices.[1]

The purpose of this study was to determine how much variability exists in the SASSTT of our patients and whether these measurements correlated with patient anthropometric data including age, sex, height, weight, and BMI. Our results suggest that despite large variations in patient body habitus, a small amount of predictable variation exists in the soft-tissue envelope surrounding the joint capsule at the superolateral entry point to the knee joint. A second purpose of our study was to determine whether a bedside device for irrigation and debridement could be a single universal size. Our data show that with such small amount of variation, multiple sizes are not needed, and a single universal device is plausible. Our findings also may help explain why others have shown the superolateral entry point more reliable and reproducible when performing intra-articular aspirations or injections of the knee.[13] Further investigations could examine the soft-tissue envelope over other common injection sites.

Our study has several limitations. Our small sample size may affect our findings, despite sufficient power. We did not account for pathological findings on MRI scans. It is unclear how specific diagnosis, or more specifically an effusion, affected our measurements. Secondly, ICD-9 codes for anterior cruciate ligament injury were used to provide uniformity to the MRI search; however, this method might have resulted in sampling patients with a lower BMI because the population may be more physically active.

In general, we observed a weak but predictable correlation between BMI and SASSTT and a weaker correlation between sex and SASSTT. These small, negligible differences help predict that for continuous irrigation of septic arthritis of the knee joint, a single universal-sized device could be successfully designed for use in both men and women.

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Midterm Results of an Anatomical Radial Head Arthroplasty for Treating Fractures and Degenerative Joint Diseases of the Radial Head

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflicts of Interest Gabriel Pertierra and Lauren Vernon report employment by Skeletal Dynamics, LLC. Francisco Rubio reports consulting fees from Skeletal Dynamics, LLC.

ABSTRACT

Background: Radial head arthroplasty (RHA) is typically performed to restore elbow stability or function in patients with fractures or degenerative joint diseases. The procedure requires a specific operating technique to avoid complications such as overstuffing, capitellar erosion, stiffness, instability, micro motion, and loosening. It is difficult to restore native radial head function reliably.

Methods: We reviewed the medical records of 45 patients who underwent radial head arthroplasty using the ALIGN radial head implant (ALIGN Radial Head System, Skeletal Dynamics, Miami, FL) at our institution. A total of 15 patients met inclusion criteria and were contacted to complete a QuickDASH questionnaire, with additional questions on range of motion, strength, stability, pain, and satisfaction. The monoblock ALIGN implant has a long, press-fit stem coated in titanium plasma spray (TPS), is comprised of cobalt chrome, and is anatomically aligned by the provided alignment jig.

Results: Of the 15 patients, one reported severe loss of motion. No patient reported severe loss of strength, loss of stability, or pain. The average QuickDASH score was 12.62 (SD, 18.06) of 100, and the average patient satisfaction score was 8.80 (SD, 2.18) of 10.

Conclusions: Radial head arthroplasty may result in suboptimal performance. Functional outcomes after using this implant with monoblock design have been favorable. The design may accurately replicate the anatomical function of the native radial head, and the long, TPS-coated press-fit stem may provide more stability and osseous integration than other implants. The results of this study indicated satisfactory midterm results after use of the ALIGN implant in radial head arthroplasty.

Keywords: Radial Head Arthroplasty, Axis of Forearm Rotation, Radial Head

INTRODUCTION

The radial head is a key component of the proximal radioulnar joint and an important element in force distribution across the elbow. Dysfunction of the radial head produces notable disability. No radial head implant has been able to restore native radial head function reliably.[1]

Fractures of the radial head constitute 33% of all elbow injuries and up to 5% of all adult fractures.[2] Most radial head fractures (85%) occur in young active adults, typically during a fall in which impact is braced by the hand, the forearm is supinated, and the elbow is in extension.[3] The radial head is a primary stabilizer to axial forearm loads and a secondary stabilizer to varus-valgus stress.[3,4] When injury results in ligamentous damage, the radial head becomes the primary stabilizer to varus-valgus.[3]

Active stability of the elbow is mostly dependent on joint compressive forces, which result from muscle action and articular congruency. The lateral and medial collateral ligament complexes and the anterior capsule maintain passive stability of the elbow. Joint forces in voluntary movement involve compression of the radial head and coronoid process against the humerus. The radial head alone can handle a load of up to three times the subject's body weight during valgus loading, when tension is high across the medial collateral ligament. The initiation of flexion about the elbow generates the greatest amount of force onto the radial head and coronoid. The elbow is most stable at 90˚ of flexion. In extension, most of the load (60%) is transmitted through the radial head and the remaining load is carried by the ulnohumeral joint (coronoid). Overall, the radioulnar joint allows an average of 75˚ of pronation and 80˚ of supination.[5]

Advanced degenerative joint disease may be treated surgically by osteotomy, resection, or radial head arthroplasty (RHA). Surgical treatment of radial head fractures may include open reduction and internal fixation (ORIF), resection of the radial head, or RHA. Indications for operative treatment include articular

displacement, irregular motion, severe pain, and instability associated with soft-tissue damage.[2]

Although ORIF is the preferred treatment for less comminuted radial head fractures, this technique has a high failure rate when the fracture is highly comminuted and unstable.[6] Resection greatly alters joint kinematics and may lead to complications such as long-term instability, displacement, positive cubital variance, and premature osteoarthritis. The interosseous ligament transfers axial loading to the ulna when the radial head is removed, leaving only the medial ligament to prevent a valgus deformity.[5] Resection is more effective in cases of isolated fracture without ligament injury owing to these biomechanical changes.[2,7] Fracture of greater than 50% of the coronoid process, comminution into three or more pieces, disruption of the collateral ligaments, or acute longitudinal radioulnar dissociation (Essex-Lopresti) lead to elbow instability and indicate the need for RHA.[8,9] RHA is also suggested for severe degenerative joint disease, failed ORIF, non-union, osteonecrosis, and posttraumatic sequelae.[4,8]

RHA requires precise surgical technique to avoid complications. Implant sizing is crucial because oversized implants, known as joint overstuffing, can decrease range of motion and lead to capitellar erosion. This is commonly the result of excessive radial head length.[7] An overly proximal bone cut or overestimation of the bone gap when the lateral collateral ligament is compromised can lead to overstuffing.[6,7] Lengthening of 2.5 mm or more alters joint kinematics and leads to excessive radiocapitellar load,[10] whereas an undersized implant will fail to stabilize the elbow properly.[7] Micro motion and loosening are more likely with larger radial neck resections and smaller implant stem lengths.[11]

Although some implants spin inside the radius with loose-fitting stems, other implants are seated (using a press-fit stem or bone cement) to restore native function. Press-fit stems are typically coated with a textured surface, such as titanium plasma spray (TPS), to promote osseous in-growth and stability. The objective of this study was to assess and report midterm follow-up results on patients who underwent RHA using a cobalt chrome, press-fit implant (ALIGN Radial Head System, Skeletal Dynamics, Miami, FL).

METHODS

After receiving approval from our facility's medical director (we emailed the approval letter to the publication staff), we retrospectively reviewed all patients who underwent RHA from January 2011 to December 2015 (n = 45). Inclusion criteria were patients with a radial head fracture or severe elbow arthritis, treatment primarily with RHA, that were skeletally mature (18 years of age) at the time of the procedure. Exclusion criteria were patients who did not have a working phone number or did not wish to participate in the study, work-related injuries, and simultaneous ipsilateral upper-extremity injuries. Studies have shown that workers' compensation claims strongly affect patient outcomes after an orthopaedic surgical procedure.[12-14] Of the 45 patients, a total of 15 met the inclusion criteria (5 men, 10 women).

Fifteen patients were contacted to complete a telephone survey (Figure 1). Our survey started with an overall patient satisfaction question (reported on a 0-10 continuous rating scale) and proceeded to questions regarding motion, strength, stability, and pain. These questions were taken from the Broberg and Morrey[15] elbow rating system that defines the limits for mild, moderate, and severe loss. Finally, we included a question on complications. If the patient reported complications, additional follow-up questions were provided. The patients were also asked to complete a QuickDASH questionnaire to assess disability.[16]

Questionnaire:

1. On a scale from 0 to 10, with 0 being completely dissatisfied, and 10 being completely satisfied, how satisfied are you with the outcome of your elbow surgery? _____
2. How would you rate your elbow range of motion now?
   a) Normal
   b) Mild loss (80% of the other side)
   c) Moderate loss (50% of the other side)
   d) Severe loss (disabling)
3. How would you rate your elbow strength?
   a) Normal
   b) Mild loss (80% of the other side)
   c) Moderate loss (50% of the other side)
   d) Severe loss (disabling)
4. How would you rate your elbow stability?
   a) Normal
   b) Mild loss (perceived by patient, no limitation)
   c) Moderate loss (limits some activity)
   d) Severe loss (limits everyday tasks)
5. How do you rate your elbow pain?
   a) No pain
   b) Mild pain (with activity, no medication required)
   c) Moderate loss (with or after activity)
   d) Severe loss (at rest, constant medication, disabling)
6. Following your surgery, did you experience any complications or require any additional elbow surgery? Yes/ No
   a. If no, proceed to next question
   b. If yes, what were the complications?
   c. If yes, did you require a second surgery?
      i. If yes, Was that procedure also carried out by Dr. _____(the original doctor)?

Figure 1. The survey on range of motion, strength, stability, pain, and patient satisfaction, conducted over the phone to 15 patients

We modified one question from the elbow rating system, regarding range of motion. The original scoring system used range-of-motion measurements to calculate the motion score. Because our survey was conducted over the phone, these measurements were not available. Instead, the question was changed to mirror the mild, moderate, and severe scale used for the strength score (reported as a percentage of the contralateral elbow).

The ALIGN radial head implant (Figure 2) is a cobalt chrome, side-loading, monoblock implant designed to be anatomically aligned to the patient's axis of forearm rotation by means of an alignment jig (Figure 3). A long stem provides three-point, press-fit fixation and has a TPS coating. The implant is installed in a modular fashion, until a lock screw secures the head to the stem,

Figure 2. The ALIGN implant (ALIGN Radial Head System, Skeletal Dynamics, Miami, FL).

transforming it into a monoblock system. RHA was performed as described by the manufacturer of the ALIGN implant.[17] Two orthopaedic surgeons with upper-extremity subspecialty training performed all surgical procedures.

RESULTS

The mean age of the 15 patients was 60.87 years (SD, 16.39) at the time of the surgical procedure (range, 26-83 years). Table 1 shows demographic data. RHA was performed on eight right and seven left hands. Patients were contacted to complete the survey at an average of 44.58 months (SD, 18.03) postoperatively. Figures 4A and 4B shows a representative radiograph of a patient at final follow-up.

The results of the patient questionnaire are shown in Table 2. With respect to motion, eight patients (53.3%) reported normal range of motion, three (20.0%) had mild loss of motion, three (20.0%) had moderate loss of motion, and one (6.7%) had severe loss of motion. Regarding strength, nine patients (60.0%) had normal elbow strength, four (26.7%) had mild loss of strength, and two (13.3%) had moderate loss of strength.

Concerning stability, eleven patients (73.3%) reported normal elbow stability, three (20.0%) had mild loss of stability, and one (6.7%) had moderate loss of stability. With respect to pain, ten patients (66.7%) reported no elbow pain, three (20.0%) had mild elbow pain, and two (13.3%) had moderate pain.

Table 1. Demographic information on 15 patients with radial head fractures treated using the ALIGN Radial Head System implant[a]

Patient number	*Age, y*[b]	*Sex*[c]	*Left or right hand treated*[d]	*Postoperative follow-up, mos*[e]
1	83	Female	Right	70.39
2	66	Female	Left	64.77
3	62	Male	Right	64.21
4	26	Male	Left	62.73
5	68	Female	Left	59.05
6	58	Female	Left	51.45
7	56	Male	Right	48.82
8	81	Female	Left	45.30
9	70	Female	Right	45.14
10	66	Female	Left	36.36
11	81	Female	Right	35.64
12	34	Male	Right	31.33
13	45	Male	Left	21.21
14	54	Female	Right	16.83
15	63	Female	Right	15.45

[a]Skeletal Dynamics, Miami, FL.
[b]Average age of all patients was 60.87 years (SD, 16.39).
[c]In total, ten patients were women and five were men.
[d]In total, eight right and seven left hands were treated.
[e]Patients were contacted to complete the survey at an average of 44.58 months (SD, 18.03) postoperatively.

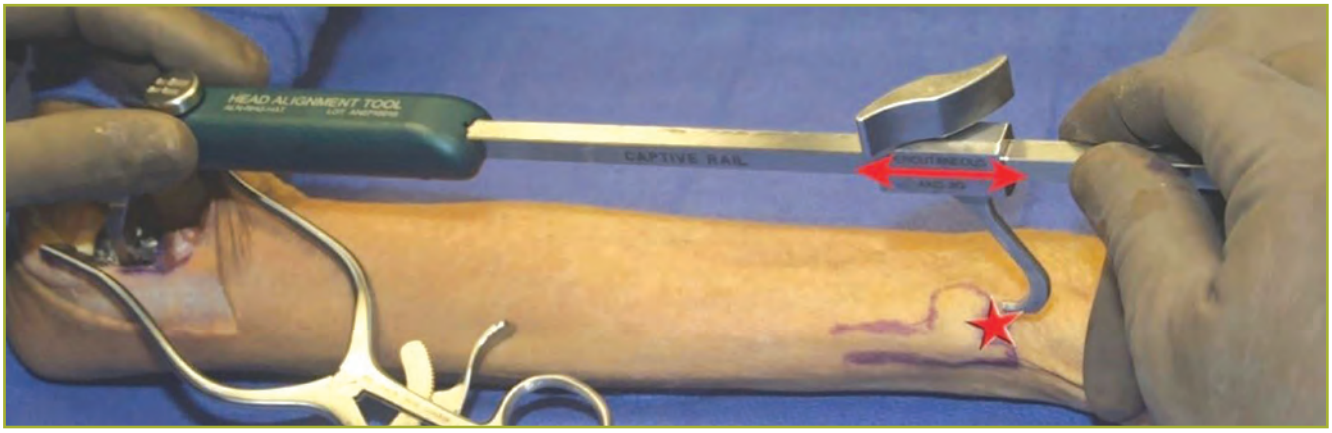


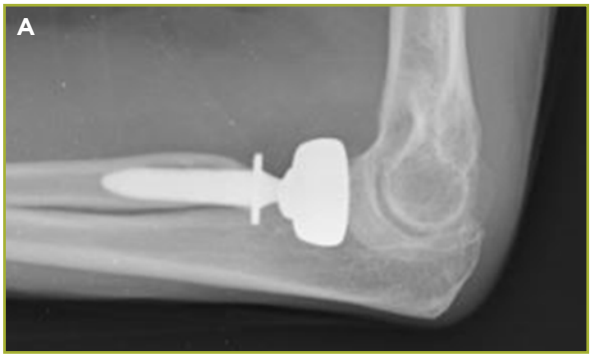
Figure 3. The ALIGN implant (ALIGN Radial Head System, Skeletal Dynamics, Miami, FL) alignment jig used to anatomically align the implant to the patient's axis of forearm rotation.

Table 2. Results of the follow-up survey given to 15 patients who underwent surgical treatment of radial head fractures using the ALIGN Radial Head System implant[a]

Patient Number	*ROM*	*Strength*	*Stability*	*Pain*	*QuickDASH Score*[b]	*Complications*	*Satisfaction Score*[c]
1[d]	normal	normal	normal	none	4.55	no	10
2	moderate loss	normal	normal	mild	4.55	no	9
3[d]	severe loss	moderate loss	moderate loss	moderate	50.00	no	5
4	mild loss	mild loss	mild loss	none	9.09	no	10
5	normal	normal	normal	none	0.00	no	10
6[e]	moderate loss	moderate loss	normal	moderate	40.00	yes	4
7	mild loss	normal	normal	mild	6.82	no	10
8[f]	moderate loss	mild loss	mild loss	none	50.00	no	5
9	normal	normal	normal	none	2.27	no	10
10[d]	normal	normal	normal	none	0.00	no	10
11[f]	normal	mild loss	mild loss	none	10.71	no	10
12	normal	normal	normal	mild	0.00	no	10
13	normal	normal	normal	none	0.00	no	10
14	mild loss	normal	normal	none	4.55	no	10
15	normal	mild loss	normal	none	6.82	no	9

ROM, range of motion.
[a]Skeletal Dynamics, Miami, FL.
[b]The average QuickDASH score was 12.62 (SD, 18.06). Patient scores ranged from 0 to 50 of 100 (QuickDASH maximum score), with a score of < 20 indicating a positive outcome.
[c]The average satisfaction score was 8.80 (SD, 2.18). Scores ranged from 0 to 10, with a score of 10 indicating the most satisfied.
[d]Patients had history of elbow pain and instability before treatment.
[e]Patient reported "golfer's elbow" (ie, medial epicondylitis) and underwent an additional procedure on the same elbow.
[f]Patients had a severe cognitive impairment, and responses were given by a family member or caregiver.

The average QuickDASH score was 12.62 (SD, 18.06; Table 2). The average patient satisfaction score was 8.80 (SD, 2.18) of 10. One patient (6.7%) reported a complication of "golfer's elbow," or medial epicondylitis, requiring additional surgical treatment of the same elbow (patient #6). Another patient had a 15-year history of elbow pain and instability before treatment, multiple operative procedures, and a ligament reconstruction (patient #3). One patient had lived with instability for more than 50 years before surgical treatment (patient #10). Of the 15 patients included in the study, none underwent surgical revision or removal of the ALIGN implant.



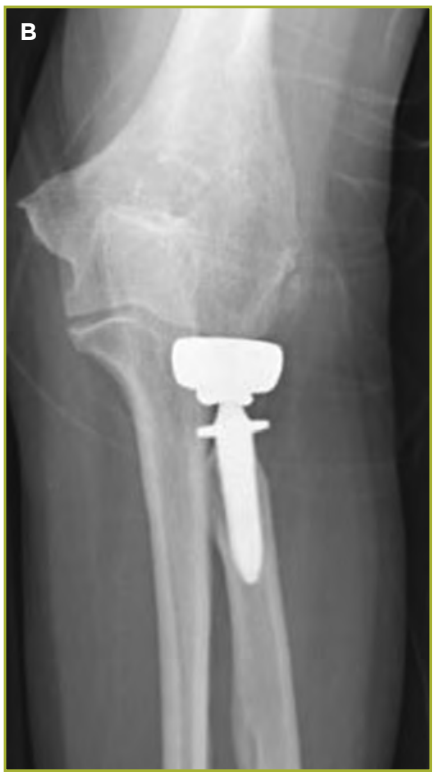


Figure 4. Representative radiographs of a patient at 3-year follow-up. A) Anteroposterior view of the elbow. B) Lateral view of the elbow.

DISCUSSION

RHA is a common orthopaedic treatment that may result in suboptimal results, revision procedures, and postoperative complications.[1,9,18] The treatment is intended to improve stability after injury, particularly when ligamentous and bony injury are combined, or to relieve pain in advanced degenerative joint disease of the radial head. Restoration of the radial head buttress restores elbow stability.

Even after ligament healing stabilizes the joint, radial head implants can produce long-term problems such as painful capitellar wear and prosthetic loosening. A study done by Wretenberg et al[19] found that up to 27% of radial head implants are removed or revised soon after implantation owing to similar issues, with an average follow-up of 3.4 years. There is no consensus for the optimal design of radial head implants thus far. Three controversies stand out: monoblock versus bipolar, loose-fitting stem versus fixed-stem implants, and anatomical versus non-anatomical designs.

Monoblock designs attempt to replace the native radial head with a rigid implant that replicates its biomechanical function. Their rigidity provides lateral support to control posterolateral instability, despite some degree of elbow subluxation. Because of the wide range of anatomic variation, it is difficult to restore the original alignment when using monoblock radial heads. These implants may produce edge loading and wear on the capitellum. Bipolar radial heads have a ball and socket articulation immediately distal to the radial head that attempts to minimize capitellar wear by alignment with the capitellum.[7] Therefore, the bipolar radial head avoids capitellar edge loading seen with monoblock implant malalignment.

A bipolar design may cause localized high stresses on the capitellum when subjected to a lateral force because the radial head transmits axial and transverse loads.[1] In cadaveric models, bipolar heads provide less stability than monoblock implants because they fail to restore lateral support in the face of slight subluxation.[9] However, recent studies have not shown enough significant clinical evidence in favor of one specific type of implant.[8]

Radial head implants with a loose-fitting stem are designed to be a simple spacer between the capitellum and the radial stump. They present a smooth, metallic, intramedullary stem introduced into the radial neck, with the intention of allowing rotational motion. Loose-fitting stems cannot transmit joint forces, especially transverse forces, in a physiological manner. They are prone to complications such as osteolysis and migration.[20]

Fixed-stem implants, on the other hand, transmit loads in a physiologic manner.[21] Fixation methods used have included press-fit, cement, and bone-ingrowth surfaces. Stably-fixed implants have some disadvantages, however. Anatomical implant alignment has been difficult to obtain and malalignment can cause capitellar wear.[8] If fixation is not successfully achieved, the textured surfaces of press-fit implant stems may cause erosion and osteolysis.[21] With uncemented implants, immediate postoperative stability is needed for bony integration and to prevent micromotion. Implant stability depends on stem length and proper resection of the radial head and neck.[11] Findings of a study done by Kodde et al[1] suggests that press-fit fixation with successful osseous integration results in long-term fixation and stability. Cemented implants, on the other hand, have been shown to loosen at the cement-bone interface in up to 10% of cases.[18]

Anatomically accurate radial head implants more evenly distribute and reduce contact stresses on the capitellum as compared to their non-anatomically designed counterparts.[5] Anatomically designed radial heads are difficult to insert in the original anatomical position.[8] Their designs are based on averages of a wide range of anatomical variations of the elbow and therefore do not conform well to individual patients. Non-anatomical radial head implants cannot be aligned properly because their stem is perpendicular to the radial neck, where fixation is typically obtained. Because the average radial head is angulated 6° from the axis of the radial neck, a wobbling motion during forearm rotation and edge loading on the capitellum can result.

The ALIGN implant has a unique long and press-fit stem design with a radial head that is custom aligned to the patient's axis of forearm rotation. This provides the bipolar-like protection of the capitellar surface and the stability of a monoblock implant. This design also permits the use of a long stem to achieve more reliable fixation while avoiding the difficulties of inserting a traditional anatomical monoblock implant.

Overall, patients reported high scores of satisfaction (average score, 8.8), with 10 patients reporting complete satisfaction (10 of 10). Similarly, five patients reported no pain, normal range of motion, normal strength, and normal stability. However, not all patients were completely satisfied. Three patients (#3, #6, and #8) reported satisfaction scores of less than 7. Interestingly, these patients had high QuickDASH scores (> 20) and reported moderate to severe loss of range of motion. In the Broberg and Morrey[15] rating system (that our survey was modeled after), range of motion is the most heavily weighted category (40% of the final score), suggesting that these patients would likely have received a fair or poor Broberg and Morrey[15] classification score.

Three patients (#1, #3, and #10), had a history of elbow instability prior to treatment. Two of these patients (#1 and #10) had promising treatment outcomes. However, patient #3 (who had a poor outcome) had full range of motion at 4 weeks postoperatively but described poor function. This may

have been due to his multiple medical comorbidities that affected his ability to perform tasks. Three patients (#3, #10, and #14) underwent RHA to treat degenerative joint disease. Twelve patients (with high satisfaction and low QuickDASH scores) reported favorable outcomes across the categories (range of motion, strength, stability, and pain), indicating an excellent or good score of the Broberg and Morrey[15] classification.

Our study has several limitations. We had a limited sample size of patients. Of the 45 patients treated with RHA, only 15 patients met inclusion criteria. Of the 30 patients who did not participate, twenty-one were unable to be contacted or declined to participate, five were involved workers' compensation claims, one was below the age of 18 years at the time of procedure, and three had severe ipsilateral injuries. Furthermore, the study was conducted using the phone, which limited the data collected to patient-reported outcomes and did not allow for objective measurements (specifically for the range of motion question) or radiographic analysis. The phone survey was therefore written to closely mirror the Broberg and Morrey[15] questionnaire, which is a validated method for assessing treatment outcomes of elbows.

In the current study, our patients exhibited favorable results after RHA for the relevant indications listed. Our findings may indicate that use of the ALIGN implant provides promising midterm clinical results, with few complications, and minimizes the need for revision procedure or implant removal.

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Clinical and Radiographic Comparison Between Patients With Achilles Midsubstance Ruptures and Achilles Sleeve Avulsions

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

ABSTRACT

Background: The diagnosis and treatment of acute midsubstance ruptures to the Achilles tendon has been well described; however, information is lacking about ruptures that occur at the bone-tendon interface known as Achilles sleeve avulsions. The aim of this study was to review the clinical and radiographic features that distinguish midsubstance ruptures from sleeve avulsions.

Methods: Medical records of patients with Achilles tendon ruptures (n = 41) and Achilles sleeve avulsions (n = 8) treated by the senior author (RM) between January 2011 and January 2017 were reviewed. Exclusion criteria were patients with non-midsubstance ruptures (n = 8) or ruptures treated nonoperatively (n = 4). Patients were also excluded who took oral steroid medication, had recent fluoroquinolone use, or received a steroid injection near the tendon (n = 0). Ultimately, patients with midsubstance ruptures (n = 29) were compared to those with sleeve avulsions (n = 8). Radiographic findings were evaluated for posterior heel abnormalities.

Results: Radiographic findings of a posterior calcaneal osteophyte, superior calcaneal prominence, or ossific fragments about the posterior ankle were seen in all patients with sleeve avulsion injuries (n = 8) and not in any with midsubstance ruptures. Faint radiodense specks at the distal aspect of the avulsed tendon were observed in half of the patients (n = 4) with an Achilles sleeve avulsion.

Conclusions: Achilles sleeve avulsions occur mostly in older patients and are less often associated with sports injuries than midsubstance ruptures. The faint radiodense specks seen during the study were termed the "Pleiades sign" owing to their similar appearance to that well-known star cluster, which may be used to assist future diagnosis of Achilles sleeve avulsions.

Keywords: Achilles Tendon, Avulsion Fracture, Ruptures, Radiographic Film, Retrospective Study

INTRODUCTION

Acute rupture of the Achilles tendon is a common injury, in which a midsubstance rupture typically occurs. Both operative and nonoperative treatment have been effective in restoring function after these ruptures. A variation of an Achilles tendon rupture is the insertional Achilles sleeve avulsion, described as an avulsion of the Achilles tendon from its insertion, which leaves few or no fibers on the calcaneus. Patients with Achilles sleeve avulsions present with similar medical history and physical examination findings as those with midsubstance ruptures; however, treatment differs. Only 64% of sleeve avulsions were recognized preoperatively in a series published by Huh et al.[1]

Although findings of magnetic resonance imaging (MRI) scans can distinguish between midsubstance ruptures and insertional sleeve avulsions, this test is expensive and thus not routinely obtained (Figure 1). Operative repair of Achilles sleeve avulsions often involves reattaching the tendon to the posterior calcaneus using suture anchors. Additionally, transcalcaneal suture techniques have been described if there is an insufficient amount of distal tendon to reattach the ruptured segment.[2] The response of Achilles sleeve avulsions to nonoperative treatment is unknown. For these reasons, it is important to distinguish a midsubstance Achilles rupture from an insertional sleeve avulsion.

In the current study, we retrospectively examined patients with insertional Achilles sleeve avulsions and midsubstance ruptures. We compared clinical and radiographic findings between groups to help distinguish particular features of sleeve avulsions, which can be used to decide proper treatment methods.

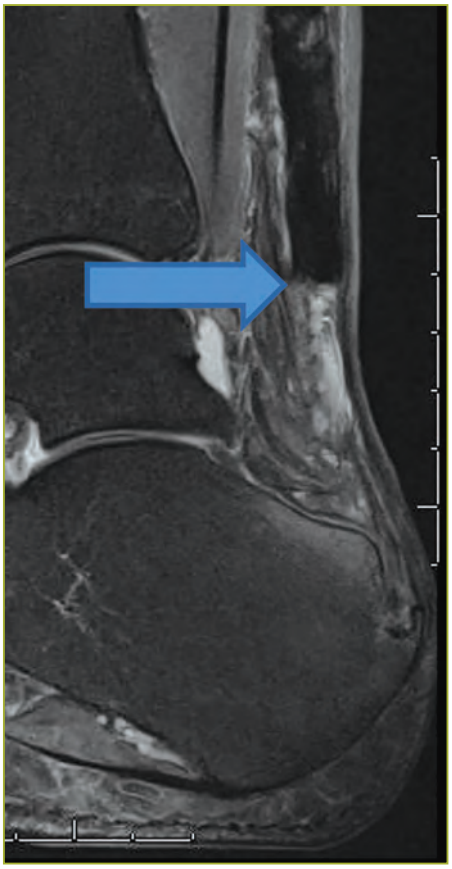

Figure 1. Magnetic resonance imaging (MRI) scan showing the end of an Achilles tendon (arrow), which was avulsed from the calcaneus without the distal tendon present for suture repair. MRI scans were obtained in 13 of the 37 (35%) patients included.

METHODS

After obtaining approval from our Human Research Review Committee (HRRC # 17-341), we reviewed medical records and radiographs of patients with acute Achilles tendon ruptures (n = 41) and Achilles sleeve avulsions (n = 8) treated by the senior author between January 2011 and January 2017. Of the 41 patients, exclusion criteria were non-midsubstance ruptures (n = 8) or ruptures treated nonoperatively (n = 4). Furthermore, patients who took oral steroid medication, had recently used fluoroquinolone, or had received a steroid injection near the tendon were excluded in both groups; however, no patient fit into these categories. Ultimately, 29 and 8 patients were included in the midsubstance rupture group and sleeve avulsion group, respectively. The location of all ruptures was confirmed by intraoperative findings. We noted patient age, associated medical conditions, side of injury, and mechanism of injury.

Because we could not obtain the medical record numbers of patients with midsubstance tears treated nonoperatively (n = 4), these were excluded. The patients were recalled by the senior author (RM) as follows: a morbidly obese man in his 30s, a male athlete in his 40s, a 74-year-old man with ruptures of both Achilles tendons, and a man (unknown age) with one rupture caused by lunging during pickleball and a second occurring spontaneously 3 weeks later. The one patient with an Achilles sleeve avulsion treated nonoperatively had been seen recently by the senior author (RM); subsequently, the associated medical record number was obtained and the patient was included in the study.

Radiographs were evaluated for posterior heel abnormalities such as osteophytes (Figure 2), calcaneal tuberosity prominence known as Haglund's deformity

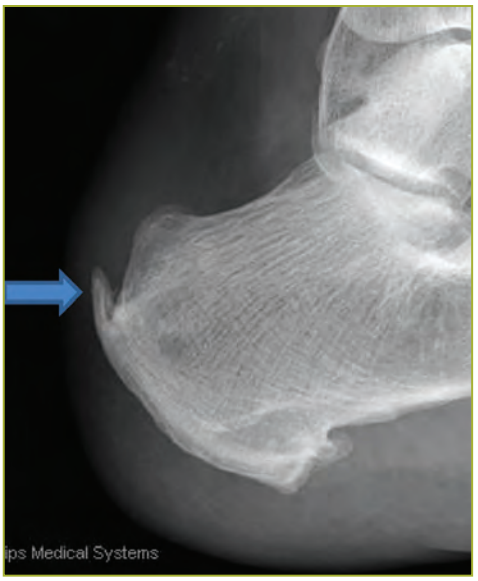

Figure 2. Radiograph showing posterior calcaneal osteophyte (arrow), seen in seven of the eight patients with sleeve avulsion injuries.

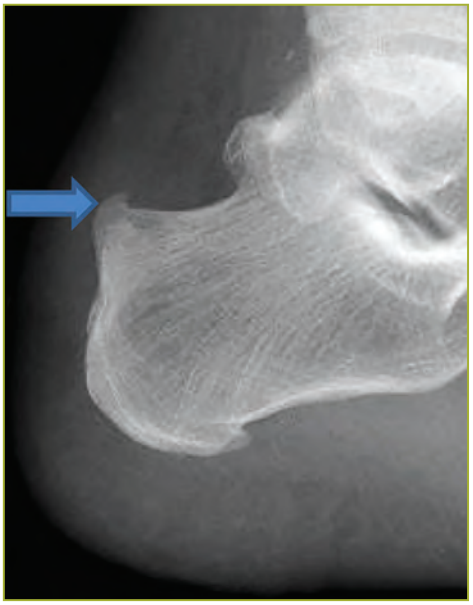

Figure 3. Radiograph showing superior calcaneal tuberosity prominence (arrow), seen in two of the eight patients with sleeve avulsion injuries.

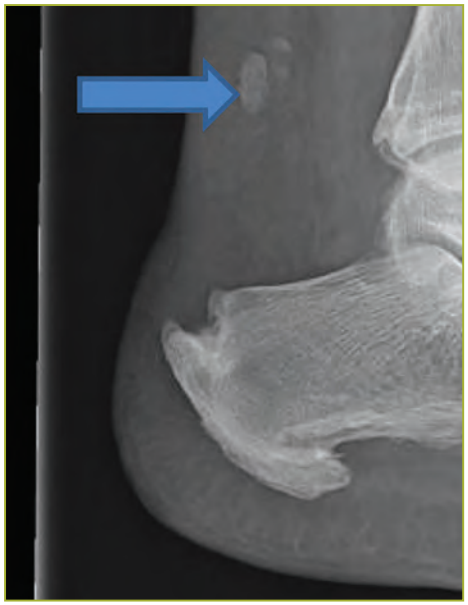

Figure 4. Radiograph showing radiodense fragments proximal to the Achilles insertion, seen in four of eight patients with sleeve avulsion injuries. Additionally, a large posterior calcaneal osteophyte is visible (arrow).

(Figure 3), and small ossific bodies in the posterior ankle region at the distal end of the avulsed tendon (Figure 4). A clear prominence or osteophyte sticking up from the calcaneal tuberosity was defined as a Haglund's deformity. The presence or absence of radiodense specks, noted as the "Pleiades sign" owing to the similar formation, was also noted on radiographs. This is an undescribed radiographic appearance of faint radiodense bodies seen at the distal end of the avulsed

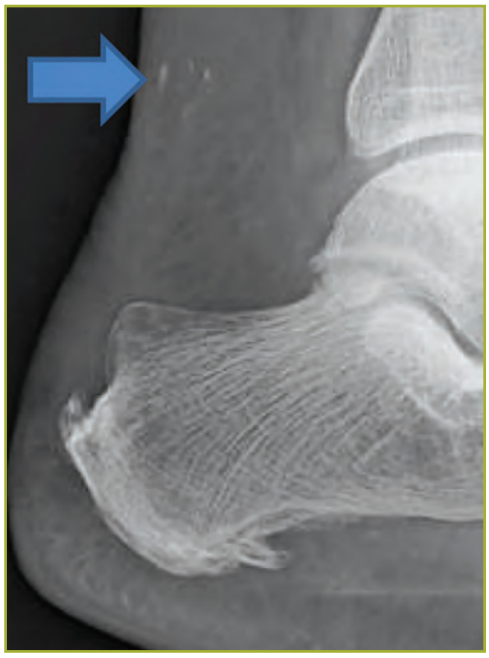

Figure 5. Radiograph showing faint radiodense specks (arrow; the "Pleiades sign"), seen in four of the eight patients with sleeve avulsion.

Figure 6. The Pleiades star cluster in the constellation of Taurus. Reprinted with permission from Trevor Jones at www.astrobackyard.com.

Achilles tendon, which resemble the faint pinpoint lights of the Pleiades star cluster (Figures 5 and 6). These radiodense specks likely represent small fragments of bone avulsed with the tendon.

Preinjury symptoms, return to employment, and return to sports were noted when data were available. However, we were unable to report clinical results of treatment owing to the limited follow-up time and incomplete documentation of these variables.

RESULTS

Demographics

Table 1 shows the distribution of men and women in the midsubstance rupture group (29) and sleeve avulsion group (n = 8) and injury laterality. Overall, 28 men and 9 women with Achilles ruptures. The left and right sides were ruptured in 29 and 8 patients, respectively.

Table 1. Information on included patients (n = 37) in the midsubstance rupture group and sleeve avulsion group

Patient variable	*Midsubstance rupture group (n = 29)*	*Sleeve avulsion group (n = 8)*
Male	23	5
Female	6	3
Left foot injury	22	6
Right foot injury	7	2

The average patient age for the midsubstance and avulsion groups were 37.8 and 57.6 years, respectively. Twenty-six of the 29 patients (90%) with midsubstance ruptures were aged < 50 years. Of the eight patients with sleeve avulsions, three (38%) were aged < 50 years and none were aged < 40 years. The oldest patient (66 years) in the midsubstance group presented with ossification at the site of tendon rupture, suggesting tendinopathy before his injury. MRI and operative findings of this patient confirmed a midsubstance rupture. In our study, Achilles sleeve avulsions most commonly occurred in the fifth and sixth decades of life whereas midsubstance ruptures most commonly occurred in the fourth and fifth decades of life (Table 2).

Table 2. Age and distribution of included patients (n = 37) in the midsubstance rupture group and sleeve avulsion group

Age, y	*Midsubstance rupture group No. patients (n = 29)*	*Sleeve avulsion group No. patients (n = 8)*
Average age (range)	37.8 (24-66)	57.6 (46-82)
Age 20-29	8	0
Age 30-39	9	0
Age 40-49	9	3
Age 50-59	2	3
Age 60-69	1	0
Age 70-79	0	1
Age 80-89	0	1

Table 3. Mechanism of injury of included patients (n = 37) in the midsubstance rupture group and sleeve avulsion group

Mechanism of injury	*Midsubstance rupture group No. patients (n = 29)*	*Sleeve avulsion group No.patients (n = 8)*
Basketball	7	1
Soccer	4	0
Volleyball	2	0
Softball	2	1
American football	1	0
Gymnastics	1	0
Running	2	0
Pushing car	2	0
Kicked	1	0
Fall from ladder	1	0
Hop, twist, misstep, trip	6	4
Stepping up or down from height	0	2

Table 3 depicts the mechanism of injury for each group. Two of the eight patients (25%) with sleeve avulsions were playing sports at the time of injury, whereas 19 of the 29 patients (66%) with midsubstance ruptures were playing sports or running at the time of injury. No patient in either group had rheumatoid arthritis or used steroid medication, steroid injection, and fluoroquinolone. Two patients (25%) in the sleeve avulsion group had type 2 diabetes mellitus. There were no patients with diabetes mellitus in the midsubstance rupture group.

RADIOGRAPHIC FEATURES

There were distinct radiographic differences between the midsubstance and sleeve avulsion groups. Radiographs of all eight patients in the sleeve avulsion group had at least one of the following features:

- Posterior calcaneal osteophyte measuring ≥ 8 mm (seven patients; Figure 2)
- Superior calcaneal tuberosity prominence or Haglund's deformity (two patients; Figure 3)
- Ossific fragments above the insertion of the Achilles tendon (four patients; Figure 4)
- Pleiades sign (four patients; Figure 5)

The Pleiades sign was seen on radiographs of four patients (50%) with sleeve avulsion injuries. This sign has not been described. It appears as faint ossific specks above the insertion of the Achilles tendon, similar in form to the Pleiades star cluster.[3] These radiodense specks are smaller than the ossific bodies in Figure 4, and they likely represent small ossific fragments that were avulsed at the distal end of the tendon. In the midsubstance rupture group, four people (14%) had a much smaller calcaneal osteophyte measuring ≤ 2 mm in size as observed in the radiographs. No Haglund's deformity or Pleiades sign were observed in the radiographs. In one radiograph, ossification at the rupture site was observed.

TREATMENT OUTCOMES OF PATIENTS WITH SLEEVE AVULSIONS

Of the eight patients with sleeve avulsions, seven underwent surgical reattachment of the tendon to the calcaneus using one or two suture anchors. The injury was confirmed by findings of MRI scans in the one patient treated nonoperatively. Of the seven patients who underwent surgical treatment, three had the injury confirmed by findings of preoperative MRI scans. In the remaining four patients, the diagnosis was suspected preoperatively and confirmed by intraoperative findings. All eight patients healed clinically. Six returned to work and one was retired. One patient was involved in a workers' compensation claim and had not returned to work after 9 months.

DISCUSSION

In 2003, Bibbo et al[2] reported on using transcalcaneal suture technique for treating six patients with Achilles sleeve avulsion injuries. They reported no statistically significant difference in the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score or peak strength between the operatively and nonoperatively treated feet. After that report, most studies have focused on the technique used for tendon repair.[4-8] Transcalcaneal sutures or suture anchors have been used. Our study is the first to compare demographic and radiographic findings between patients with midsubstance ruptures and sleeve avulsions of the Achilles tendon.

Huh et al[1] reported a 7.6% incidence of Achilles sleeve avulsions amongst operatively treated Achilles tendon ruptures at their institution. During a 6.5-year period, eleven patients had sleeve avulsions. We found a higher incidence in the current study, although our patients only represented the experience of one surgeon and not the entire institution. We do not know why our incidence was higher; it may be related to referral patterns to the foot-and-ankle subspecialist. Huh et al[1] found 72.7% of patients had preexisting symptoms at the insertion of the Achilles before avulsion, and 90.9% were sustained during recreational athletic activity. The average patient age was 44 years (range, 24-63 years). Their patients had improved clinical results after surgical treatment, in which 10 of the 11 reported AOFAS ankle-hindfoot scores of 90 to 100. We had insufficient data to report preoperative symptoms or results of treatment.

Similar to that of our study, Huh et al[1] commonly observed radiographic signs in patients with Achilles sleeve avulsions. In that study, ten of the eleven patients had a Haglund's deformity and eight had radiodensities of 0.4 to 2.5 cm in size proximal to the Achilles insertion. Radiographs of all eight patients in our study had one or more noted signs. Also, four of our eight patients had radiographs with faint radiodense specks proximal to the Achilles insertion. Each of these patients also had a prominent posterior calcaneal osteophyte or a Haglund's deformity noted on the radiographs. We termed this radiographic finding the Pleiades sign because its appearance was similar to the Pleiades star cluster, which can only be faintly seen with the naked eye. This star cluster was used by sailors for navigation and is referenced in the *Iliad* by Homer.[9,10]

We found Achilles sleeve avulsions more common than midsubstance ruptures in patients who were older, less likely to be injured during sporting activities, and had radiographic findings about the posterior heel. In this demographic of patients, healthcare professionals should consider the possibility that an Achilles sleeve avulsion exists instead of a midsubstance rupture to help decide appropriate surgical treatment.

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Simulated Method to Perform the Coleman Block Test in Educating Orthopaedic Residents Outside of the Clinic

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

Informed Consent The participant (senior author, RAM) was informed that the data concerning his case would be submitted for publication, and he provided verbal consent.

ABSTRACT

The Coleman block test is an important examination performed on patients with a cavovarus foot deformity. Unfortunately, resident physicians in orthopaedic programs have limited exposure to patients with this deformity. Few residents witness the Coleman block test, and it is difficult to understand without observing. We devised a method to simulate a cavovarus foot to instruct orthopaedic residents on performing the test. A 2-cm wedge was placed beneath the medial metatarsals to simulate the plantar-flexed first ray seen in a cavus foot. The position of the lift tilted the heel into varus owing to the tripod effect. The Coleman block test was then performed. Comparison of the heel positions before and after use of the test provided clear demonstration of the Coleman block test. Furthermore, residents can practice performing the test without a patient. The Coleman block test can then be demonstrated for teaching purposes.

Keywords: Foot Deformities, Medical Education, Physical Examination.

INTRODUCTION

Cavovarus feet are characterized by a high arch and varus position of the heel. Symptoms include recurrent sprains, lateral-sided foot pain, and metatarsalgia. Cavovarus feet may develop without a known cause or because of a neurological disorder such as the Charcot-Marie-Tooth disease. Cavus develops owing to relative plantar flexion of the first ray, which causes the heel to tip into varus with weight bearing because of the tripod effect. This varus heel deformity eventually can become more pronounced as stabilizing structures stretch and the peroneal tendons develop more pathological features. The heel varus can become fixed. The Coleman block test helps determine the flexibility of this heel deformity.[1]

The Coleman block test was described by Sherman Coleman, MD, and William Chestnut, MD in 1977.[2] The test is used on patients with a cavovarus foot deformity to determine whether the hindfoot varus deformity is fixed or flexible, and the result helps guide the type of orthotic device and operative treatment needed. If the hindfoot varus deformity is flexible, a dorsiflexion osteotomy of the first ray can be performed. If it is fixed, a lateral closing wedge osteotomy of the calcaneus is also required.[3] We devised a method to perform the Coleman block test for educational use in orthopaedic residency programs.

METHODS

During the Coleman block test, the foot is placed on a block high enough to avoid touching the ground when placing the plantar-flexed first metatarsal over the block's edge. The medial metatarsals are placed off the edge while the rest of the foot remains on the block. This way, the plantar-flexed first metatarsal cannot tilt the foot into varus. If the heel deformity corrects while weight bearing during this maneuver, the deformity is flexible. If the heel deformity does not correct, there is a fixed hindfoot deformity.

In the current study, a 2-cm wedge was created out of any firm material (we used rubber wrapped with coband). The wedge was 2-cm high, 9-cm long, and 5-cm wide. The wedge was placed beneath the first metatarsal of a volunteer (senior author, RAM) with a normal and flexible foot. The wedge was held using coband or tape wrapped about the foot (Figure 1).

RESULTS

When the participant stood, the wedge tended to tilt the heel into a more varus position as seen when viewed from behind (Figure 2). Figure 3 shows this wedge in position from a medial-side view. A large

amount of varus was not seen because of the ability of the metatarsal-cuneiform joint to dorsiflex in our participant's healthy foot. Also, our participant did not have a chronic heel deformity, and secondary structures such as the subtalar ligaments only allowed limited motion. Compared to the position in Figure 2, the position of the heel obtained during the Coleman block test (Figure 4) provided a successful demonstration. Notably, the heel returned to a position of slight valgus during the test, signifying a flexible deformity.

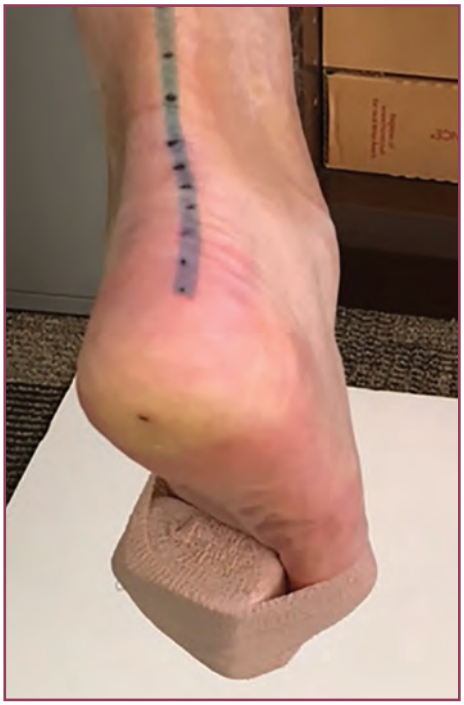

Figure 1. The wedge placed beneath the first metatarsal, simulating a cavus foot.

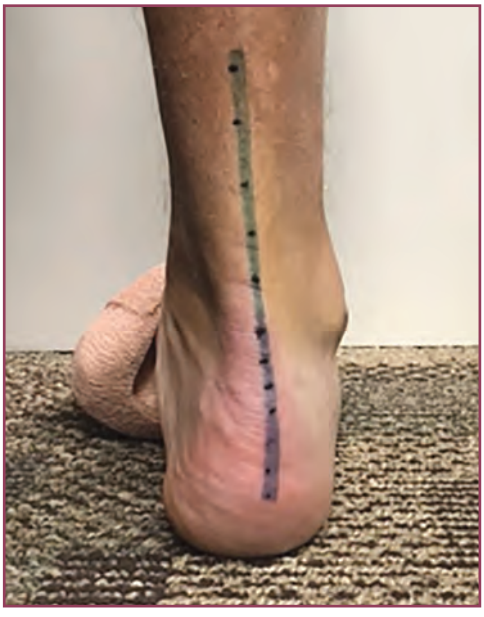

Figure 2. The position of the heel in slight varus while weight bearing with the lift in place.

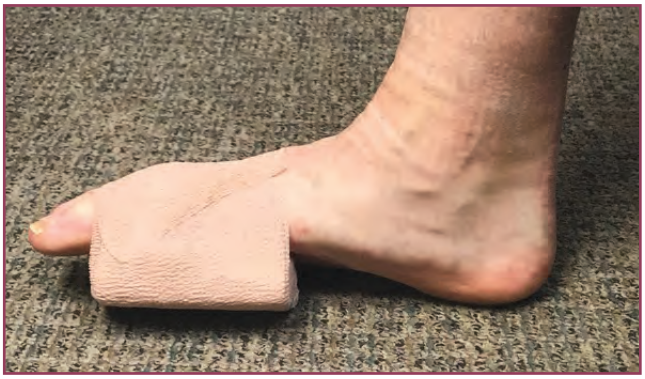

Figure 3. Medial view of the wedge in position.

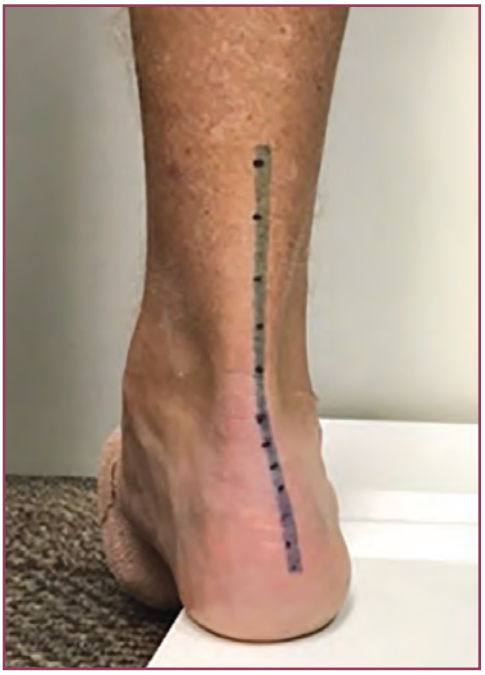

Figure 4. Restoration of normal heel valgus during the Coleman block test, consistent with a flexible deformity.

DISCUSSION

Performing and interpreting results of the Coleman block test can be difficult concepts to understand. Orthopaedic residents may not be exposed to many patients with cavovarus foot deformities; subsequently, residents may not see the test performed often during their training.

The commonly used Orthobullets website currently poses five questions pertaining to the Coleman block test.[4] Those questions have 3946 responses, of which only 2853 (72%) have been correct. The percentage of correct responses for each individual question ranges from 56% to 78%. Furthermore, questions about the Coleman block test are occasionally seen on the Orthopaedic In-Training Examination (OITE). In 2016, the OITE had two questions about the Coleman block test.

The Coleman block test is a necessary examination to learn during orthopaedic residency, yet it is performed infrequently and can be difficult to understand. The simulation method described in this paper allows orthopaedic residents to witness the Coleman block test without a patient, learn how to perform the test, and interpret subsequent results.

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Patterns in Bone Drilling Performance Before and After the 2017 Motors Skills Course of the Southwest Orthopaedic Trauma Association

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Funding This project was funded in part by the Scholarship in Education Allocations Committee (SEAC).

ABSTRACT

Background: Although experience within the operating room can help surgeons learn simple bone-drilling techniques, outside training may be better suited for complex procedures. We adapted a rotary handpiece to evaluate bone drilling skills of orthopaedic resident physicians during the 2017 motor skills course of the Southwest Orthopaedic Trauma Association (SWOTA).

Methods: A total of 25 postgraduate year-one orthopaedic residents from seven institutions were asked to perform a bicortical drilling task three times before and after attending a motor skills course. Kinetic and kinematic data were collected using force, acceleration, and visual sensors.

Results: A total of 16 parameters were measured. Variables statistically significant after the course were as follows: over-penetration (28.8-18.2 mm), skiving (22%-6%), preparation time (27.3-9.65 seconds), drilling time (8.28-9.35 seconds), palmar-dorsal vibration (1.76-2.05 m/s^2), maximum drilling force (58.56-84.30 N), and maximum revolution per minute (RPM; 917-944). The interdependence of these parameters taken separately for pre- and post-course performance are presented. Notable correlations include: over-penetration with force (0.65), palmar-dorsal toggle (0.65), vibration in palmar-dorsal (0.53), time (-0.41), and RPM (-0.36); time with both RPM (0.38) and palmar-dorsal toggle (-0.40); and force with both RPM (-0.41) and palmar-dorsal toggle (0.32).

Conclusions: The correlation data presented provide insight into patterns between measured parameters regarding where performance metrics are and are not coupled. Evidence for motor skill acquisition across both short- and long-time scales are elucidated.

Keywords: Resident Training, Surgical Skill, Skill Assessment

INTRODUCTION

The specialty of orthopaedic surgery demands a range of motor skills that require deliberate training. Historically, these skills were primarily acquired in the operating room (OR). Although this may be an effective method of training for treating simple fractures or low-risk injuries, more complicated operations or high-risk situations (eg, spinal procedures, potential for vascular or nerve injury, etc) should be simulated in the laboratory before performing the tasks in the OR. Orthopaedic surgery was one of the earliest surgical fields to teach surgical skills to residents outside of the OR.

In 1975, Lippert et al[1] offered a motor skills course at the University of Washington. Since then the modes for and interest in this type of training have continued to grow.[2,3] Meanwhile, an increasingly clear picture has been developed for patient safety[4] and costs associated with surgical complications.[5] It has been estimated that including residents in general surgery cases and subsequent time loss results in a national annual cost of $53 million.[6]

Simulated surgical procedures (or focused skills laboratory) have several clear advantages, including reduced stress to residents. Furthermore, a particular

aspect can be trained, which can result in more rapid acquisition of particular skills.[2,7-13] As of July 2013, the Patient Protection and Affordable Care Act prompted the American Board of Orthopaedic Surgeons (ABOS) and the Residency Review Committee (RRC) for Orthopaedic Surgery to mandate formal motor skills training outside of the OR.[14,15] Many orthopaedic procedures involve drilling holes in bone. The drilling of a "good" hole entails precise location and orientation while avoiding the use of excessive force, over-penetration, toggle, and skiving.[16-21] The objective of this study was to quantify the surgical performance of residents before and after a motor skills course.

METHOD

Hardware

Fundamentally, the hardware design of the current study aimed to facilitate quantification of all parameters related to the failure or success of drilling a "good" hole in the context of orthopaedic surgery. The device used is an improvement upon similar devices used in previous years (Figure 1).[16,17,21] With each iteration, the goal has been to maximally preserve (or improve upon)

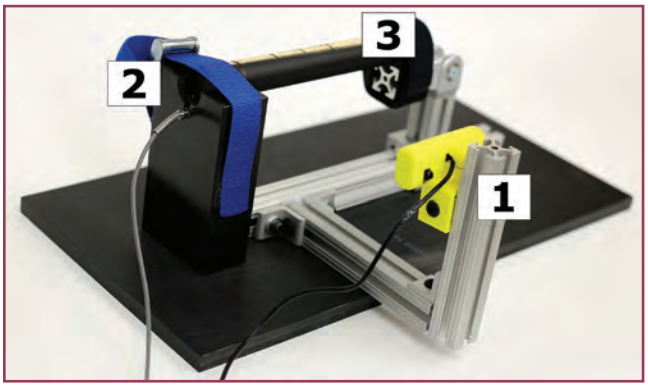


Figure 1. A custom fixture was built to hold the bone analog, support a small camera (1) used, in part, for measuring over-penetration, and a load cell (2) for measuring applied load. At one end of the fixture, the sample is supported by a hinge joint (3), and the button load cell (2) provides the support force at the other end. Actual force measurement required knowing where the drill was positioned along the length of the bone. This was controlled for during the experiment.

the utility compared to previous devices while reducing device cost, size, and complexity. The hardware consists of 1) a modified Stryker 4203 System 5-rotary Handpiece (Stryker Industries, Kalamazoo, MI) with dual-trigger and drilling attachments; 2) a synthetic bone fixture with integrated force sensor and camera; and 3) various electronic and computer components to read from sensors, analyze data, and allow visualization of results. Additionally, a thermal imaging camera was used to observe specimen heating during drilling (FLIR T640, FLIR Systems Inc, Wilsonville, NC).

Parameters measured included drill orientation and vibration, over-penetration, applied force, drill revolution per minute (RPM), skiving, and drill-bit temperature. Drill orientation (ie, roll, pitch, and yaw), vibration, and rotational speed were measured using a combination of a Bosch BNO055 9-DOF orientation sensor (Robert Bosch GmbH, Stuttgart, Germany) and an external, calibrated camera. The accelerometer and other hardware were assembled into the battery housing to provide constant external power supply. External power was used to ensure that drill performance did not change with variations in battery performance or from participant to participant. The synthetic bone fixture included a camera-mount that eliminated the need for re-registration and incorporated a load cell to measure the force applied during drilling (Figure 1). Drill speed was measured using a small magnet attached to the chuck along with a reed switch and associated electronics attached to the drill body (Figure 2).

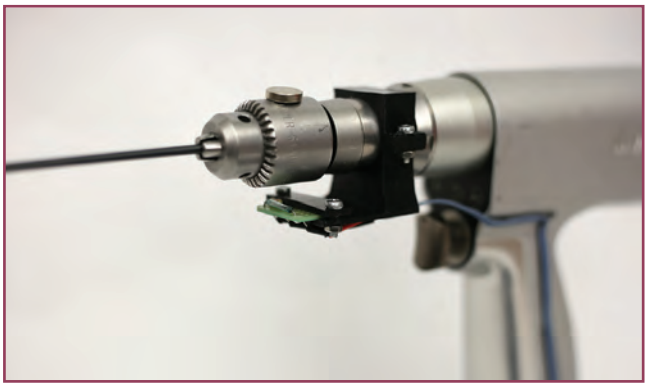


Figure 2. Drill speed was measured using a small magnet attached to the drill chuck. Adjacent to this, and supported by the drill body, a reed switch allowed measurement of chuck rotation. This signal was decoded by a computer algorithm.

Data from the kinematic sensors and camera were recorded using an Arduino Uno microcontroller and a desktop computer (Intel Core i7, 6700 3.4GHz processor, 8GB RAM). Force data were recorded using a CompactDAQ (National Instruments Corporation, Austin, TX) data acquisition system and a second desktop computer (dual core Intel, 2.4GHz processor, 32GB RAM). Sufficient performance required tuning and careful synchronization of these data streams. Among the technical solutions, a Python script was used to synchronously pull sensor data from the Arduino serial ports (one thread) while pulling frames (separate thread) from the camera at 52 frames per second. A manual control box was used to cue data recording on both machines. Figure 3 shows some representative parameters obtained.

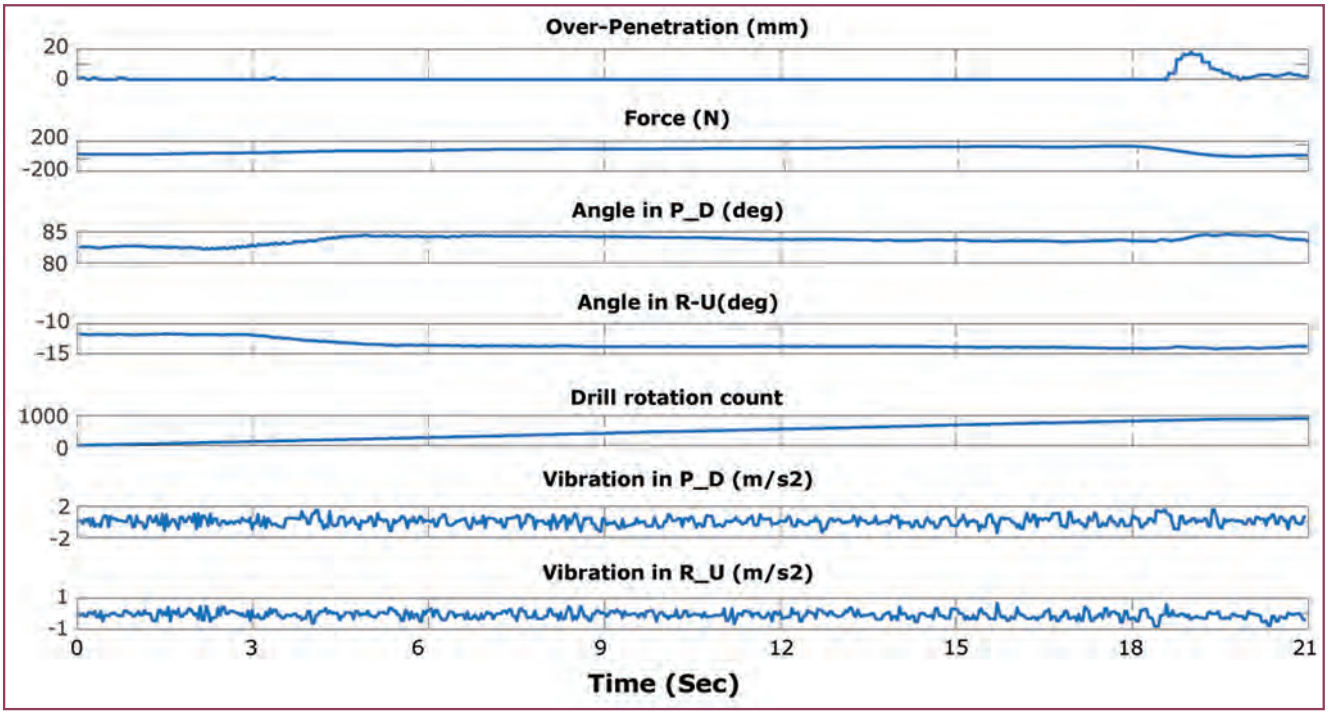


Figure 3. Representative data for some of the parameters measured. Over-penetration was measured using a camera (52 frames per second) along with accelerometer data (45 Hz). Here, over-penetration is calculated to be zero until at about 19 seconds, when it begins to spike to 20 mm. Force data were recorded using a load cell and CompactDAQ (National Instruments Corporation, Austin, TX) at 1.4 kHz. Here, the force is seen to steadily increase to 110.9 N, then drop shortly before the drill exits the sample. Similarly, five other parameters that describe drill orientation (both in the palmar-dorsal and radial-ulnar directions), drill revolution per minute (rotation count), and drill vibration are depicted (all captured at 45 Hz).

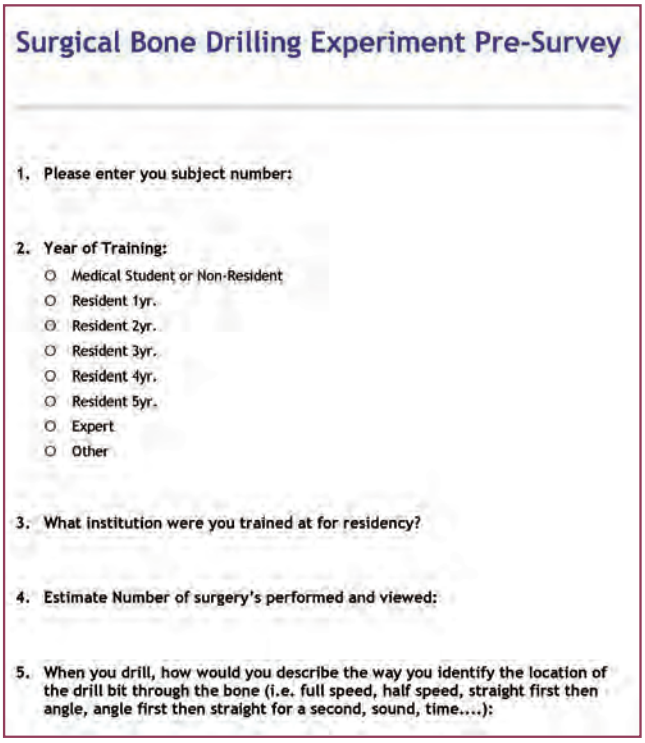
Participants

This study was approved by the Human Research Review Committee at The University of New Mexico Health Sciences Center (HRRC #15-087). Participants were recruited during the 2017 motor skills course held by SWOTA for postgraduate year-one orthopaedic residents in Albuquerque, NM. The event is an ABOS-approved surgical skills training course joined by 25 residents (9 women, 16 men) in orthopaedic residency programs from New Mexico, Arizona, Texas, and Nevada.

Task Design

Before the start of the course, participants completed a survey to quantify prior experience and other relevant factors (Figure 4). During the task, each participant was asked to drill a perpendicular hole through the entire cross-section of a 2.54-cm (1-in) aspen dowel, while taking into consideration any performance factors relevant to bicortical drilling in a clinical setting. This task was performed three times. A fourth hole was requested if a false start, measurement error, or similar factors affected data collection for any of the three performances.

After the task, participants were trained for 3 days in splinting and casting, external fixation, K-wire use, internal fixation basics, olecranon osteotomy, plating



Surgical Bone Drilling Experiment Pre-Survey

1. Please enter you subject number:

2. Year of Training:
   - O Medical Student or Non-Resident
   - O Resident 1yr.
   - O Resident 2yr.
   - O Resident 3yr.
   - O Resident 4yr.
   - O Resident 5yr.
   - O Expert
   - O Other

3. What institution were you trained at for residency?

4. Estimate Number of surgery's performed and viewed:

5. When you drill, how would you describe the way you identify the location of the drill bit through the bone (i.e. full speed, half speed, straight first then angle, angle first then straight for a second, sound, time....):

Figure 4. Survey provided to participants before the first test.

basics, distal femur locking plates, proximal tibia locking plates, incision, exposure, and soft-tissue handling (cadaver), compartment syndrome, distal radius repair, and fingertip repair. After 3 days of training, we asked each participant to repeat the task.

Data Capture and Analysis

Over-penetration was measured in real time by combining the orientation of the drill per the accelerometer with a Creative Live HD 720p camera (Creative Technology, Singapore, Australia) to view the underside of the drilling sample. During drilling, debris tends to fall in the area viewed by the camera for over-penetration. To ignore this noise source, eroding, dilating, and Gaussian filters were used to differentiate the drill bit from the debris. To maximize visual contrast, care was taken to color the drilling sample, background, and selection of drill bit. After each parameter was processed, the Matlab function corrplot was used to determine correlation coefficients (parameter interdependence). Pre- versus post-course performance differences were tested for statistical significance using Matlab's *anova1* function (single factor).

RESULTS

Information gathered from the survey, experimenter observations, and integrated data acquisition system is summarized in Table 1. Analysis of the data was made separately for pre- and post-course performances. Statistically significant changes included the following: increase in vibration in the palmar-dorsal (P-D) direction; increase in drill RPM; increase in drill force; drilling time ($P < 0.01$, pre-mean = 8.28, post-mean = 9.34); reduced frequency of skiving ($P < 0.01$, pre-mean = 22, post-mean = 6); and preparation time ($P = 0.01$, pre-mean = 27.3, post-mean = 9.7). Other notable yet not statistically significant changes (see Table 1 for *P* values) included reduction in over-penetration (28.8-18.2 mm), reduction in skiving (22%-6%), and reduction in preparation time (and total time consequently; 27.3-9.65 seconds).

The approach taken by each resident varied more than expected. Several trials (11 of 75 pre-course, 13 of 69 post-course) were not correctly recorded or were eliminated during the trial analysis owing to some unanticipated movement pattern, which resulted in

Table 1. Bone drilling performance averaged across 25 year-one orthopaedic residents from seven institutions

Variable	*Pre-course scores, average (SD)*	*Post-course scores, average (SD)*	*Pre- vs post-course scores (P value)*
Over-penetration, mm[a]	28.8 (54.8)	18.3 (18.7)	0.322
Toggle in P-D, deg[b]	3.94 (13)	1.40 (0.93)	0.499
Toggle in R-U, deg[b]	30.4 (97.5)	44.3 (118)	0.169
Vibration in P-D, m/s[2c]	1.76 (0.91)	2.05 (0.75)	0.001
Vibration in R-U, m/[s2]c	0.7 (0.41)	0.71 (0.48)	0.772
Skiving, %[d]	22 (42)	6 (24)	0.009
Hole angle[e]	1.7 (1.6)	1.4 (1.1)	0.222
RPM, cycles/min[f]	917 (77.2)	944 (72.1)	0.074
Drilling force, N[g]	58.6 (31.8)	84.3 (44.9)	0.004
Total time, s[h]	35.6 (39)	19 (7.97)	0.576
Preparation time, s[i]	27.3 (38.4)	9.65 (6.34)	0.012
Drilling time, s[j]	8.28 (7.04)	9.35 (4.56)	0.002
Pullout force, N[k]	0.94 (0.42)	0.89 (0.39)	0.905

P-D, palmar-dorsal; R-U, radial-ulnar; RPM, revolution per minute.
[a]Maximum distance the drill bit protrudes through the distal surface.
[b]Range of angles in the corresponding plane during drilling (entire hole).
[c]Mean of the values reported from the corresponding axis of the accelerometer (entire hole).
[d]If the subject was observed to skyve while beginning to drill, it was noted by the experimenter.
[e]Deviation from perpendicular, measured retrospectively using a custom goniometer fixture (*X-Z* plane).
[f]Maximum observed during the final four seconds before the drill reaches maximum depth.
[g]Maximum applied force during drilling.
[h]Measured from the time the experimenter provides the instruction to begin until the time they pull out the drill bit.
[i]Measured from the time the experimenter provides the instruction to begin until the drill begins to rotate.
[j]Total time minus preparation time.
[k]Specimens were mounted to a modified angle vise that allowed positioning the screws in line with the test actuator. A cyclically load was then applied using an MTS 858 Mini Bionix II (MTS Systems Corporation, Eden Prairie, MN) frame following a protocol described.[24]

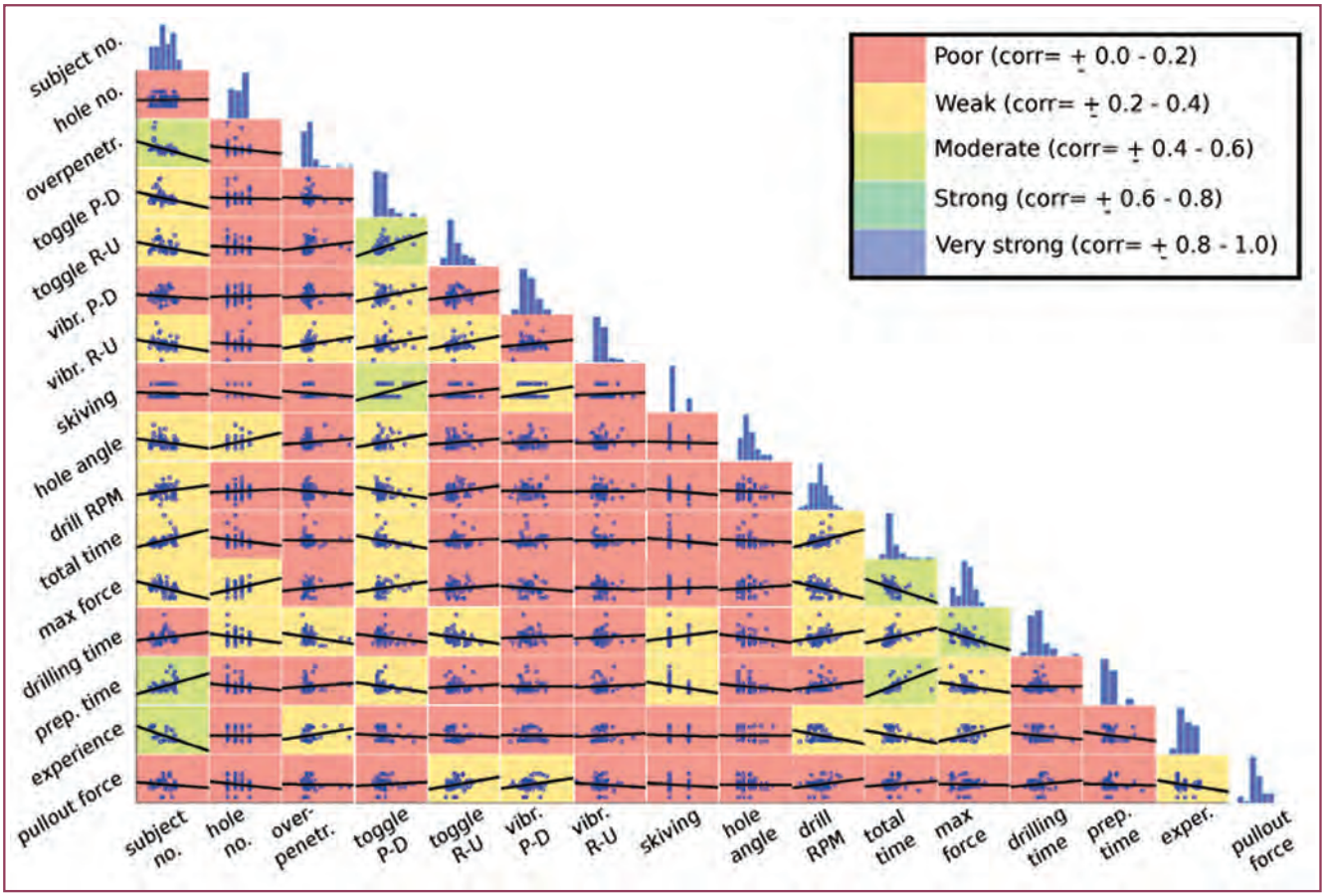


Figure 5. Correlation matrix for the performance parameters measured during the pre-course task. The matrix below shows the correlation between each pair of parameters. Also, scatter plots of the variables are shown after outlier rejection. The slope of the lines in each box is equal to the related correlation coefficient (slope of ±1 equivalent to perfect positive and negative correlation). Histograms of the variables are shown along the matrix diagonal.

a miscalculation of one or more of the 16 measured parameters. Beyond the variables themselves, much can be inferred from their correlations (Figures 5 and 6). First, the strength of correlations between post-course parameters was generally stronger. Notable correlations included over-penetration with drilling force (0.65), P-D toggle (0.65), P-D vibration (0.53), drilling time (-0.41), and drill RPM (-0.36); drilling time with both drill RPM (0.38) and P-D toggle (-0.40); and drilling force with both drill RPM (-0.41) and P-D toggle (0.32).

Effect of reported *Experience Level* on performance was not strongly present in the data. However, this was assessed as a self-reported parameter obtained from the survey ("estimate number of surgeries performed and viewed"); responses range from 40 to 200. Interestingly, none of the residents distinguished between how many procedures viewed versus performed. This may suggests that residents considered those two experiences as equivalent, though it seems clear they would not be from a pedagogical standpoint. The wide range in responses likely reflected various teaching styles between orthopaedic residency programs. Similarly, some non-trivial correlations were observed over *Subject Number.* This ordinal effect is almost certainly coupled to the fact that participants were ordered in groups based on their home institution owing to scheduling convenience.

The survey asked residents to explain their tactics when drilling. Approximately three-quarters of the responses mentioned using full RPM for at least portion of the time and "feeling" for the distal cortex. About half of the responses mentioned listening for a change in pitch associated when reaching the distal cortex. Around a quarter of the responses mentioned beginning normal to the proximal cortex and then acquiring the desired hold angle as needed, changing speed as a function of depth, maintaining target angle (not toggling), and applying less pressure at the distal cortex. Three residents stated that they would "tap" the drill against the distal cortex when they determined to reach it. One resident said that they generally used a slower feed rate throughout the task.

DISCUSSION

In the current study, we quantified the drill performance of residents before and after a motor skills course with use of a custom-made rotary handpiece. Performance parameters with statistically significant changes

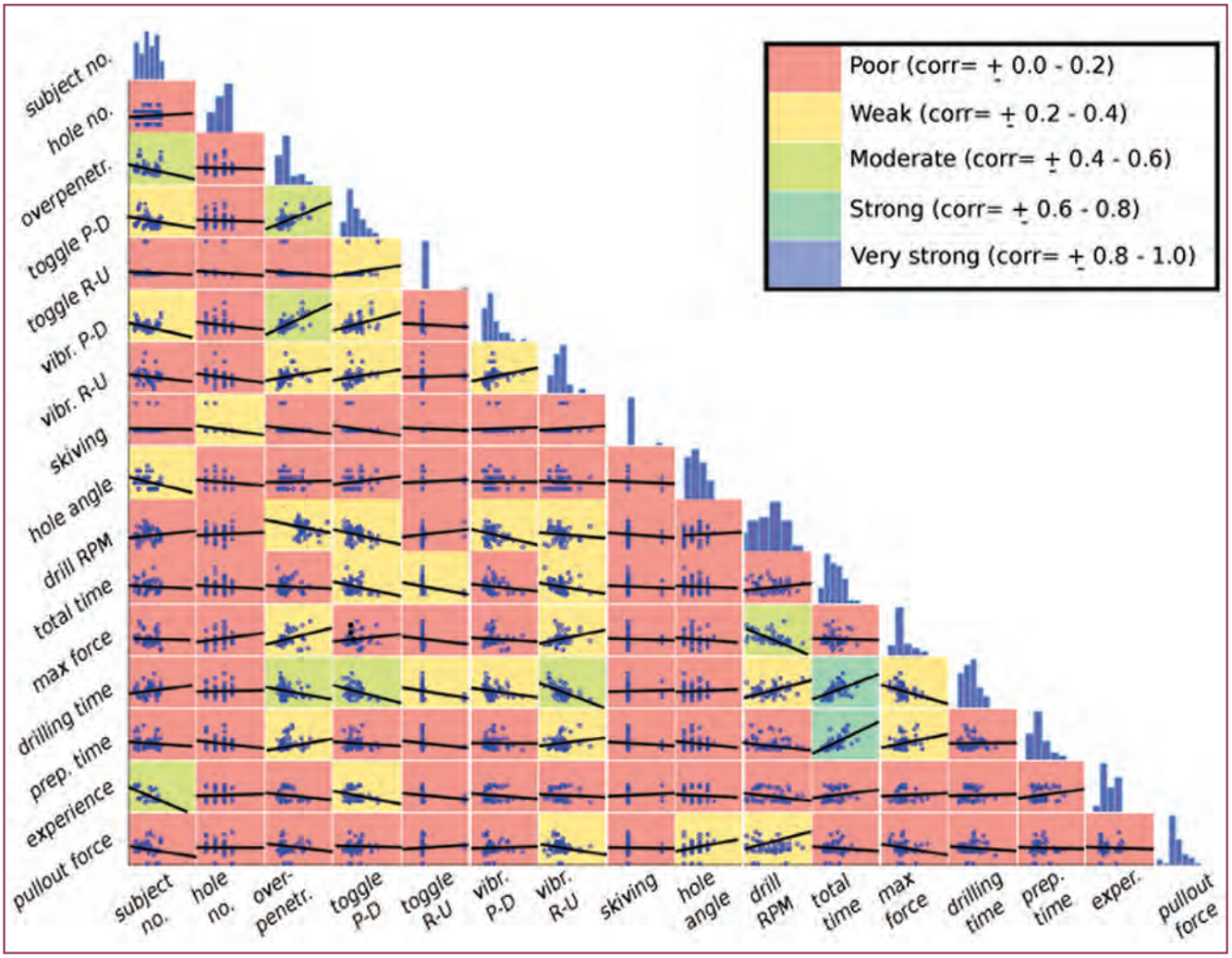


Figure 6. Correlation matrix for the performance parameters measured during the post-course task. The matrix below shows the correlation between each pair of parameters. Also, scatter plots of the variables are shown after outlier rejection. The slope of the lines in each box is equal to the related correlation coefficient (slope of ±1 equivalent to perfect positive and negative correlation). Histograms of the variables are shown along the matrix diagonal.

included drill vibration in the P-D direction, drill RPM, drill force, drilling time, skiving frequency, and preparation time. Because of the intensive r-day motor skills course, which included both didactic and hands-on components, it is no surprise to see evidence of performance improvement in the data. High variability is evident for most of the measured parameters both within and between participants.

Using much larger sample sizes, additional patterns might be observed with statistical significance. A weak trend with associated performance and *Hole Number* suggest that a more careful evaluation of this factor may reveal learning and adaptation on short time scales. The variability observed in the self-reported responses regarding drilling strategy indicates that the residents at SWOTA had different cues and tactics in mind. The role of tactile and auditory feedback may also merit further investigation.

Many inferences can be made regarding the correlations found. From a simple mechanics standpoint, these relationships can be predicted (eg, drilling force with drill vibration and RPM). Similarly, aspects of human motor control (eg, delay associated with proprioceptive feedback) are aligned with correlations between drilling time (with associated force), over-penetration distance, and drill force and toggle. Hypotheses explaining why some changes were observed might be informed by correlations in the data. For instance, an increase in P-D vibration was noted, which may initially seem counterintuitive. However, this parameter is negatively correlated with drilling time in both pre- and post-course trials. The correlations found should be further explored to determine situations in which parameters are fundamentally linked by mechanics, human motor control, and level of training.

The noted correlations (eg, over-penetration with drilling force P-D toggle, drilling time, and drill RPM) may help guide training protocols for orthopaedic residency programs. In future work, we hope to explore the difference in performance that correlates to the residency program. These differences may elucidate critical pedagogical factors. We also hope to decouple the roles of practice and quality of initial instruction in the eventual skills obtained by orthopaedic surgeons.

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Pelvic Ring Emergency Stabilization System (PRESS)

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Conflict of Interest The authors have no conflicts to declare. This technology was protected by a US provisional patent application during prototype development (No. 62/432386). A full patent application has been submitted to the US Patent and Trademark Office (2016-042-04US) filed December 9, 2016.

Funding This study was supported in part by the National Center for Research Resources and the National Center for Advancing Translational Sciences of the National Institutes of Health through grant number UL1TR001449, the University of New Mexico Clinical and Translational Science Center. This study was also supported by The University of New Mexico School of Engineering through an unrestricted grant from the Dean's office.

ABSTRACT

Pelvic ring fractures can be lethal owing to the potential for hemodynamic instability or arterial hemorrhage when the pelvic volume is increased. Pelvic binders are the standard of care used to provide circumferential compression to the pelvis, reducing the volume and increasing the intra-pelvic pressure. While commercially available options have been shown to provide adequate stability to the unstable pelvis, the circumferential nature of the binders limits access to the abdomen and groin regions, where accessibility is often necessary during the course of emergency treatment. We introduce a new technology known as the Pelvic Ring Emergency Stabilization System (PRESS). The PRESS device satisfies all required characteristics of a pelvic binding system in a configuration that does not obstruct abdominal or groin access to the patient.

Keywords: Pelvis, Medical Device Design, Closed Fractures, Bone Fractures

INTRODUCTION

Pelvic ring fracture is a disruption of the bony structure of the pelvis in at least two locations, (both anteriorly and posteriorly), causing a separation of the bones that form the pelvic ring (Figure 1). This fracture can occur due to high-energy trauma such as motor vehicle accidents or fall from a great height and represents 2% to 8% of all skeletal injuries.[1] While the incidence of pelvic ring fracture is low, hemodynamic instability or arterial hemorrhage from this fracture type results in a 40% to 60% mortality rate.[2] In emergency transport, the pelvis must be stabilized to prevent death before definitive treatment can be performed at a primary surgical facility. This is especially impactful in a state like New Mexico, where the only level 1 trauma center is located in Albuquerque and emergency transport from rural areas may occur frequently.

Historically, a pelvic binder has been the ideal choice for initial stabilization of pelvic ring injuries and the

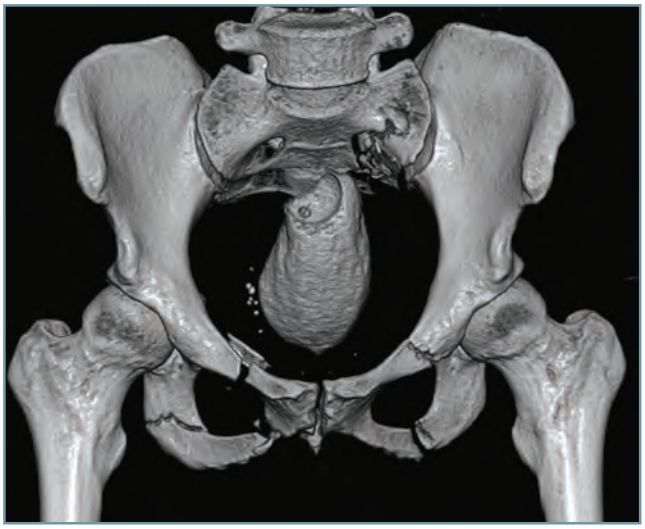
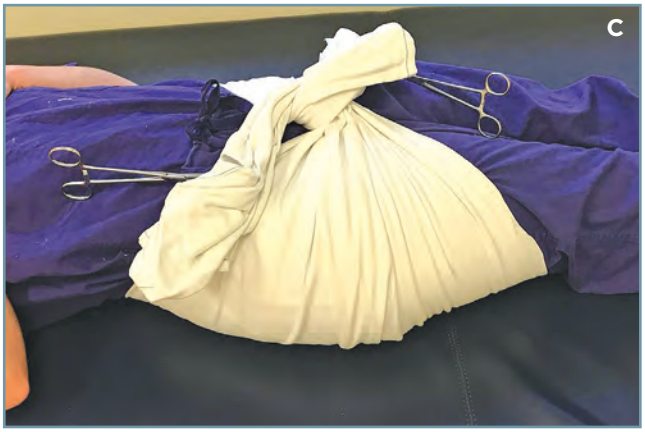


Figure 1. Pelvic ring fracture indicated by a fracture or tissue disruption in two or more areas. This image shows how the opening of the pelvis can increase volume, allowing for hemodynamic instability. Reprinted with permission from CTisus and image courtesy of Elliot K. Fishman MD and www.ctisus.com.

Figure 2. A) The T-POD (Teleflex, Wayne, PA) is a circumferential pelvic binder that uses a pulley system to bring the two ends of the device toward each other, across the abdomen. Depending on placement, there is limited groin access between the pulley cables. Reprinted with permission from Teleflex. B) The SAM Pelvic Sling is a force-controlled circumferential pelvic belt (SAM Medical, Wilsonville, OR). Notably, the buckle lies directly over the groin but allows for lower abdomen access. Reprinted with permission from SAM Medical. C) Bed sheets have long been used for temporary pelvic stabilization. This method of circumferential compression allows for abdominal access but no groin access. Photograph curtesy of Tony Pedri, MD, and Brianna Patti, MD.

management of exsanguinating pelvic trauma. The binder should be placed over the greater trochanters of the femurs, which provides the best mechanical stability for the pelvic ring.[3] This is a very effective, simple procedure to limit the motion of the fracture by applying a large compressive force to the pelvic ring to reduce the volume of the pelvis and reduce pain during transport or pre-surgical care. Though the pelvic binder cannot control arterial hemorrhage directly, it helps in stabilizing and compressing the pelvis, thus reducing hemodynamic instability by increasing intra-pelvic pressure.[4] While patients undergo emergency treatment, the binder should allow easy access to the groin and the abdominal area without removal or reposition of the device. Removal of this device, even temporarily, may risk arterial hemorrhage into the enlarged pelvic region.

In the present market, several types of non-invasive binders are available (Figures 2A through 2C). The most commonly used pelvic binders include the T-POD (Teleflex, Wayne, PA; Figure 2A) and SAM Pelvic Sling (SAM Medical, Wilsonville, OR; Figure 2B). These have been shown to provide sufficient reduction in partially stable and unstable pelvic fractures with little adverse reaction.[5] Often, bed sheets are used as temporary circumferential stabilization devices but have been



associated with a higher incidence of lethal hemorrhage than the commercially available options.[6] Unfortunately, most of the non-invasive, mobile binders on the market do not allow for abdominal or groin access. Because of the increased demand for surgical access in the current binders market, we propose the development of a model for a totally exposed abdominal and groin region, which may potentially provide less complexity in emergency intervention.

An ideal pelvic binder should satisfy the following characteristics: 1) easy to use and require limited training for paramedic, pre-hospital area, and emergency department personnel; 2) allow for full abdominal and groin access during use with procedures such as laparotomy and angioembolization; 3) stabilize the pelvis for a period of time that may extend beyond 24 hours and must maintain stabilization during patient movement; 4) allow for two-person deployment, with an option for single-person deployment; 5) be radiolucent for radiograph and computed tomography (CT) scans; 6) have an evenly distributed load area to minimize pressure sores[7]; 7) be adjustable to various shapes and sizes; and 8) be low cost and disposable or high cost and sterilizable. We introduce the Pelvic Ring Emergency Stabilization System (PRESS), a pelvic binder that improves the efficiency of application and ease for pre-surgical/emergency treatment access.

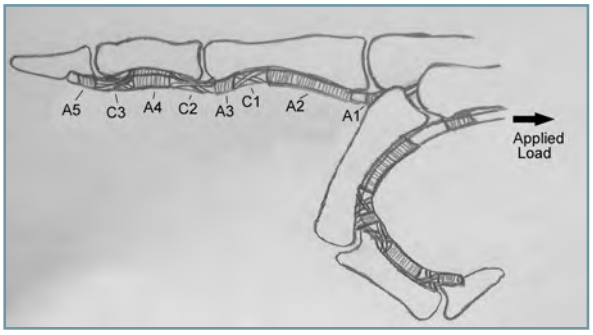


Figure 3. Representative image of the tendon-and-pulley system of the hand. Annular and cruciate pulleys in the finger are noted as A-1 through A-5 and C-1 through C-3, respectively. The tendon is pulled by the muscle along the trajectory of the arrow. A bending motion occurs at each joint. This mechanical system was used as the model for the proposed device.

DESIGN

The device is bioinspired by the movement of the fingers in the hand (Figure 3). As muscles contract, they apply tensile load to tendons that extend along the fingers. These tendons pass under flat pulleys that

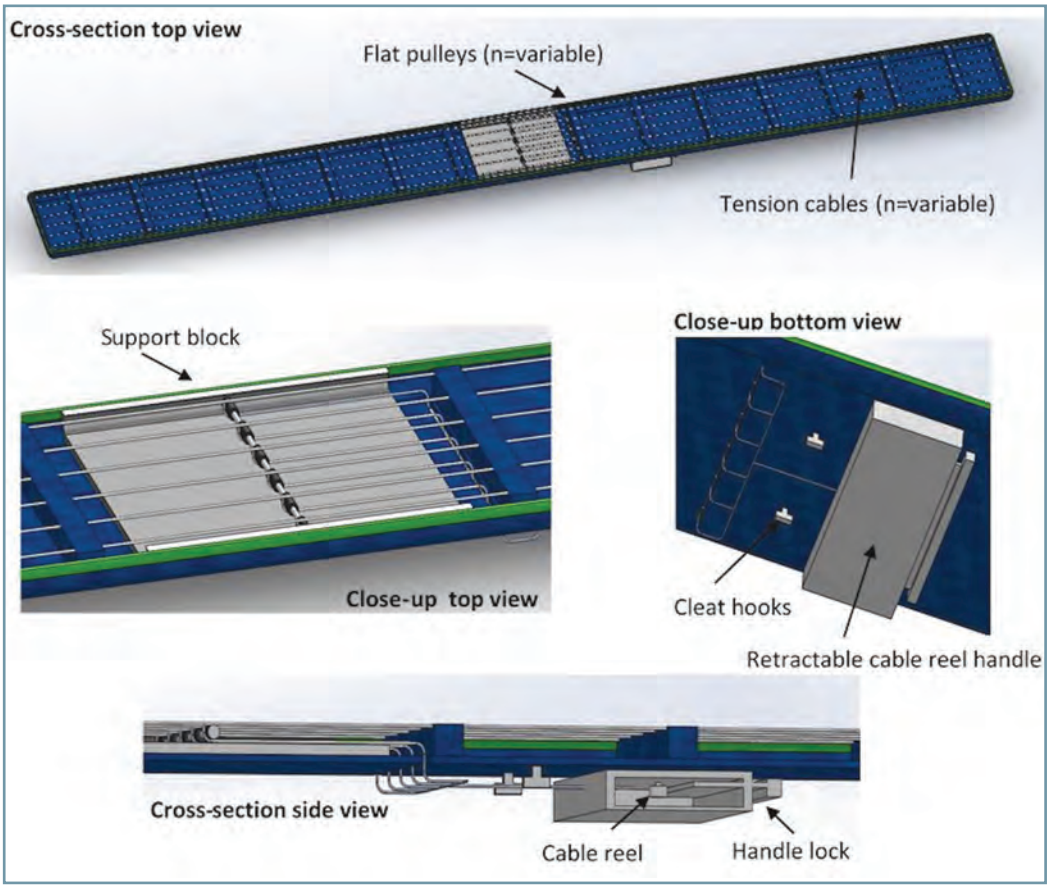


Figure 4. Graphical description of the device design using cross-sectional views to show interior details. The top-views show the flat pulleys, tension cables, and support block. The bottom view shows the cleat hooks and retractable cable reel handle. The side view shows a cross section of the cable handle detailing the handle lock mechanism.

produce a bending motion at each joint. This simple, mechanical system allows for high-strength pinch and grip actions. We used this same mechanical system to meet the user requirements one through eight, outlined above.

The top-view in Figure 4 shows the fully extended device with a cross-sectional display showing the interior of the technology. Tension cables extend along the length of the PRESS system, stabilized by flat pulleys spaced evenly along the length of the system, anchored at each end. The number and spacing of the tension cables and flat pulleys are variable based on the size and expected compression strength of the system. The cables converge at the center and flow through a support block as seen in the close-up top view. All cables exit the lower end of the device and merge into a single cable system as shown in the close-up bottom view. The merged cables proceed into the retractable cable reel of the handle as shown in the cross-section side view (Figure 4). The cleat hooks serve to temporarily support the cable when the device is deployed. The handle lock provides the ability to tension the cable when deploying the device and allows for retracting the excess cable when released.

The fabric surface of the PRESS is a multi-ply device made from flexible, biocompatible materials. The internal surface of the PRESS (adjacent to the body) includes a soft, comfortable, breathable liner with optional extended ribs adapted to reduce the potential for developing pressure ulcers. This surface transitions from a breathable liner to the female side of a hook-and-loop system toward the ends of the device, longitudinally. The internal hook-and-loop surface is used for connection to an optional attachment that serves as a temporary anterior support made from the male side of a hook-and-loop system that can be used when deploying the device. The external surface of the PRESS is made from a hook-and-loop system (female), but transitions to the male side of a hook-and-loop system toward the ends, longitudinally. When the PRESS is deployed, the ends are folded down against the side to adjust for length; as such, the hook-and-loop system maintains the adjusted size.

The device is deployed using the following procedure (Figure 5). First, the PRESS is laid flat under the body; centered at the support block, in line with the greater trochanters. Second, the device is lifted around the body; ends are folded down to adjust for patient size. A temporary anterior support strap connecting the two ends of the anterior portions of the PRESS (using a hook-and-loop attachment) can be used to hold the device around the body during tensioning and would be removed when the device is deployed. Third, the retractable handle is locked and pulled until the device is completely secured around the body. Finally, the cable is wrapped around the cleat hooks to temporarily maintain the compression applied by the tensioned cable; the handle retracts and secures to the device.

CONCLUSION

The technology presented in this manuscript is recommended as an alternative to commercially available pelvic binders. We propose that the PRESS device would perform similarly to the commercially available options regarding maintenance of fracture stability and exsanguinating pelvic trauma. Furthermore, the device has the following additional features: 1) allows for complete access to the abdominal and groin regions; 2) can be designed with one or two handles allowing for single or two-person deployment; 3) requires limited training for use; 4) is made from radiolucent materials for radiograph and CT scans;

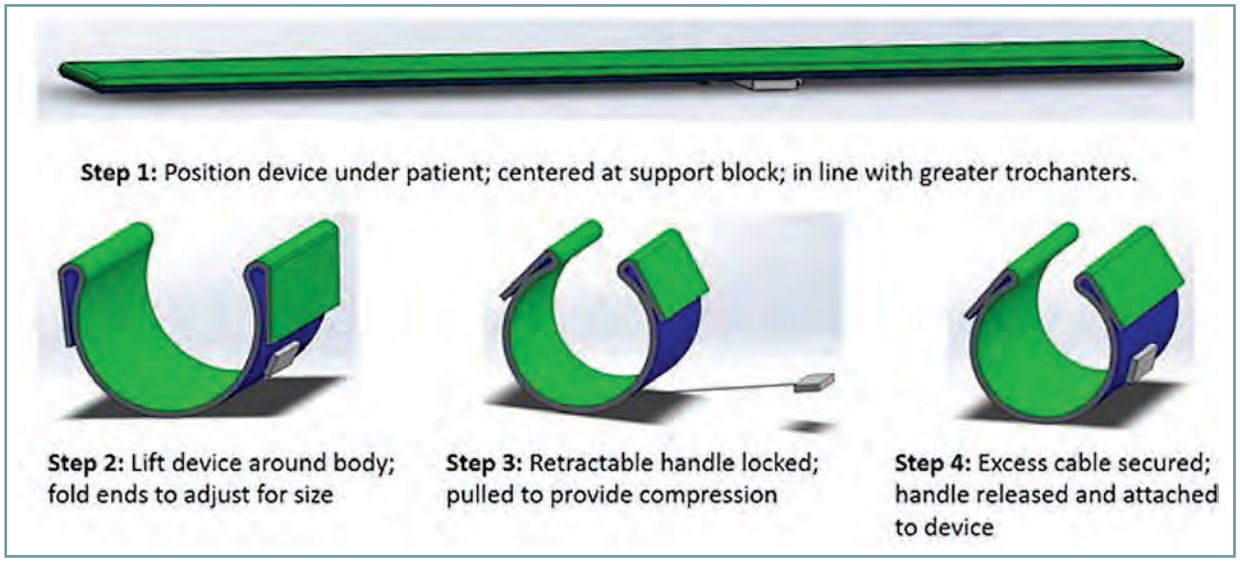


Figure 5. Detailed steps 1 through 4 for device deployment, indicating the ease of use and limited training needed. Notably, step 2 shows where the temporary anterior support strap may be used to hold the ends around the body while the device is being deployed (step 3). Once deployed, the support strap may be removed.

5) has a breathable, soft, load area, optimized to provide distributed coverage to the greater trochanters to limit pressure sores; and 6) is low cost and disposable. Future testing of the prototype will be used to quantitatively evaluate the features described above.

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Comparison of Techniques Used for Application of Hip Spica Cast to Treat Femoral Shaft Fractures in Children: Long-Term Follow-Up

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

ABSTRACT

After treatment using hip spica casts, femoral shaft fractures in children can appear well reduced in the operating room. However, the resulting bone length may quickly angulate or shorten. We describe a technique that places a well-molded hip spica cast to help decrease the risk of revision procedures and malunited fractures. We compared results of patients aged 1 to 6 years treated by one pediatric orthopaedic surgeon using the casting technique described (Group A, n = 25) to those treated by other orthopaedic surgeons who did not use the technique (Group B, n = 46). Although not statistically significant, results indicated less shortening and varus angulation in the patients who underwent the described casting technique. Findings of the current study may help guide and recommend this technique in treating children with femoral shaft fractures.

Keywords: Hip Fracture, Children, Plaster Casts, Femur

INTRODUCTION

Children between the ages of 6 months to 5 years with femoral shaft fractures typically undergo surgical treatment with hip spica casts.[1] Complications of hip spica casts can include skin breakdown, malalignment of the fracture, excessive shortening or overgrowth at the fracture site resulting in limb-length discrepancy, and compartment syndrome. Femoral shaft fractures treated in a cast tend toward apex lateral deformity and can shorten excessively.

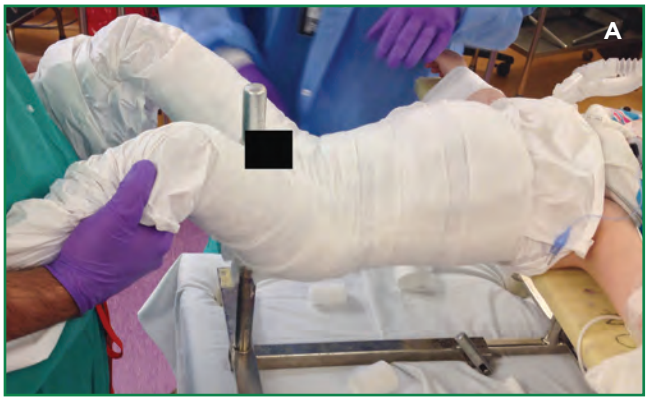
Few studies have specifically examined techniques using one-and-one-half hip spica cast application for treating femoral fractures. In 1995, Fraser[2] described a hammock suspension technique used in children aged under 2 years with femur fractures. Two years later, Czertak and Hennrikus[3] described use of a below-knee cast to pull traction on the femoral fracture owing to muscle pull while the remainder of the hip spica cast was applied. They emphasized using a valgus mold at the fracture side and the importance of padding the popliteal fossa. In 2006, Mubarak et al[4] reported an increased risk of compartment syndrome if a below-knee cast was applied first and then used for traction on the femoral fracture. Gill et al[5] later described an inexpensive hip spica table by use of a "box-and-bar" technique.

However, no study has reported on the technique currently proposed for treating displaced femoral shaft fractures in children. In the current study, we examined short- and long-term results of using one-and-one-half hip spica casts as described by the senior author (EAS). We hypothesized that this technique may result in fewer problems (ie, with bone shortening, malangulation, and limb-length discrepancy) compared to those of techniques used by other orthopaedic surgeons.

TECHNIQUE

The described technique involving a one-and-one-half hip spica cast uses a padded fracture table (Figure 1). The patient's hips and knees are held in gentle flexion, and with traction applied to the fractured femur (Figure 2A). The surgeon applies the thigh piece of the cast first (Figure 2B). Three to four layers of cast padding are evenly applied to the thigh (Figure 3A). After this, the fiberglass is rolled under slight tension around the thigh

Figure 1. Padded hip spica table.



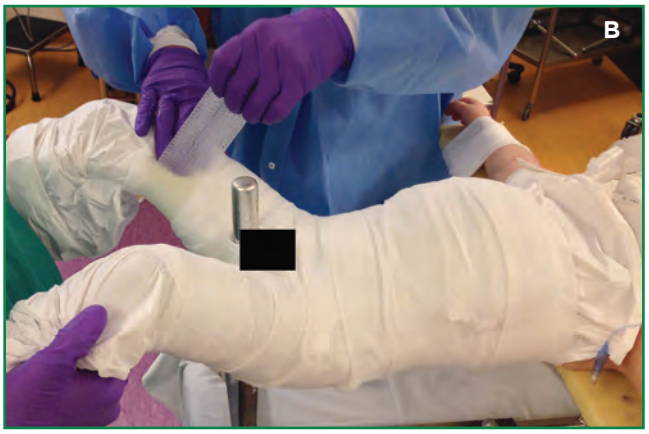
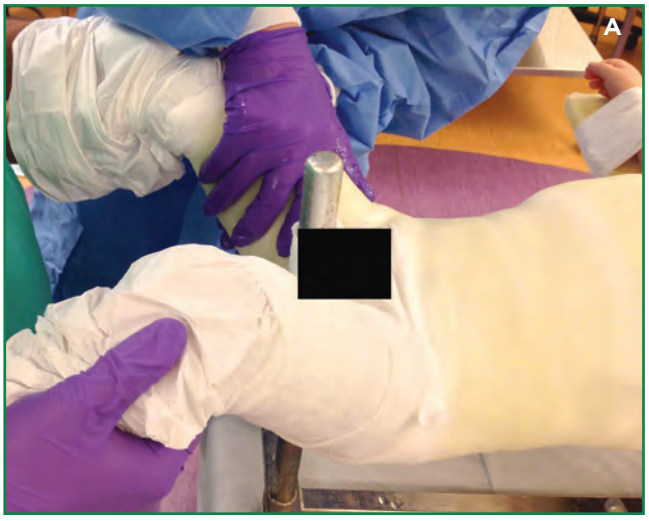


Figure 2. Surgeon technique for applying a one-and-one-half hip spica cast. A) Assistant holds hips and knees in a slightly flexed position with traction applied to the fractured femur. Cast padding has been evenly applied. B) Surgeon rolls fiberglass under slight tension around the thigh.

and molded into a quadrilateral shape to minimize risk of bone malangulation (Figure 3B). The quadrilateral shape also provides improved control of the diaphyseal bone in its cylindrical soft-tissue envelope. When the quadrilateral thigh piece has hardened, the remainder of the hip spica cast is applied to the lower extremities, including the ipsilateral foot (Figures 4A through 4C).



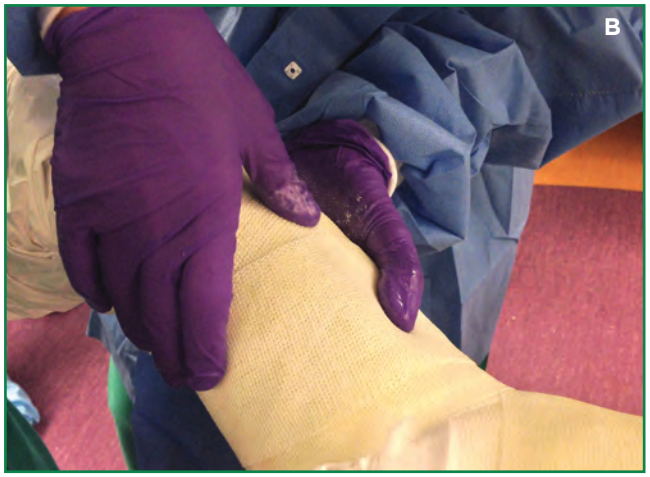
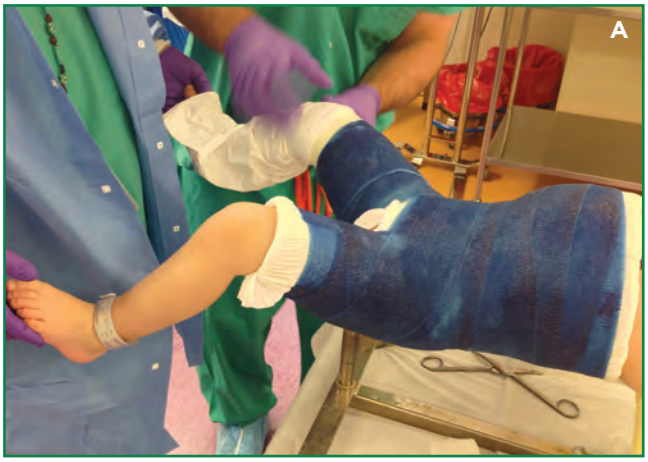


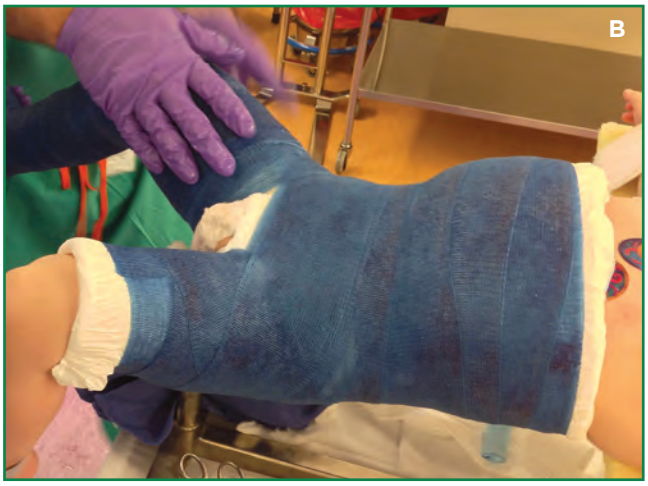
Figure 3. Quadrilateral mold applied to the thigh piece. A) Cast padding layers are evenly applied to the thigh. B) The fiberglass is molded into a quadrilateral shape to minimize angulation.

Patient Recruitment

After receiving approval from our Human Research Review Committee (HRRC #12-365), we reviewed medical records using current procedural terminology codes relating to treatment of femoral shaft fractures from January 1, 2004 to June 1, 2011 (n = 377).

Inclusion criteria were as follows: radiographs available in our facility's digital radiograph database, patients aged 1 to 6 years at time of injury, treatment using a hip spica cast, diaphyseal and displaced femoral fractures, and no medical comorbidities that would affect bone density. Exclusion criteria were non-displaced fractures and treatment with operative fixation. After applying inclusion and exclusion criteria, a total of 71 patients were eligible for analysis. Of the 71 patients, twenty-seven completed a joint survey (obtained over the phone or returned in the mail).





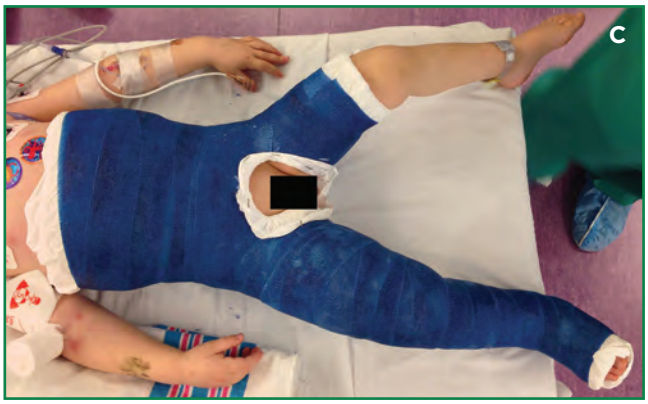


Figure 4. Application of the rest of the one-and-one-half hip spica cast. A) The cast is applied to the ipsilateral foot. B) Finished applying the cast to the ipsilateral foot. C) Final cast in place.

Evaluation

We measured bone shortening and angulation seen on radiographs obtained immediately after the first cast was applied and obtained at final application of the cast. The results of the joint surveys were evaluated for limb-length discrepancies and angulation in the coronal plane only. We compared results of patients treated by the senior author (EAS) to those of patients treated by other surgeons at three different intervals: in the initial cast, at the clinic visit during which the cast was removed (using radiograph findings), and long-term follow-up (using the joint survey).

Group A comprised patients casted using our proposed technique, whereas patients in Group B were casted using other techniques by orthopaedic surgeons in our practice. Measurements included angulation, shortening, and limb-length discrepancy. Patient demographics such as mechanism of injury, associated injuries, city of residence, body mass index, age, and gender were recorded (Table 1). We looked for complications such as necessity of return to the operating room, skin breakdown, infection, altered rotation of the limb, nerve palsy, compartment syndrome, and contracture, or revision surgical treatment. Analysis was done through basic percentages of variables including demographic data, measured bone angulation, and measured bone shortening at the time of initial casting, final casting and long-term follow-up.

Table 1. Demographics as percentages of the 71 patients included in the study[a]

Variable	*No. patients (%)*
Mechanism of Injury	--
Fall	62 (87.3)
Pedestrian vs auto	6 (8.5)
Motor-vehicle collision	2 (2.8)
All-terrain vehicle collision	1 (1.4)
Associated injuries[b]	--
None	66 (93)
Skull fracture	2 (2.8)
Scalp laceration	2 (2.8)
Ramus fracture	1 (1.4)
Clavicle fracture	1 (1.4)
Residence	--
Urban	55
Rural	45
Mean age at time of injury, y	2
Sex	--
Male	63
Female	37
Fracture pattern	--
Oblique	82
Transverse	17
Comminuted	1

--, not applicable.
[a]These values show percentages of patients except in the mean age at time of injury (shows years).
[b]One patient had a ramus fracture and scalp laceration.

Table 2. Results of initial casting, final casting, and long-term follow-up of patients using described casting technique (Group A) and other techniques (Group B)[a]

	Initial casting		*Final casting*		*Long-term follow-up*	
Measured variables	*Group A (n = 25)*	*Group B (n = 46)*	*Group A (n = 25)*	*Group B (n = 46)*	*Group A (n = 9)*	*Group B (n = 18)*
Mean shortening, mm	6	10	12	18	--	--
Mean varus angle,°	1	0	5	8	2	1
Mean anterior angle,°	10	2	15	11	--	--
> 2 cm shortening, %[b]	0	2.2	1.7	3.5	--	--
> 10° varus/valgus[b]	8	11	16	35	--	--
> 10° anterior/posterior[b]	50	13	62	53	--	--
Mean limb-length discrepancy, mm	--	--	--	--	6	9

--, not applicable.
[a]In total, the initial and final casts were applied to 71 patients (Group A, 25 patients; Group B, 46 patients). Long-term follow-up was reported on 27 patients (Group A, 9 patients; Group B, 18 patients).
[b]Corresponding values reflect percentages of patients in each group with the noted angulation.

RESULTS

Average follow-up was 40 months (range, 16 weeks-6 years) Table 2 shows results of the different casting technique used between groups. In Group A, less instances of acute bone shortening, long-term limb-length discrepancy, and varus malangulation were noted. There was slightly more apex anterior malangulation in Group A, however. Of the patients in Group B who completed the joint survey, a total of 11% had limb-length discrepancy of greater than 2 cm at long-term follow-up. This level of discrepancy was not noted in Group A.

At long-term follow-up, one-third of patients in each group had varus or valgus malangulation of more than 5°. No patient in either group developed compartment syndrome or underwent revision procedures. One patient in each group returned to the operating room for repeat casting (Table 2).

DISCUSSION

The techniques and results of using hip spica casting for treating femoral shaft fractures in children can vary. In the current study, we aimed to describe a new technique created by the senior author (EAS) and determine whether the proposed technique would result in fewer complications. Malangulation with apex anterior was slightly higher in Group A, which is acceptable because this deformity is in the plane of motion of the knee joint. Differences between the groups in bone angulation and shortening were small. Complication rates were low and almost equal between groups; again, it should be noted that we studied a small number of patients.

Studies have focused on internal fixation for treating femoral fractures in preschool children. Ramo et al[6] found promising outcomes with flexible intramedullary nail fixation for treating femoral fractures in children aged 4 and 5 years, with a low complication rate. The study also detailed some problems that can occur with closed treatment of femoral fractures in this age group, including bone malunion and shortening. We believe that these problems can be avoided with placement of a well-molded hip spica cast as outlined in current study. Jauquier et al[7] concluded that immediate hip spica placement for treating femoral fractures in preschool-aged children was as effective and more efficient than flexible nailing. They noted that the technique used when placing a cast may be related to how well the fracture maintains alignment.

Our study was limited in analysis regarding long-term follow-up because many patients did not complete the joint survey. Furthermore, many phone numbers were out of service or the calls were unanswered, and many patients lived in remote areas without available transportation. One parent did not bring a participant to avoid subjecting the child to more physician visits or tests. Further research would include attempting to recontact the patients who did not respond and collecting data over several more years to increase statistical power. Although we had an insufficient sample size for a power analysis, we noted a trend toward less bone shortening and apex varus malangulation at both the short- and long-term follow-ups in the group casted by the described technique (Group A).

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Subperiosteal Abscess of the Distal Radius in a 13-Year-Old Boy: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Children and adolescents have the tendency to develop osteomyelitis in metaphyseal sinusoids because turbulent blood flow increases the probability of bacterial growth. Osteomyelitis in children is frequently misdiagnosed owing to lack of symptoms and specific findings from laboratory tests. Without rapid antibiotic treatment of osteomyelitis, complications such as subperiosteal abscesses may occur. We describe a 13-year-old boy who underwent irrigation and debridement to treat a subperiosteal abscess of the right distal radius and ulna, caused by acute osteomyelitis. After debridement, the patient was placed on a continuous 6-week course of nafcillin infusion through a peripherally inserted central catheter (PICC). The patient's condition notably improved in the 2-, 6-, 10-, and 18-week follow-ups. Use of PICC to deliver antibiotics after irrigation and debridement may be clinically effective within certain pediatric populations.

Keywords: Adolescent, Osteomyelitis, Abscess, Wrist, Catheters

INTRODUCTION

A subperiosteal abscess, defined as a collection of pus under the periosteum, forms after an infection breaks through the metaphyseal cortex.[1] Subperiosteal abscesses may form as complications of osteomyelitis caused by inflammation and infection of the bone marrow.[2] The prevalence of acute osteomyelitis (<14 days in duration) amongst children and adolescents is 8 to 13 per 10,000, with boys affected more than girls (1.9:1).[3] Acute osteomyelitis most commonly occurs from hematogenous spread of *Staphylococcus aureus*, but studies have also reported extension from soft-tissue infections or direct inoculation of bacteria with open fractures.[4]

Non-specific symptoms such as fever, erythema, edema, and intensity-increasing pain make acute osteomyelitis difficult to diagnose. Noninvasive laboratory tests to determine C-reactive protein (CRP) levels and erythrocyte sedimentation rate (ESR) reveal successful but non-sensitive and non-specific treatment options.[5,6] Plain radiograph findings can be useful to detect lytic bone lesions, but lesions are only visible when greater than 50% of the bone has been demineralized.[7] Findings of T-1 weighted magnetic resonance imaging (MRI) scans can also reveal signs of acute osteomyelitis, including bone marrow edema and periosteal collections, seen with subperiosteal abscesses.[6,8]

Surgical irrigation and debridement of the necrotic bone can treat subperiosteal abscesses in acute osteomyelitis. Intraoperatively, culture samples are collected for postoperative antibiotic treatment. However, a positive culture is found in only 50% to 60% of patients owing to previous antibiotic therapy and difficulty with detecting the causative organism.[6] Patients with methicillin-susceptible *Staphylococcus aureus* (MSSA) can be prescribed anti-staphylococcal methicillin such as nafcillin, whereas patients with methicillin-resistant *Staphylococcus aureus* receive clindamycin or vancomycin.[6,9] Duration of antibiotic treatment is typically 3 to 6 weeks, depending on the progression of osteomyelitis.

In the current case, our adolescent patient presented with subperiosteal abscesses of the right distal radius and ulna. He underwent surgical irrigation and debridement, followed by continuous PICC infusion of nafcillin for 6 weeks.

CASE REPORT

In August 2016, a 13-year-old boy presented to the emergency department with a 3-day history of fever, peaking at 102˚F and progressively worsening. Pain, swelling, and erythema of the right dorsal forearm and wrist were noted, which resulted in limited flexion, extension, and gripping motions. The patient reported a family history of rheumatoid arthritis but did not

have any previous trauma, overuse, or autoimmune disease. Laboratory test results showed the following: mild levels of leukocytes, 10.3 x 10^9/L; increased levels of neutrophils s-segmented, 8.1 x 10^9/L; and elevated CRP, 10.5 nmol/L. Findings on MRI scans showed a subperiosteal abscess of the right distal radius and ulna. During 24 hours, a mild improvement was seen with use of intravenous cefriaxone. The patient was scheduled for same-day irrigation and debridement.

Before periosteum incision, fluid from the distal radius was extracted and sent for culture testing (Figure 1). On gross appearance, the periosteum of the distal dorsal radius and ulna were swollen. After aspiration, the periosteum was incised, elevated, curetted, and irrigated. The pus of the distal radius appeared localized and organized, whereas the subperiosteal fluid of the distal ulna appeared murky

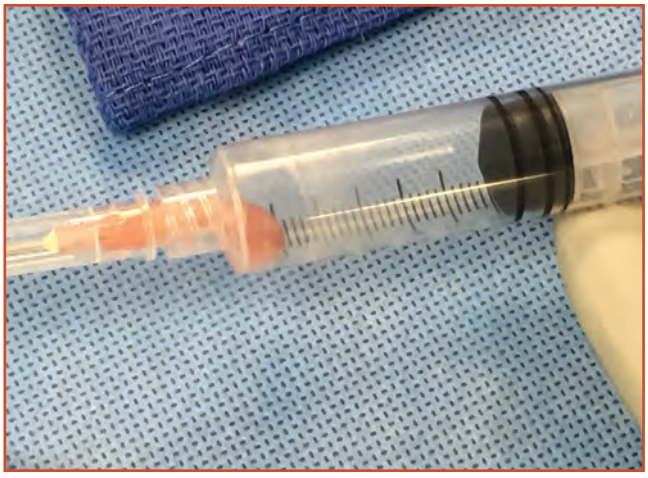

Figure 1. Gross appearance of fluid aspirated from the right distal radius before incision.

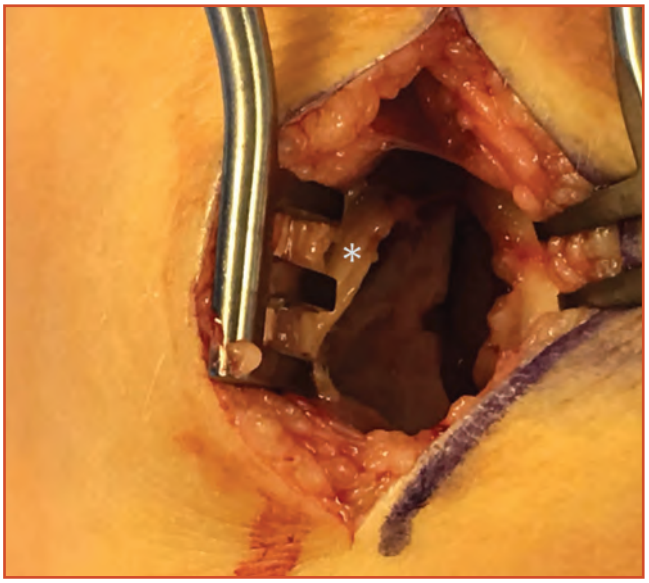

Figure 2. Appearance of the distal radius upon incision, showing a clear collection of pus underneath the periosteum (asterisk).

but lacked pus on incision (Figure 2). After irrigation and debridement, the patient was admitted to the hospital and placed on cefazolin and cefriaxone. The bacterial culture tested positive for MSSA and the patient's CRP levels decreased to 1.4 nmol/L. Cefriaxone was discontinued, and the patient switched to continuous infusion of 10 g of nafcillin using the PICC for 6 weeks. At 2 weeks postoperatively, the symptoms resolved in the right forearm and the patient returned to normal activities of daily living. No complications or concern for chronic osteomyelitis were noted at 6, 10, and 18 weeks postoperatively.

DISCUSSION

Subperiosteal abscesses are more common in children and adolescents because the cortical bone is thinner, allowing infection to spread easily from the medullary cavity to the periosteum. Additionally, pus accumulates easily within the subperiosteal space because the periosteum is loosely attached to the underlying bone.[10,11] In the current case, the subperiosteal abscesses found within the distal radius and ulna necessitated irrigation and debridement to reduce the risk of periosteum rupture and soft-tissue infections.

T1-weighted MRI scans are preferred owing to easy detection of subperiosteal abscesses. The region with abscess-containing pus produces a low signal on T1-weighted images, with a rim of medium-intensity granulation tissue in the periphery.[11,12]

Treatment of acute osteomyelitis after irrigation and debridement varies. For example, 7 days of parenteral therapy followed by oral antibiotics have been compared to continuous intravenous antibiotic infusion using PICC, showing mixed results. Whereas some studies have reported that use of oral antibiotics are as effective as a PICC, other studies have found greater relapse rates with oral antibiotic treatment.[13-15]

In the current case, use of a PICC helped successfully treat acute osteomyelitis in a 13-year-old boy. Subsequently, a PICC may be a reliable method of treatment in this age group. Patients may recover without complications. Future studies may focus on evaluating the efficacy, ease of compliance, and risk factors associated with intravenous infusion versus oral antibiotic treatment of acute osteomyelitis in pediatric populations.

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Rhabdomyolysis of the Abdominal Wall in a 23-Year-Old Football Player: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Rhabdomyolysis is a syndrome caused by injury to skeletal muscle, which results in leakage of large quantities of potentially toxic intracellular contents into plasma. Causes include direct trauma, drug use, genetic muscle diseases, hyperthermia, seizures, ischemia, and severe exertion.

We describe a rare case of exercise related rhabdomyolysis of the abdominal wall in a 23-year-old football player. He presented with painless hematuria after starting a new abdominal workout routine to lose weight. Although the workout was not excessively strenuous, it involved new exercises targeting a poorly trained muscle group. Results of initial workup indicated severely elevated levels of creatine kinase. Furthermore, an abdominal computed tomography scan revealed intrafascial and intramuscular edema in and around both external oblique muscles. The patient required no hospitalization and was successfully treated with oral hydration, with recommended close follow-up.

Keywords: Rhabdomyolysis, Abdominal Wall, Football, Conservative Treatment

INTRODUCTION

Rhabdomyolysis is caused by muscle breakdown and leakage of skeletal muscle contents into the bloodstream. In the United States, the National Hospital Discharge Survey reported more than 26,000 cases of rhabdomyolysis each year.[1] Patients can present with various signs and symptoms such as myalgias, dark urine, weakness, swelling, and crush injuries. The diagnosis is made clinically, with detection of elevated serum creatine kinase (CK) levels. Causes of rhabdomyolysis include injury, infection, exposure to extreme temperatures, drug use, and exercise.

Although overexertion during training sessions is a common cause, studies have found little or no association between creatine supplements and rhabdomyolysis.[2] Risk factors include dehydration, exercise in hot temperatures, and sickle cell trait (SCT).[3] Rhabdomyolysis can occur after considerable increases in workout loads or changing workouts to focus on a new muscle group that is poorly trained. Usually, rhabdomyolysis is seen in healthy athlete-patients with normal musculature findings. The media has often reported rhabdomyolysis among football players in high school and college.[4,5] We describe a 23-year-old male athlete who presented with isolated rhabdomyolysis of the abdominal wall.

CASE REPORT

A 23-year-old male football player, self-reported as white, presented with dark discoloration of his urine, which started 1 day earlier. He reported no previous occurrence of this symptom. He noted no pain, dysuria, frequency, discharge, hesitancy, or incomplete voiding. The patient reported no medical history of chronic conditions, urinary stones, or sexually transmitted diseases (he noted he was never sexually active). On his initial preparticipation physical test, laboratory results were negative for SCT. He noted no presence of the following problems: chronic illnesses, recent acute illnesses, myalgias, nausea, vomiting, diarrhea, fevers, back pain, groin pain, or colicky abdominal pain. The patient reported no changes in his diet or any new supplement use. During the past several weeks, he had intentionally "lost some weight to slim down."

He had performed a new abdominal workout 1 day before presentation and did not feel that it was overly strenuous.

Results of urine analysis at the time of presentation to the training room showed high levels of protein (100 mg/dL; usually ≤ 20 mg/dL), large red blood cells, and few bacteria. Findings were negative for nitrites and positive for uric acid crystals. After initial evaluation, results of differential diagnosis suggested exercise-induced hematuria, nephrolithiasis, glomerulonephritis, rhabdomyolysis, or urinary tract infection. Because the patient presented initially without myalgias and pain, a computed tomography (CT) urogram was obtained. Although CT findings did not reveal a urinary stone as expected, inflammation and intramuscular and intrafascial edema were observed throughout and around both external oblique muscles (Figures 1 and 2). Further workup results revealed preserved renal

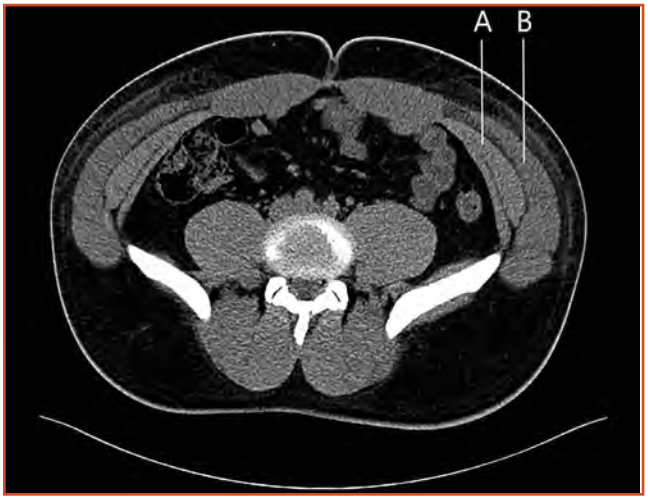

Figure 1. Axial view of abdominal computed tomography scan, showing intramuscular edema and inflammatory stranding of internal oblique (marked with "A") and external oblique (marked with "B") more prominent on the left side.

function, elevated liver enzymes (AST 791, ALT 155, Hepatitis panel negative), and elevated CK levels of 1178.1 µkat/L (70,546 U/L). Subsequently, a diagnosis was made of abdominal wall rhabdomyolysis.

Owing to the patient's preserved kidney function and hydration tolerance, inpatient admission was avoided in favor of closely monitoring him as an outpatient. At 9 days after discharge, his CK and liver enzyme levels returned to normal. The patient did not have any long-term complications and returned to his usual exercise routine.

DISCUSSION

This case is interesting owing to the described rare location of rhabdomyolysis. Few studies have reported isolated rhabdomyolysis of the abdominal wall caused by exercise,[4-10] and the injury has been typically misdiagnosed at first.

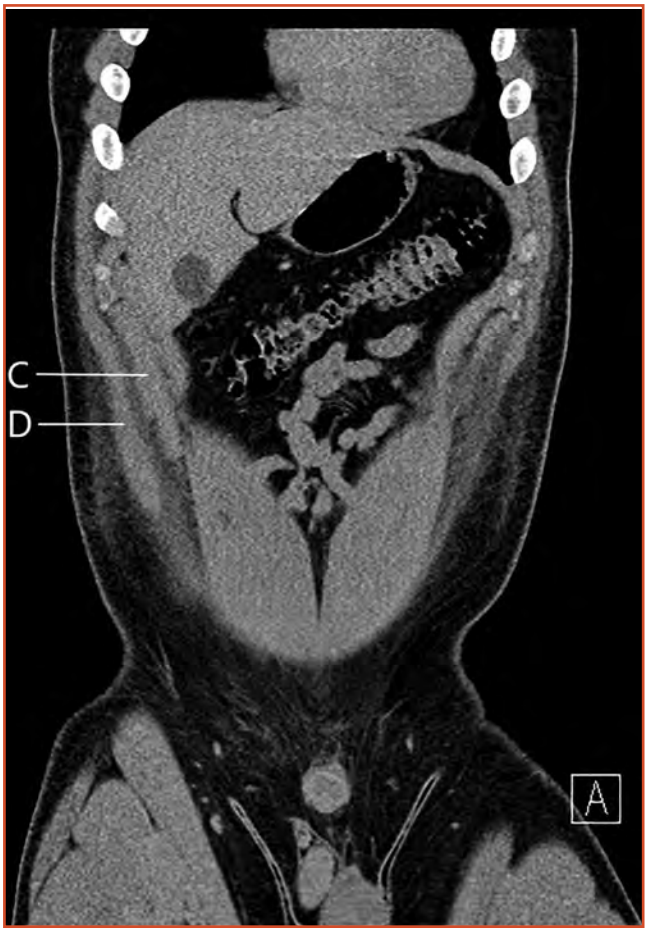

Figure 2. Coronal view of abdominal computed tomography scan, showing intrafascial edema separating internal oblique (marked with "C"), external oblique (marked with "D"), and intramuscular edema in the external obliques.

In January 2010, twelve members of the University of Iowa football team were hospitalized with rhabdomyolysis after strenuous physical activity.[4] In August of the same year, more than 50% of a high-school football team in Oregon was hospitalized after participating in a training camp.[5] Isolated abdominal rhabdomyolysis was reported in one hospitalized patient, though caused by an injury from a bed rail rather than exercise.[6] Another instance was reported in a sailor who started a new exercise program.[7] Initially, a misdiagnosis was made of acute cholecystitis because the patient presented with right upper-quadrant pain.[7] Furthermore, another injury was misdiagnosed as acute appendicitis in an amateur boxer who often drank alcoholic beverages and noted an increase in his training activity.[8] One study described an incidental finding of rectus abdominis rhabdomyolysis, treated with skeletal scintigraphy.[9] The patient had recently performed 30 to 40 sit-ups per day continuously for 5 days. Lastly, a soldier presented with abdominal rhabdomyolysis after completing a routine 1-hour abdominal exercise.[10]

These cases[4-10] described patients with symptoms of abdominal pain and tenderness. In the current case, our patient did not note abdominal pain and instead had dark urine discoloration. After the diagnosis, however, the patient did note previous presence of some abdominal soreness. Dark discoloration of urine can have varied results from differential diagnosis. Transient exercise-induced hematuria and proteinuria are common diagnoses but should not be assumed during initial presentation or when associated myalgias are noted.

Abdominal wall rhabdomyolysis can easily be mistaken for abdominal pain owing to a renal stone, appendicitis, and other intra-abdominal pathological features. Healthcare professionals should consider presence of rhabdomyolysis if an athlete presents with acute hematuria. Rhabdomyolysis can result from physical activity of a new workout routine regardless of perceived level of difficulty.

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Chronic Tenosynovitis Caused by *Mycobacterium Avium-Intracellulare* of the Flexor Tendons in a 65-Year-Old Man: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

We report a rare case of *Mycobacterium avium-intracellulare* flexor tenosynovitis in the hand of a 65-year-old man. The patient reported no history of penetrating trauma but was an avid gardener and presented nearly 2 years after the onset of symptoms. Our case highlights the difficulty in diagnosing mycobacterial infections owing to their lack of classic clinical and laboratory findings. Our patient underwent successful surgical debridement followed by oral antibiotic therapy, initiated 4 weeks after the culture was positive for a slow-growing organism.

Keywords: Mycobacterium Avium Complex, Chronic Disease, Tenosynovitis, Hand

INTRODUCTION

Nontuberculous mycobacteria (NTM) are ubiquitous in the environment, yet rarely cause disease in immunocompetent hosts, especially in the United States. Infection of the musculoskeletal system is rarer still.[1-4] Chronic NTM hand infections have been well described, though typically seen at the skin or subcutaneous level.[2] Chronic flexor tenosynovitis due to NTM is unusual and described only in limited case reports and small series.[3] The diagnosis of NTM flexor tenosynovitis is difficult because of the lack of typical clinical or laboratory findings. Patients often experience ongoing infection for several months before diagnosis.[2,3]

CASE REPORT

A 65-year-old Caucasian man presented to our office with a 20-month history of swelling in his left hand. He recalled no injury or penetrating trauma, but noted that he was an avid gardener. He first presented to a different hand surgeon after 6 weeks of swelling and pain along the volar index finger. A rheumatologic condition was suspected; however, because his pain had resolved, no immediate action was taken. The patient reported that although he no longer experienced pain, swelling gradually worsened during the next several months, coursing throughout the volar index finger and palm, in line with the index flexor tendons.

About 16 months after initial symptoms, the patient developed a small draining sinus. He underwent treatment at multiple urgent care centers, including needle aspiration and a short course of cephalexin. At presentation to our clinic, he reported no improvement. Findings from physical examination showed marked swelling over his index flexor tendons extending from the mid palm to the proximal interphalangeal joint. No pain to palpation was elicited, and he showed full range of motion. A 2-mm sinus over the volar index proximal phalanx, with scant clear drainage, was evident. Laboratory inflammatory markers of white blood cell count, sedimentation rate, and C-reactive protein were normal. Chronic flexor tenosynovitis was suspected, and debridement with biopsy was recommended.

During open debridement, markedly thickened tenosynovitis was noted from mid-palm to the A4 pulley. Granulomatous tissue was noted to be non-caseating. No white “rice bodies” were encountered (Figure 1). Diseased synovial tissue was debrided (Figure 2) and sent for histological analysis and testing for aerobic, anaerobic, fungal, and mycobacterial cultures. Working in consultation with our infectious disease (ID) colleagues, we decided to hold any antibiotic therapy until a specific organism was identified.

Histological analysis showed epithelioid granulomas, and no organisms were identified on multiple stains, including acid fast bacilli (AFB). All cultures were initially negative for aerobic, anaerobic, and fungal growth. However, after 4 weeks, growth appeared on

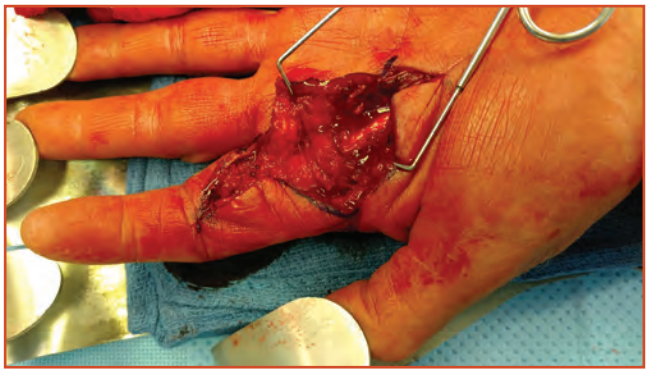

Figure 1. Open exposure of flexor tendons and pulley system, with thickened synovitis and no visible "rice bodies."

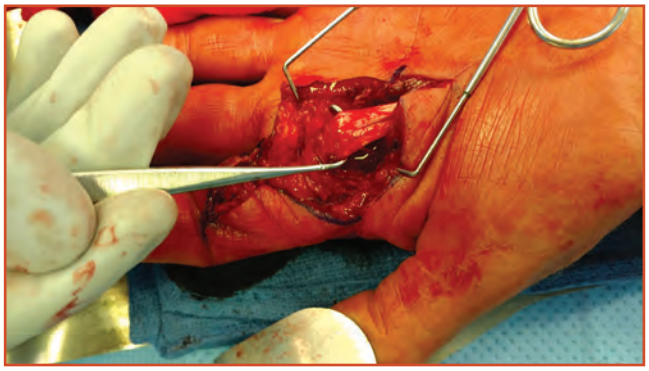

Figure 2. Flexor tendons status after debridement of synovitis.

AFB culture and *Mycobacterium avium-intracellulare* was identified. The patient received oral antibiotic therapy in accordance with his ID specialist. At 3 months postoperatively, the patient showed no recurrence of infection.

DISCUSSION

Chronic tenosynovitis due to NTM is an exceedingly rare malady. Of the 15 species of NTM known to cause human infection, *M. mariunum* and *M. kansasii* most commonly cause tenosynovitis.[4,5] Only seven cases reported NTM tenosynovitis caused by *Mycobacterium avium-intracellulare*.[3,6-9] Diagnosis is difficult because of limited symptoms. In our patient, Kanavel signs were missing, and laboratory markers were usually negative for infection.[2,3] A history of puncture trauma may be elicited.[3] Physicians should consider the possibility of NTM because only swelling, and sometimes a sinus, may be present.[5]

Gross surgical findings include tenosynovitis and non-caseating granulomas.[2] White, nodular rice bodies are often seen grossly,[10] although the current case did not include this finding. Histological findings most often reveal epithelioid granulomas, and AFB staining is typically negative for presence of *Mycobacterium*.[2,3] Culture results are almost always the key to successful diagnosis.[2,3] Again, a high index of suspicion is required as NTM grow slowly on solid media from 2 to 12 weeks.[2,3]

Treatment often includes a combination of surgical debridement and antibiotic therapy. A thorough surgical debridement can decrease the pathological burden, improve efficacy of drug therapy, and shorten its required duration.[3,5] After consultation of our ID colleagues, we did not initiate antibiotic therapy until an organism was identified by culture. Antibiotic regimen remains controversial, however, with some advocating initiation of drug therapy immediately after surgical treatment. Although consensus is lacking owing to the rarity of this disease, one study reviewed four patients initiating drug therapy only after culture positive results, at an average of 3.8 weeks postoperatively. None of these patients exhibited signs of recurrence of NTM.[3]

Our case highlights NTM tenosynovitis as an integral part of differential diagnosis in evaluating unusual hand swelling. A high index of suspicion is required to prevent prolonged disease and unnecessary treatments. Physicians should communicate closely with ID and microbiology laboratory specialists because NTM are slow-growing organisms.

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Suspected Propofol-Related Infusion Syndrome After Lumbar Spinal Fusion With Total Intravenous Anesthesia: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Propofol-related infusion syndrome (PRIS) is a well-documented yet rare complication of prolonged infusions of propofol. It is characterized by a myriad of metabolic abnormalities, including cardiac arrhythmias, rhabdomyolysis, acute kidney injury, metabolic acidosis, and other disturbances. First described in children receiving extended propofol infusions to maintain sedation while in the intensive care unit, PRIS has now been described in every age group. It typically results in death. Management of this potentially devastating complication involves supportive treatment of the metabolic problems encountered and discontinuing the use of propofol. We describe a patient with suspected PRIS who underwent a two-stage lumbar spine procedure with total intravenous anesthesia, using propofol as the anesthetic. At 6-weeks postoperatively, he could walk without assistive devices and did not require pain medication. Findings of the current case may help inform healthcare providers of the possibility of PRIS after spinal fusion, allowing for a potentially life-saving diagnosis.

Keywords: Propofol-Related Infusion Syndrome, Lumbar Vertebrae, Spinal Fusion, Intravenous Anesthesia

INTRODUCTION

Propofol is a common medication used for its sedative properties in the intensive care unit and as an anesthetic agent in the operating room. It is typically well tolerated by patients and considered relatively safe. Propofol-related infusion syndrome (PRIS) is a well-documented complication of the use of propofol. The condition was initially described in children but has been observed in all age groups.[1,2] Symptoms typically include cardiac arrhythmias, metabolic acidosis, acute kidney injury, rhabdomyolysis, and metabolic disturbances.[3]

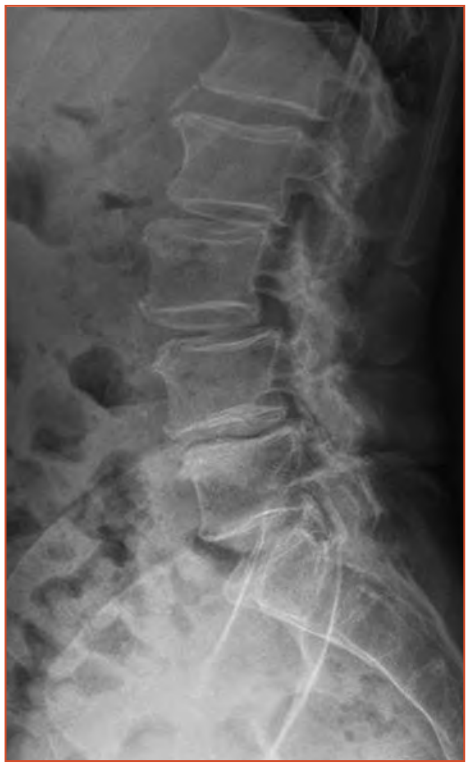
Patients with this life-threatening condition are typically critically ill in intensive care units and receive prolonged infusions for more than 48 hours for sedation.[4] Most patients described in studies died as a result. PRIS has rarely been noted in patients with short-term infusions as is typical with most surgical procedures.

To our knowledge, PRIS has not been described in patients who underwent spinal fusion using total intravenous anesthesia. Surgical treatment of spinal deformity in adults is complex owing to combined anterior and posterior approaches for circumferential correction and fusion. It is associated with considerable complications and can be performed in a single day or staged fashion. Operating times range from 6 to 12 or more hours, with a common estimated blood loss of more than 2 L.[5] Propofol is often used as the anesthetic because of it allows intraoperative neurophysiological monitoring. We present a patient who developed PRIS after lumbar spine decompression and fusion for treating lumbar degenerative scoliosis.

CASE REPORT

A 60-year-old man presented with severe degenerative scoliosis of the lumbar spine with stenosis, neurogenic claudication, and radiculopathy (Figures 1 and 2). Nonoperative treatment was unsuccessful. Operative correction such as lateral interbody fusion with posterior spinal fusion was discussed with the patient. His medical history included alcohol abuse, tobacco abuse, hyperlipidemia, and chronic pain. He had no previous complications with surgical procedures but did report “difficulty waking up” after a remote procedure several years before, of which he said he did not remember the details. There was no family history of difficulties with anesthesia.

The patient was taken to the operating room and underwent anterior decompression and interbody fusion



Fgure 1. Preoperative lateral view of the lumbar spine, showing severe multilevel facet arthropathy and degenerative disc disease with anterolisthesis of levels L3-L4 and L4- L5.

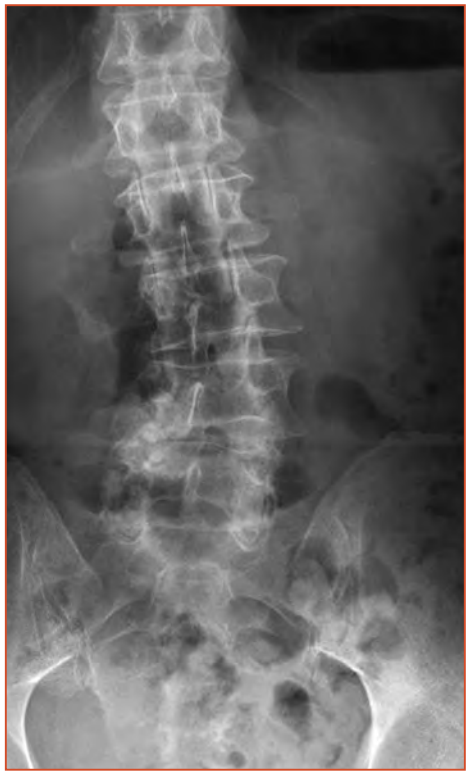


Figure 2. Preoperative anteroposterior view of the lumbar spine, showing severe multilevel facet arthropathy, degenerative disc disease, and degenerative levoconvex scoliosis.

using an extreme lateral technique at the levels L2-L3, L3-L4, and L4-L5.[6] While under the same anesthetic, he was repositioned and underwent posterior decompression and instrumented fusion of level L2-L5. No intraoperative complications were noted, with successful correction of the complex degenerative scoliosis (Figures 3 and 4).

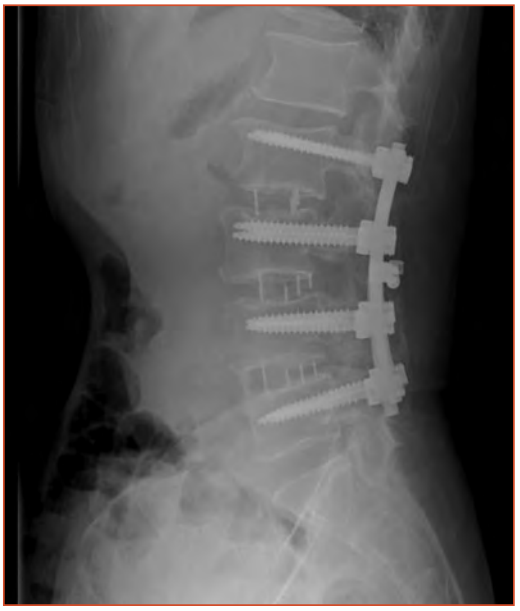


Figure 3. Lateral view of the lumbar spine, showing interbody fusions at levels L2-L3, L3-L4, and L4-L5 with posterior instrumentation at level L2-L5.

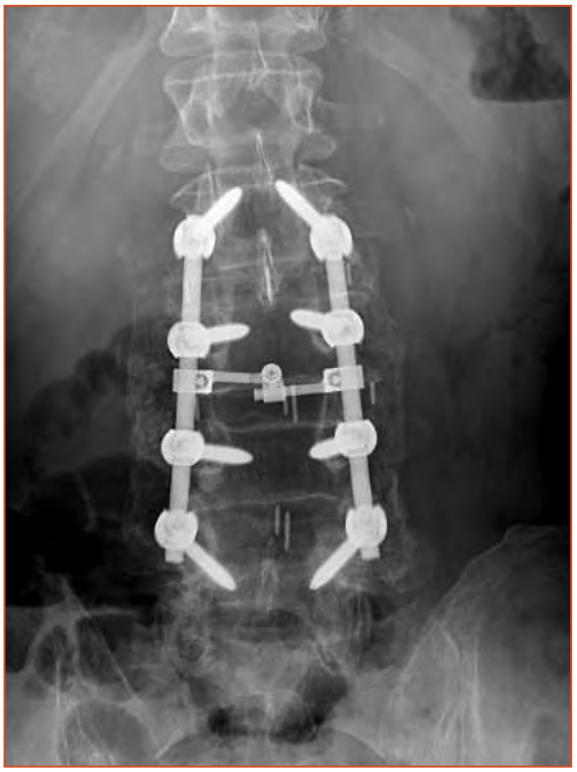


Figure 4. Anteroposterior view of the lumbar spine, showing interbody fusions at levels L2-L3, L3-L4, and L4-L5, with posterior instrumentation at level L2-L5.

Before incision, tranexamic acid was administered to minimize blood loss.[7] The patient was in the operating room for about 10 hours and 48 minutes, with a total anesthesia time of 9 hours and 30 minutes and a mean propofol infusion rate of 6.8 mg/kg per hour. During the second stage of the procedure, an arterial blood gas was drawn that showed a mild metabolic acidosis to a pH of 7.31. At the completion of the procedure, the patient was awoken from anesthesia-induced sleep and extubated without observed complication. Estimated blood loss throughout the surgical procedure was 850 mL, with urine output measured at 550 mL. A total of 5000 mL of intravenous crystalloid was administered, and no blood products were given. Postoperatively, hematocrit volume was 0.3 (30%), down from a preoperative measurement of 0.4 (40%).

In the immediate postoperative period, the patient could move extremities on command but had decreased mental activity and was severely agitated, requiring restraints for safety. A cardiac arrhythmia comprising tachycardia with premature atrial complexes and ST segment changes were detected on continuous cardiac monitoring, and he was subsequently transferred to the intensive care unit. Results of initial workup revealed an acute kidney injury with a 0.36 increase in creatine levels, severe rhabdomyolysis, metabolic acidosis, and elevated troponins. No obvious cause of the sudden symptoms was identified. He was treated with close monitoring and aggressive resuscitation. The patient's creatine kinase level peaked at 312.3 µkat/L (18,693 U/L), and the troponin I level elevated to 0.938 µg/L. During the next 5 days, the patient's metabolic abnormalities resolved, his kidney function returned to baseline levels, and his arrhythmia resolved without intervention. His mental activity improved considerably, and he was discharged to an inpatient rehabilitation facility.

At his 6-week postoperative visit, the patient walked without assistive devices and did not require any pain medications. The previous symptoms caused by neurogenic claudication and radiculopathy were resolved. His mental activity was at its baseline level, with no reported residual effects of his prolonged hospital stay. He did report "very little recollection" of the several days after the operation.

DISCUSSION

PRIS is a rare but potentially life-threatening condition associated with the use of a common and relatively safe medication. It has been described mostly in patients undergoing prolonged sedation for treating critical illness such as respiratory failure or traumatic brain injuries.[2] Bray[8] described diagnostic criteria to include sudden bradycardia progressing to asystole in addition to one of either metabolic acidosis, derangement of liver function, lipemic plasma, or rhabdomyolysis. The definition now includes hypotension, acute kidney injury, hyperkalemia, and hypoxia.[4] PRIS may be dose dependent, with patients most at risk who receive dosages higher than 4 mg/kg per hour for a prolonged duration.[9] Treatment typically involves cessation of propofol and then treatment of the sequelae.[9] PRIS often results in patient death. Many authors have tried to identify risk factors or develop screening tests to prevent PRIS.[10,11]

To our knowledge, PRIS has not been documented to occur after spinal fusion. PRIS is typically a diagnosis of exclusion because many of the signs and symptoms often result from much more common pathological features. In our patient, there was concern he was under-resuscitated or suffering from medication withdrawal. Under-resuscitation was unlikely, however, because of standard levels of blood loss, adequate urine output, and only minor abnormalities found on intraoperative blood gas. Medication withdrawal was unlikely owing to near immediate onset of symptoms postoperatively and the failure to identify any offending agents initially during review of medical records, interviews with the patient's friends and family, and discussion with the patient when the symptoms resolved.

Our patient exhibited typical findings of PRIS. At our institution, degenerative scoliosis procedures with multiple stages are typically performed using one anesthetic agent. Our experience has been similar to that of others, in which this single prolonged procedure is safe. That is, major complications are rare, with similar outcomes to staged procedures performed during several days. These procedures are also usually performed with total intravenous anesthetic. A review of our patient's medical history did not indicate the risk of developing PRIS.

Although PRIS is rare, surgeons performing prolonged procedures with the use of continuous infusion of propofol should be aware of the condition. It can be difficult to diagnose, and delay in doing so may result in death of patients.

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Simultaneous Avulsion Fractures of the Tibial Tuberosity of Both Knees in a 14-Year-Old Boy: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Fractures of the tibial tuberosity are uncommon injuries in adolescents, representing an estimated 0.4% to 2.7% of all pediatric fractures. Most of these injuries occur in young, active males commonly between the ages of 12 to 17 years. Sports, particularly those involving jumping or sudden starts and stops, are most often implicated. Injuries of the tibial tuberosity of both knees are especially rare, with little more than 30 cases reported in the past 60 years. We present a 14-year-old male football player with simultaneous avulsion fractures of the tibial tuberosity of both knees. We reviewed the anatomy, mechanisms of injury, classification systems, treatment strategies, and complications regarding this rare injury.

Keywords: Bone Fractures, Tibia, Avulsion Fracture, Adolescent, Football

INTRODUCTION

In 1954, Borsch-Maden[1] first described fractures of the tibial tuberosity of both knees. About 30 additional cases have since been described.[2-6] The proximal tibia has two ossification centers: the primary proximal tibia epiphysis that comprises the tibial plateau, and the tibial tubercle (a smaller, anterior ossification center). The proximal tibial physis closure progresses in a posterior to anterior direction, whereas the tibial tubercle physis proceeds proximally to distally, finally closing in patients between the ages of 13 and 15 years in adolescent girls and 15 to 19 years in adolescent boys.

Furthermore, as observed by Ogden,[7] the histological features of the physis underlying the tibial tubercle are unique. The features are composed almost entirely of fibrocartilage as opposed to the normal columnar physeal cartilage usually seen in growth plates. The tensile strength of fibrocartilage is greater than that of the columnar physeal cartilage and can better resist the force exerted on the tibial tubercle by the knee extensor mechanism from the patellar tendon. However, the tibial tubercle physis begins to close with age, and the fibrocartilage is replaced with columnar physeal cartilage, which weakens the area and increases the risk of fracture. Given this, the most common injury is caused by active extension of the knee (eg, jumping) or forced passive flexion of the knee (eg, falling on knees) against a contracted quadriceps muscle.

Owing to the involvement of two ossification centers and physes, new classification systems have been developed to categorize tibial tuberosity fractures, as opposed to the traditional Salter-Harris classification system. Watson-Jones[8] first categorized tibial tubercle fractures into three types: type I, distal portion of the tibial tubercle is avulsed; type II, entire tibial tubercle is avulsed along with a distal fragment of proximal tibia epiphysis at the level of the physis; and type III, fracture extends through tibial tubercle and proximal tibia epiphysis to the joint. Ogden et al[9] further modified this system to include subtypes A (non-comminuted) and B (comminuted).

Since then, several additions have been proposed including type IC, avulsion of tibial tubercle with accompanying patellar tendon avulsion[10]; type IV, separation of the tibial tubercle physis extends posteriorly, involving entire proximal tibial physis[11]; and type V that combines types III and IV to create a Y-shaped fracture line as shown in Figure 1.[12] Most recently, Pandya et al[13] proposed a new classification

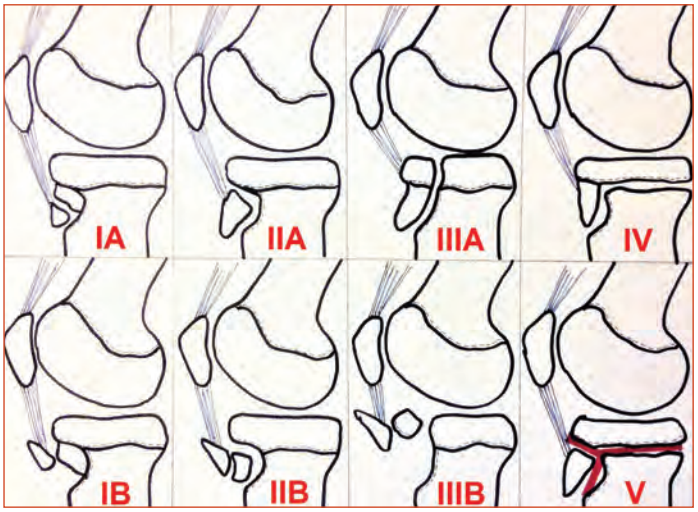

Figure 1. Classification system of tibial tuberosity fractures, showing types IA, IIA, IIIA, IV, IB, IIB, IIIB, and V.

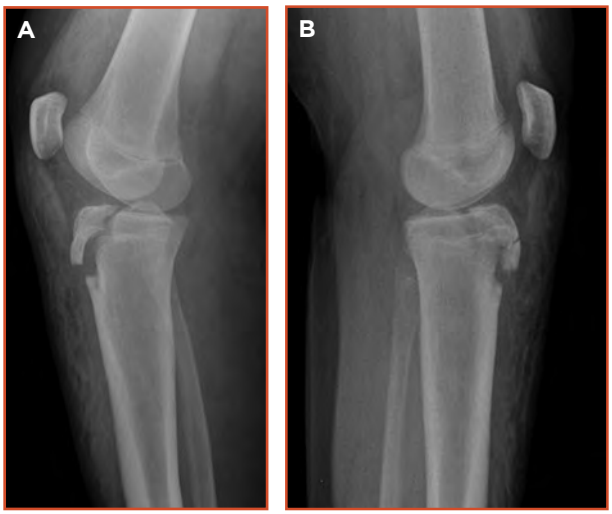

Figure 2. Radiographs of the A) right and B) left knees, showing avulsion fractures of the tibial tuberosity in both knees.

system that placed additional emphasis on intraarticular extension. We describe a 14-year-old adolescent male football player who presented with simultaneous avulsion fractures of the tibial tuberosity of both knees.

CASE REPORT

A 14-year-old male football player presented to an outside emergency department with acute pain in both knees. The patient was running sprints during football practice when he felt a "pop" in both knees and immediate pain. He fell to the ground and was unable to walk. He reported no history of knee injuries. Findings of radiographs revealed tibial tuberosity avulsion fractures of both knees. The patient was transferred to our facility for further care.

On physical examination, the patient had moderate edema of both knees without ecchymosis or erythema. He had tenderness to palpation over the tibial tuberosity of both knees. He was unable to extend either knee and had pain with limited range of motion. His distal neurovascular status was intact, including dorsalis pedis and posterior tibial pulses, capillary refill, sensation, and ankle and toe plantar and dorsiflexion. He was notably obese with a calculated body mass index of 39.1 kg/m^2. Radiograph findings showed tibial tuberosity avulsion fractures of both knees, consistent with Ogden type IIIA fractures with the right knee (Figure 2A) more displaced than the left (Figure 2B).

The patient was admitted to the orthopaedic service about 24 hours after the injury. He underwent open reduction and internal fixation. After the incision, the tibial tubercle was reduced under direct visualization and placement was confirmed using a Steinmann pin and fluoroscopy. Two fully threaded cortical screws (4.5 mm) were used to secure each tibial tubercle, directed anteriorly and posteriorly. Intraoperatively, the right tibial tubercle was fractured in a single, large

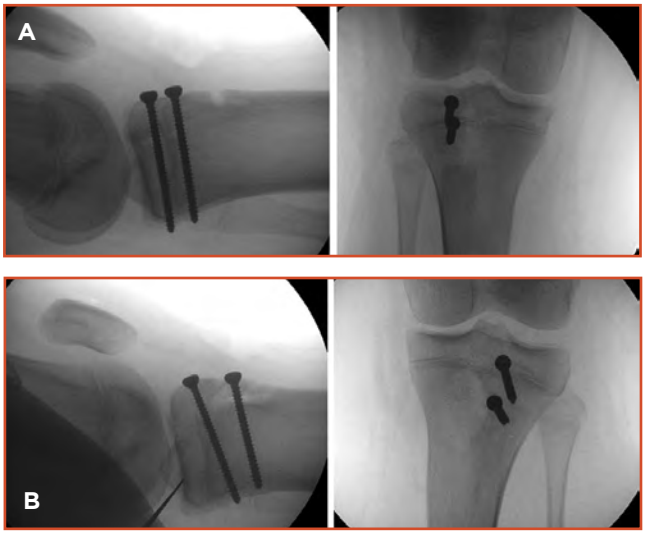

Figure 3. Intraoperative fluoroscopic images of the A) right and B) left knee after open reduction and internal fixation.

piece through which two screws were placed (Figure 3A). The left tibial tubercle was in two pieces, and one screw was placed through each fragment (Figure 3B). Postoperatively, all lower-extremity compartments were notably soft with brisk capillary refill distally. The patient's knees were placed in hinged Bledsoe knee braces, locked in full extension at 0°. He was able to bear weight as tolerated with the assistance of a walker.

At 4-weeks postoperatively, the patient's braces were opened to 0˚ to 30˚ of extension when not bearing weight but remained locked while bearing weight. At 8-weeks postoperatively, he had full range of motion while non-weight bearing; however, he was instructed to continue using the braces while walking. At 14-weeks postoperatively, the patient no longer required the braces and a new radiograph revealed complete healing

of the fractures (Figure 4). Although the extensor mechanism was intact on both knees, considerable quadriceps weakness was noted; subsequently, the patient was referred to a physical therapist. At 7-month follow-up, he had returned to playing football. Hardware removal will be considered at about 1 year postoperatively.

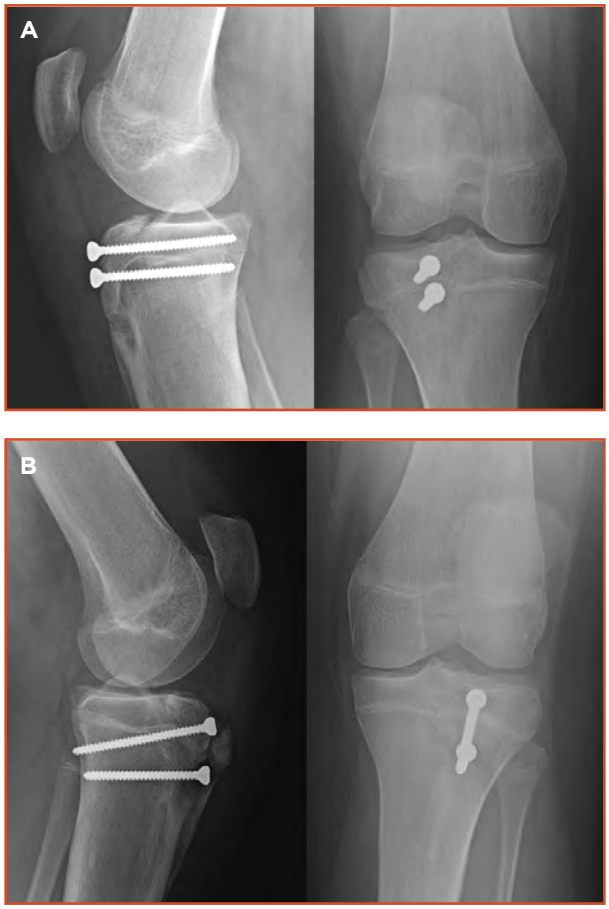

Figure 4. Radiographs of A) right and B) left knees at 14-weeks postoperatively, showing healed fractures.

DISCUSSION

The current case is a typical example of avulsion fractures of the tibial tuberosity of both knees. Roy et al[2] described the average patient age in the reported cases as 14 years, with adolescent boys most commonly affected (20 of 21), fitting our patient's profile. This may be because of the age difference between the closure of tibial tubercle physis with girls (ages 13 and 15 years) and boys (notably later at 15 to 19 years). Our patient was injured by a common mechanism of injury, involving active extension against a contracted quadriceps muscle while sprinting.

A reported complication of tibial tubercle fractures includes compartment syndrome, possibly caused by damage to the nearby anterior tibial recurrent artery. Higher degree, comminuted fractures are at greater risk, and a prophylactic anterior compartment fasciotomy can be considered at the time of surgical treatment. Brey et al[14] found a higher incidence of complications in patients with tibial tubercle fractures that extended through the posterior metaphysis. The study also noted three cases of re-fracture after initial nonoperative treatment. Considerable growth deformities are not usually observed after tibial tubercle fractures because the physes are naturally nearing to closure. Genu recurvatum, leg-length discrepancy, malunion, nonunion, and patella alta and infera have been reported as rare complications. Postoperative bursitis due to prominent hardware has been described, for which the use of smaller screws has been suggested as a preventative measure.[15]

Treatment choices depend on the degree of displacement, comminution, and intraarticular involvement of injury. Type IA injuries can be managed nonoperatively, with a 4- to 6-week course of immobilization and the knee in full extension (by using a brace or long leg cast), followed by rehabilitation. Nearly all type IB, II, III, IV, and V fractures require surgical repair, with either use of pins or cancellous screws to obtain fixation. Short-term outcomes of tibial tubercle fractures are generally promising, but few studies have reported long-term outcomes.[15]

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Cutaneous Manifestations in the Fingertips After a Supracondylar Humerus Fracture in a 6-Year-Old Girl: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

A 6-year-old girl jumped from a swing and fell on her left arm, presenting to our clinic with a supracondylar fracture of the distal humerus. The child underwent closed reduction and percutaneous pinning. At 3-week follow-up, anterior interosseous nerve palsy was noted with concurrent manifestations in the median nerve distribution. Our patient was treated nonoperatively; at 8-week follow-up spontaneous resolution of cutaneous and motor symptoms was observed. Healthcare professionals should be aware that cutaneous lesions may develop after injury to the median nerve of the proximal forearm, which can result from supracondylar humerus fractures.

Keywords: Cutaneous Lesions, Humerus, Bone Fractures, Child, Median Nerve

INTRODUCTION

Fractures of the distal humerus above the epicondyles, also called supracondylar fractures, are classified into two types. The classification depends on displacement of the distal fragment, flexion type, and extension type.[1] These fractures are commonly seen in children aged 5 to 8 years,[2] occurring after falling on outstretched hands and forced hyperextension of the elbow. Symptoms include swelling, pain, and limited range of elbow motion.[2] Findings of radiographic evaluation and further categorization of the injury can help determine appropriate treatment.[1]

Early complications of supracondylar fractures include damage to the anterior interosseous nerve (AIN) branch (ie, median nerve) and vascular injuries. Malunion can occur in the later period after the injury.[3] To our knowledge, no studies have noted cutaneous manifestations in the median-nerve distribution from proximal lesions after supracondylar fractures. We present a 6-year-old child in whom closed reduction and percutaneous pinning for treating a supracondylar fracture led to AIN palsy and blistering of skin in the median nerve distribution.

CASE REPORT

A 6-year-old girl presented to our clinic with a supracondylar fracture of her left upper extremity. She had leapt from a swing, fell about 6 ft (1.8 m) onto her elbow, and was admitted to an outside facility for treatment of her left elbow. Radiographic findings revealed a supracondylar fracture of her left upper extremity, with complete displacement of the distal humerus (Figure 1). She was transferred to our hospital for definitive treatment. On clinical examination, she had intact motor and sensory neurological functions and no symptoms of AIN palsy.

The patient was taken to the operating room and underwent closed reduction and percutaneous pinning. She was discharged with intact neurological function of her left hand. At 1-week follow-up, AIN palsy was noted with inability to flex the interphalangeal (IP) and distal

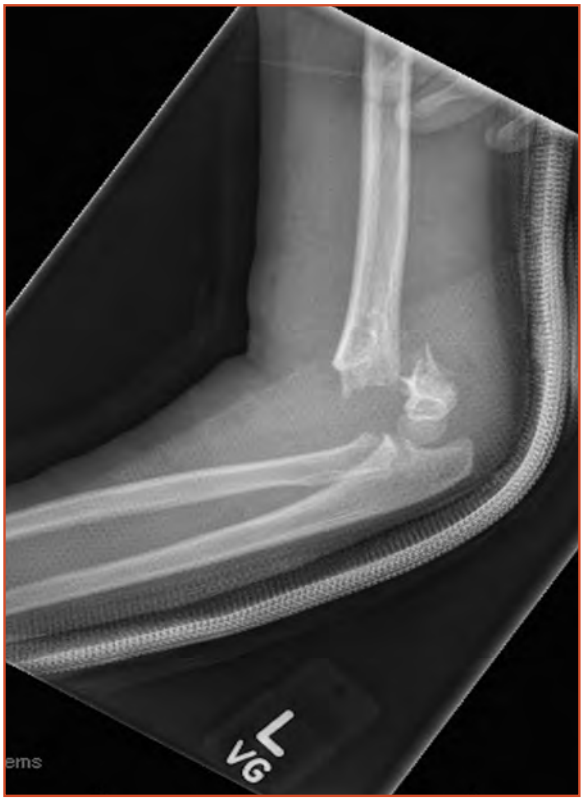


Figure 1. Lateral radiograph of left elbow from an outside facility, showing a posteriorly displaced distal humerus fracture.

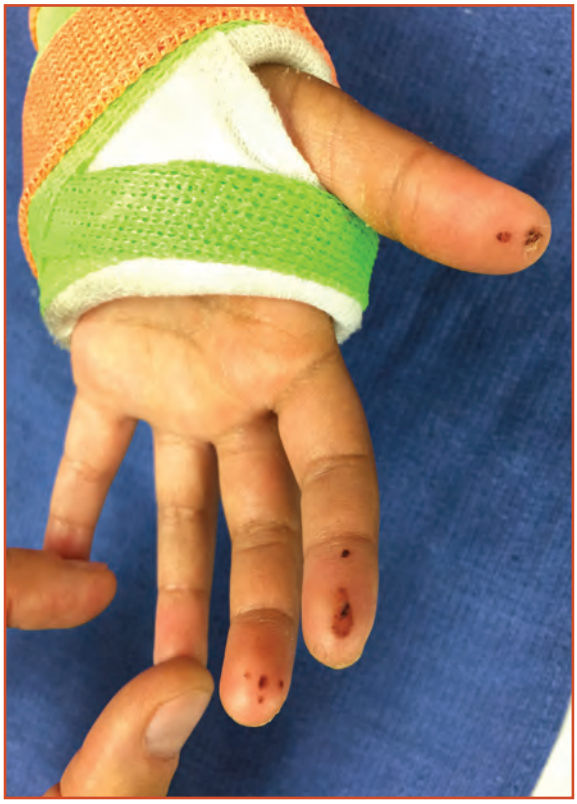


Figure 2. At 4 weeks postoperatively, ulcerations are visible on the volar aspect of the thumb, index, and middle fingers in the median nerve distribution.

IP joints of the thumb and index finger. She had normal levels of sensation in the median nerve distribution. At 3 weeks postoperatively, the pins were removed from her left upper extremity. The patient's mother was informed that AIN palsy was discovered and that the deficit would be monitored closely.

At 3 and 4 weeks postoperatively, symptoms of AIN palsy were still persistent. At both follow-ups, the capillary refill time was brisk at less than 3 seconds, no evidence of vascular compromise was noted, and results of a two-point discrimination (≤ t5 mm) test revealed an intact sensation in the elbow. Although no history of injuries or burns was reported, the patient had blistering in the middle, index, and thumb fingertips on the volar aspect of her left hand. At 4 weeks postoperatively, the punctate blisters were healing (Figure 2).

At nearly 8 weeks postoperatively, we noted dry skin in the median nerve distribution and complete healing of the lesions (Figure 3). The patient's parents reported that the blistering had resolved about four days earlier. The patient was able to flex and fully extend the IP joint of her thumb and form an "OK" sign, by opposing her thumb to the tip of her index finger (Figures 4A and 4B). Strength required to hold the sign was mildly limited; otherwise, sensation remained intact in the median nerve distribution.

At about 14 weeks postoperatively, the patient continued to show improvements in strength. She was able to hold an "OK" sign and had full grip strength

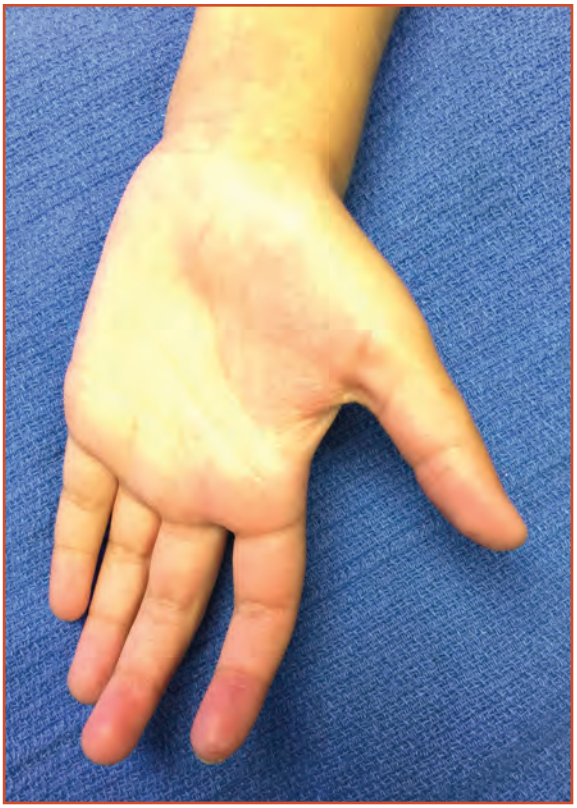
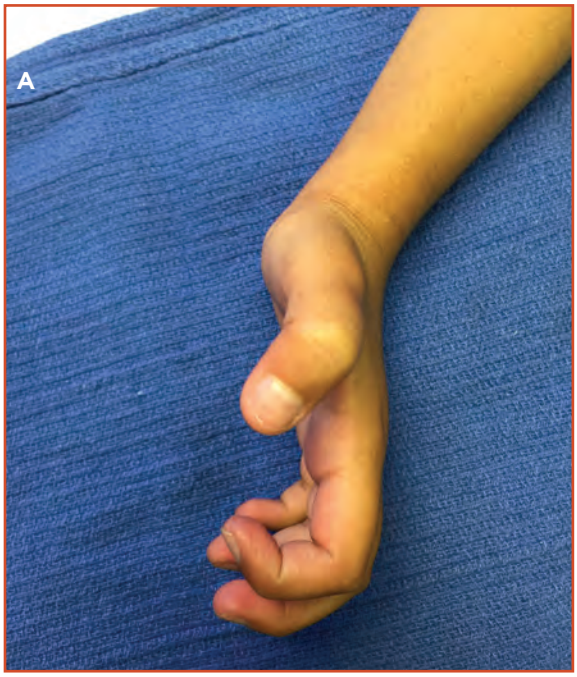


Figure 3. At 8 weeks postoperatively, ulcerations on volar aspects of thumb, index, and middle fingertips of left hand are healed.



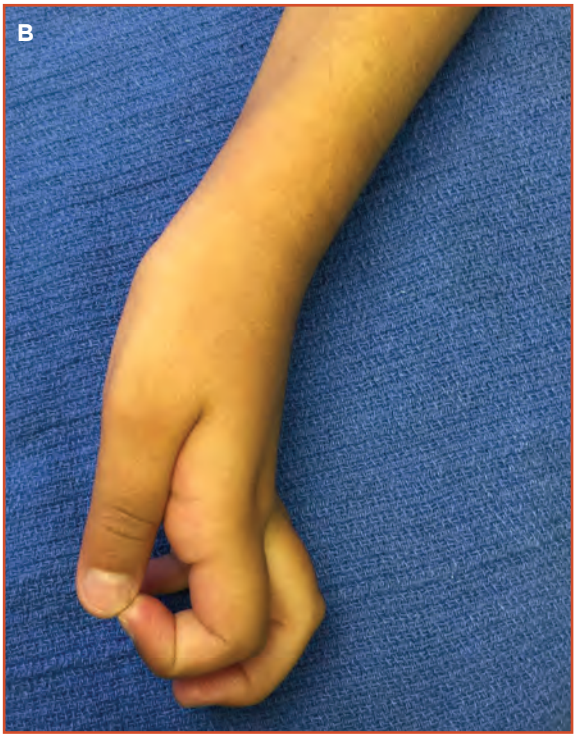


Figure 4. A) At 8 weeks postoperatively, patient is able to flex interphalangeal joint of thumb. B) She can also oppose her thumb to the tip of her index finger, with strength required minimally limited.

comparable to the uninjured hand. She also had full range of motion and intact sensation to light touch in all digits. Because the patient regained all function in the median nerve distribution, she was discharged from the hand service.

DISCUSSION

Few studies have described cutaneous lesions (eg, erythema, ulcers, blisters, and painless ulcers) in the median nerve, with most involving carpal tunnel syndrome (CTS).[4-6] In 2011, Foti et al[5] described releasing compression of the median nerve for treating cutaneous lesions caused by CTS, with resolution of the lesions with no recurrence. In another case, several weeks of topical treatment for skin lesions associated with CTS resulted in complete healing.[4] The findings of the current case reinforce the efficacy of nonsurgical treatment of cutaneous lesions. Furthermore, cutaneous lesions may develop after an injury proximal to the median nerve, opposed to distally in CTS.

The cause of cutaneous manifestations to the median nerve is still debatable. Some studies have attributed the lesions to hypoesthesia, which can result in repetitive strain of the nerve.[5,6] A leading theory describes compression of autonomic fibers and sympathetic vasospasm.[5,6] In our case, the first explanation is unlikely because sensation was intact in the median nerve distribution. However, closed reduction for treating the fracture may have resulted in injury to the median nerve, possibly leading to sympathetic vasospasm and subsequent cutaneous manifestations.

Our patient was initially thought to have isolated AIN nerve injury, without evidence of median nerve sensory or motor palsy. With the cutaneous manifestations in the median nerve distribution (palmar digital cutaneous branch), it was postulated that her injury was to the posterior aspect of the median nerve, proximal to AIN branch. An injury to the posterior aspect of median nerve would cause both an AIN motor deficit and median nerve sensory loss, without median motor loss.[7] Although our patient did not report sensory loss, it is possible that she was unable to verbalize subtle sensory loss in her fingertips owing to her young age.

In children, nerve palsy after supracondylar fractures are thought to be transient, with self-resolution in 2 to 3 months.[8] Further investigation and surgical exploration may be required if symptoms do not resolve within this time.[8] The blisters in our patient resolved simultaneously with the symptoms of AIN palsy. However, further studies are needed to assess the relationship between cutaneous lesions and injuries to the median nerve at proximal locations. We believe the results of the current case can help guide research on causes of these rare manifestations and appropriate treatment.

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Brachial Artery Vasculitis and Associated Stenosis Presenting as Elbow Pain in a 16-Year-Old Soccer Player: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Chronic vascular occlusion in the upper extremity can result from repetitive trauma, atherosclerosis, proximal embolic events, hypercoagulable states, and systemic diseases such as collagen vascular disease and vasculitis. Considerable functional impairment can result from these maladies; however, sometimes the condition develops slowly with minimal effect on the patient. We describe a 16-year-old soccer player with slow-progressing elbow pain and loss of range in motion caused by brachial artery vasculitis and resultant brachial arterial stenosis. Although vascular insults and lesions rarely cause chronic vascular occlusion, physicians should consider this possibility in patients with localized pain or atrophy, especially if the condition develops slowly.

Keywords: Elbow, Vasculitis, Pathologic Constriction, Soccer, Adolescent

INTRODUCTION

Elbow pain in adolescent athletes has a wide differential diagnosis. Common findings include overuse and acute trauma such as tendon sprains, ulnar collateral ligament injuries, osteochondritis dissecans lesions, fractures, and dislocations.[1] However, atypical causes such as tumors, infections, and vascular problems should not be overlooked. Vascular problems causing elbow pain can include posttraumatic changes, endofibrosis, vasospasm, peripheral vascular disease, vasculitis, arteriovenous malformations, and compression from tumors.

In the current case, our adolescent patient presented with impairment of his brachial artery with considerable stenosis that caused considerable pain with activity. We examined anatomical and pathophysiological factors that led to his symptoms, common complications of the disorder, and available treatment options.

CASE REPORT

A 16-year-old male soccer player presented to the student health sports medicine clinic (SHSMC) of his high school with chronic intermittent pain in his left elbow. He was left-hand dominant and self-identified as Congolese. He reported experiencing this pain during throwing activities (eg, throwing the ball from the touchline), with an intermittent locking sensation. The patient thought the elbow pain may have started after a soccer-related fall "many years ago." He did not seek care at the time of the fall.

At his initial visit to the SHSMC, the findings of the physical examination revealed no obvious deformity. On palpation, a tender area (7 cm by 4 cm) of fullness was present without distinct margins over the anterior-

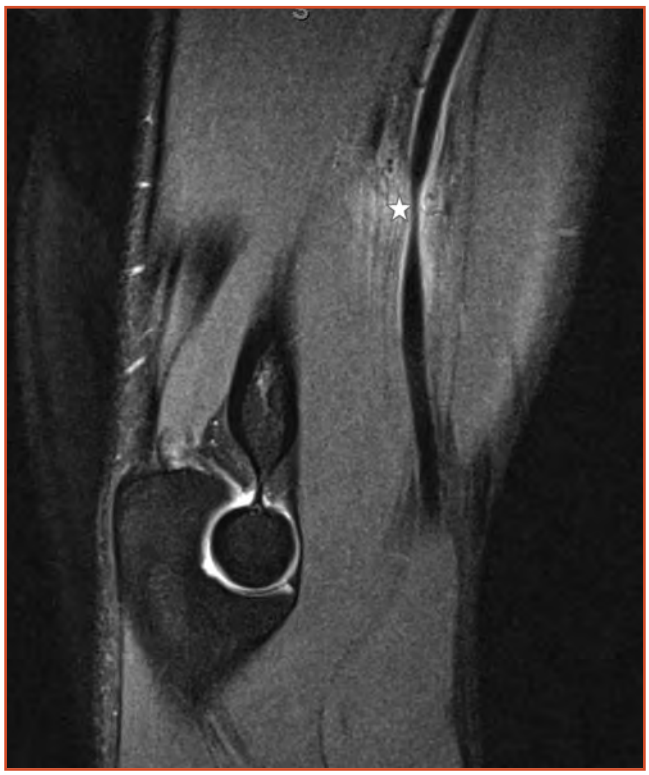

Figure 1. Sagittal view of magnetic resonance imaging of left arm, showing stenosis of brachial artery.

medial brachium proximal to the elbow. Elbow extension was limited (10° less than the right side), but pronation and supination had complete range of motion. He had no ligament instability, with atrophy generalized of the left arm and forearm.

Findings of radiographs of the elbow and humerus were normal. Non-contrast magnetic resonance imaging (MRI) revealed a brachial artery stenosis with potential focal vasculitis, with involvement of the median nerve. Laboratory test results revealed that blood count, metabolic panel, antinuclear antibodies, C-reactive protein levels, and erythrocyte sedimentation rate were normal. Afterward, a Doppler ultrasound ordered. The patient was referred to specialists from pediatric surgery and vascular surgery for further upper-extremity evaluation. Findings from the magnetic resonance arthrogram revealed brachial artery stenosis (Figures 1 and 2).

Vascular surgery specialists diagnosed brachial artery vasculitis or trauma with resultant arterial stenosis. The patient developed collateral vessels and had promising blood circulation. At his last clinic visit, we noted diffuse atrophy of the elbow muscles likely owing to inactivity. Because symptoms were minimal, observation was recommended.

DISCUSSION

Our diagnosis suggests vasculitis as a cause of the patient's symptoms; however, social factors may have delayed prompt and efficient evaluation. Some causes of vasculitis include Behçet disease, Buerger disease,

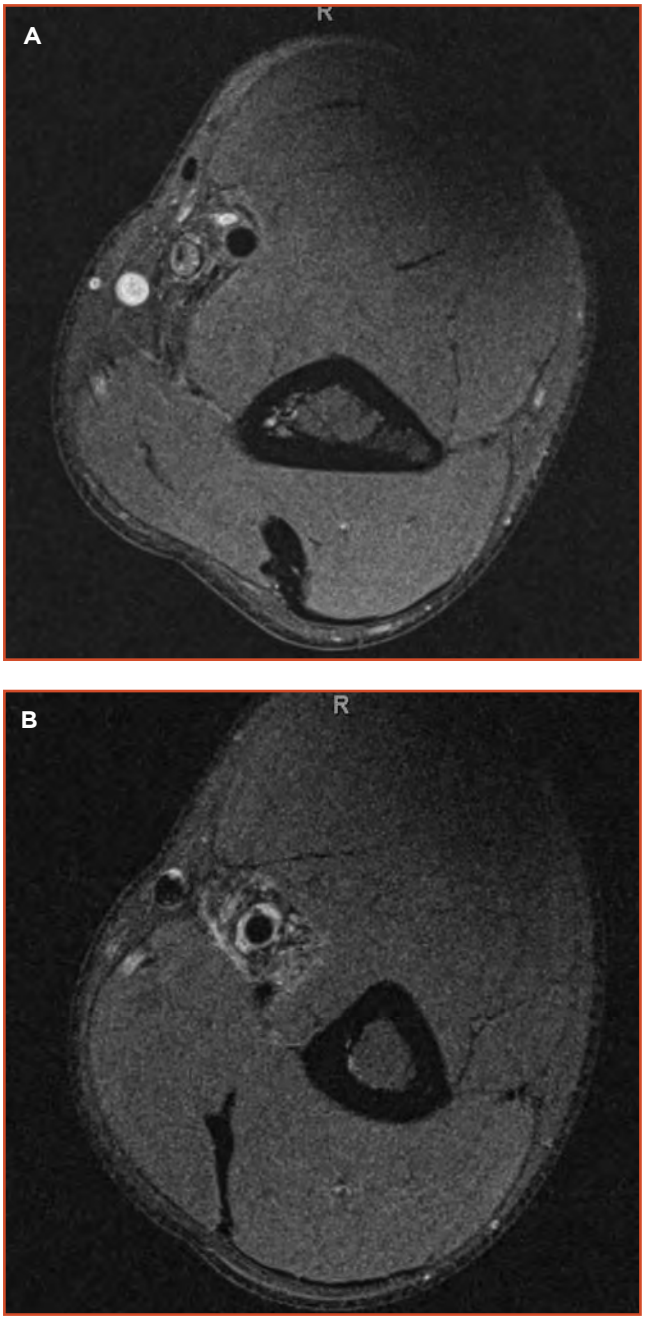

Figure 2. Axial view of magnetic resonance imaging of the arm through the zone of stenosis. A) Normal brachial artery girth proximal to the area of stenosis. B) Stenosed brachial artery.

Churg-Strauss syndrome, cryoglobulinemia, giant cell arteritis, granulomatosis, Henoch-Schonlein purpura, Kawasaki disease, and Takayasu arteritis.[2]

Although our findings of workup did not reveal active inflammation or vasculitis, several causes may have led to the noted inflammation in the MRI. In 1961, one report described localized blunt trauma to the area with an initiation of the coagulation cascade, which resulted in a local inflammatory reaction leading to intimal stenosis.[3] A single-center study of 569 joint and paraarticular fractures found an incidence rate of 1.5% of vascular injuries.[4] Because our patient had no evidence of a

previous fracture in the area, the noted brachial artery stenosis was probably not caused by trauma.

In the current case, our patient grew up in the Congo region of Africa. Subsequently, another possible mechanism of insult is an insect bite from spiders and scorpions or sting from honeybees and yellow jackets. Multiple reports have described that spider bites can result in cutaneous loxoscelism, initiating sphingomyelinase D and ANCA activation. This can cause vasculitis locally and on a systemic level.[5]

Vasculitis can produce symptoms related to progressive narrowing of the arterial lumen. A diameter reduction of 50% or a cross-sectional area reduction of 70% reveal a notable hemodynamical lesion. These lesions produce a pressure drop across the stenotic area where collateral blood vessels supply the distal arterial bed. Symptoms include exercise-induced fatigue because the demand for blood exceeds the supply.[6] Providentially, our patient was relatively asymptomatic and developed abundant collateral circulation. However, the development of vasculitis in other arterial locations is feasible; thus, a follow-up visit was recommended.

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Posttraumatic Radioulnar Synostosis in a 63-Year-Old Man With Isolated, Non-Displaced Ulna Shaft Fracture: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Radioulnar synostosis in adults is a rare pathological fusion of the two forearm bones. When seen in adults, it is an uncommon complication after a minimally displaced ulnar fracture. We describe a 63-year-old man who presented with radioulnar synostosis after closed treatment of a left ulna midshaft fracture sustained 7 months earlier. At 10 weeks after presentation, the patient underwent radioulnar synostosis excision with nonsteroidal adjuvant therapy. At 18 months postoperatively, no pain was noted, with complete degree of flexion. Healthcare professionals should consider treating radioulnar synostosis with an operative excision in adults as initial management when forearm pronosupination is affected.

Keywords: Radioulnar, Synostosis, Heterotrophic Ossification

INTRODUCTION

Synostosis is defined as the fusion of two bones, with radioulnar synostosis involving the fusion of the radius with the ulna. Radioulnar synostosis is a debilitating condition that prevents pronosupination of the forearm. In adults, radioulnar synostosis is an uncommon complication after traumatic injuries to the forearm, with incidence rates reported between 0% and 9.4%.[1]

Multiple risk factors have been identified with the initial forearm injury. These factors include fractures to both the ulna and radius at the same level, Monteggia fracture, severe comminution and displaced bone fragments of radius or ulna, extensive soft-tissue injury of the forearm, trauma to the interosseous membrane (ie, penetrating trauma), and hematoma formation in the radioulnar interval.[2] We present a man with an isolated non-displaced fracture of the distal third of the ulna, complicated by the development of radioulnar synostosis and loss of forearm rotation.

CASE REPORT

A 63-year-old man was referred to our outpatient orthopaedic clinic owing to radioulnar synostosis after closed treatment of a left ulna midshaft fracture sustained 7 months earlier. Examination findings of the left forearm revealed no obvious deformity or tenderness to palpation. Because of the radioulnar synostosis, he had considerably diminished rotation of the forearm with only 10° of arc motion in supination and pronation from neutral position. Range of motion was normal at the wrist and elbow. Distal circulation, sensation, and motor function were intact. Radiograph findings showed a subacute isolated non-displaced fracture of the distal ulna with extensive regional callus formation (Figures 1A and 1B).

At 10 weeks after presentation, the patient underwent excision to remove heterotopic ossific bone bridging the interosseous membrane of the left forearm. A volar Henry approach was used to allow sufficient exposure of the heterotopic bone. Surgical treatment was decided based on the severely limited motion and the possibility of not regaining motion if the procedure was delayed further. The bone appeared mature on radiographs across multiple imaging studies, with little to no change in radiographic appearance during 4 months. Heterotopic bone bridging the distal radioulnar interval was removed in fragments, and restoration of supination and pronation was achieved with gentle manipulation of the arm. No complications occurred intraoperatively, and the patient was discharged the same day. He was prescribed for 800 mg of oral ibuprofen, three times a day.

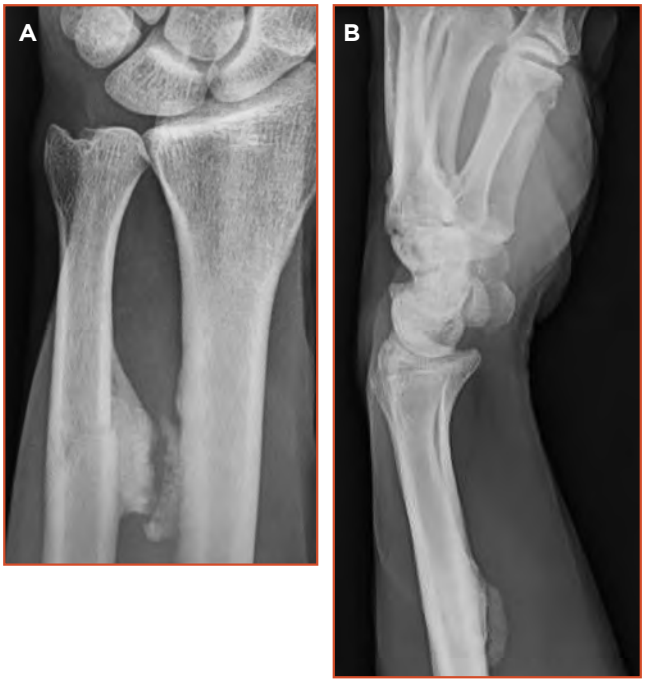

Figure 1. Radiographs of the left forearm, showing an isolated non-displaced fracture of the distal third of the ulna with extensive callus formation invading the interosseous space. A) Anteroposterior view. B) Lateral view.

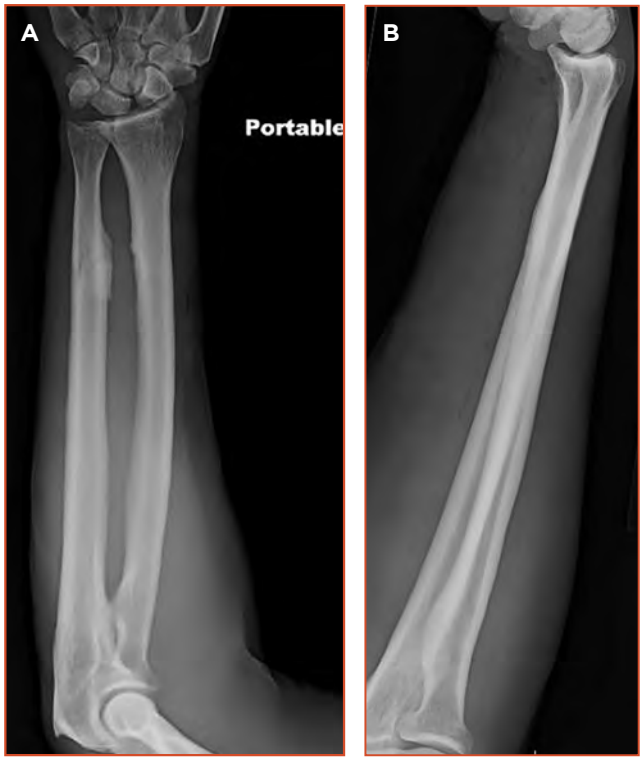

Figure 2. Radiographs of the left forearm after excision of the radial ulnar synostosis. A) Anteroposterior view. B) Lateral view.

At 10-days postoperatively, improved forearm range of motion was observed with 45° arc motion during pronation and supination. Therapy was started immediately. He had no restrictions and was not splinted. Radiographs at this time showed no interval osseous complication. Ibuprofen use was discontinued. At another follow-up 6 weeks later, he showed marked improvement, with increased range of motion from a 0° to 45° arc of pronosupination. He returned to work full time (Figures 2A and 2B). At 18 months postoperatively, the patient had 60° arc of pronation and supination. He could completely flex the elbow but lacked 15° to full extension. No pain was noted.

DISCUSSION

Radioulnar synostosis requires aggressive surgical treatment. Failla et al[3] recommended waiting at least 12 months after manifestation to avoid operating on a metabolically active synostosis. Operative treatment may be warranted in patients with compromised range of motion, in which delays may lead to severe, irrecoverable stiffness.[4] Despite excision, range of motion may not be regained.

In the current case, surgical resection of the heterotopic bone was undertaken because the forearm was completely ankylosed. Furthermore, no improvement was noted in 4 months. Study findings have shown that earlier resection of heterotopic bone may be indicated, with better range of motion and no increase in surgical complication or recurrence.[4] Numerous surgical techniques have been documented that involve using intraoperative flaps and grafts to avoid recurrence; however, no method has shown superior results.[2] Surgical success depends on return of sustained forearm rotation, and an arc motion greater than 60° is required to perform nearly all activities of daily living.[5] Nonsteroidal adjuvant therapy is a common treatment after synostosis excision and may decrease heterotopic bone formation after total hip replacement.[6]

Multiple medications can be used to lessen or prevent the development of heterotopic ossification. In the current case, we chose ibuprofen because it is easily obtained over the counter, has manageable side effects, and was tolerated by the patient. The duration of prophylaxis in studies ranges from 6 weeks to 12 weeks.[6] Because no recurrence of heterotopic bone was seen on our patient's follow-up radiographs, the decision was made to stop prescribing ibuprofen. We had promising results with excision followed by 8 weeks of nonsteroidal adjuvant therapy and intense rehabilitation.[7] At 18 months postoperatively, the symptoms were resolved, with a 60° arc of motion, no pain, and return to full-time work.

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Radiographic Features and Remodeling of Proximal Radius Osteomyelitis in a 14-Month-Old Child With Long-Term Follow-Up: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

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

ABSTRACT

Pediatric primary hematogenous osteomyelitis is uncommon. Studies have been mainly small case series with limited clinical and radiographic follow-up. We present a child with primary hematogenous osteomyelitis and osteolysis of the proximal radius. Inflammatory laboratory values were normal, and blood and elbow aspirate cultures were negative for osteomyelitis. Diagnosis was made by findings of magnetic resonance imaging. The patient was successfully treated with intravenous antibiotics. At 4-year follow-up, she had normal range of motion and near symmetric proximal radial morphological features radiographically. To our knowledge, this is the most long-term radiographic follow-up of a patient with spontaneous osteomyelitis. The reported findings can help guide surgeons in treating this potential hand condition in children.

Keywords: Osteomyelitis, Child, Hand, Radius

INTRODUCTION

Pimary hematogenous osteomyelitis in children is uncommon. Patients can present with acute (< 2 weeks) or subacute (> 2 weeks) symptoms, which typically include pain and swelling at the site of infection and difficulty moving the affected limb. Many organisms have been implicated, although *Staphylococcus aureus* is the most common.[1] Diagnosis can be challenging; however, results from laboratory tests and advanced imaging can aid in the diagnosis.

To our knowledge, only one case report has presented long-term radiographic follow-up after treatment of hematogenous osteomyelitis[1]. We describe a patient with 4-year follow-up who initially presented with a diagnosis of nursemaid's elbow that was later found to be proximal radius osteomyelitis.

CASE REPORT

A 4-month-old infant presented to our institution with pain in her left elbow. She was initially seen by her pediatrician, with a suspected diagnosis of nursemaid's elbow. Her pediatrician performed a reduction maneuver and referred her an orthopaedic hand surgeon owing to her persistent pain. She was otherwise healthy.

On presentation to our clinic 2 weeks after her visit to the pediatrician, the patient had no fever and was diffusely tender around the elbow during examination. She could move her elbow with mild discomfort. She was able to use her left arm when playing with toys. She had no notable erythema or effusion around her elbow, and radiograph findings obtained at the time of presentation were normal. She was placed in a longarm cast to treat presumed persistent pain due to nursemaid's elbow. Family history revealed multiple siblings with nursemaid's elbow. There were no recent infections, travel outside of the country, or infectious exposure.

At 2-week follow-up, she had increased swelling and tenderness in her left elbow. Radiograph findings revealed lytic destruction along the proximal aspect of the radius with associated periosteal reaction (Figures 1A and 1B). She was admitted from the clinic to the pediatric department. On admission, her laboratory values were as follows: white blood cell count (WBC), 8.2 x10^9/L (8200 µL); erythrocyte sedimentation rate (ESR), 2 mm/h; and C-reactive protein (CRP), < 28.5714 nmol/L (< 3 mg/L). The normal ranges for each value are as follows: WBC, 4.5 to 11 x10^9/L (4,500 to 11,000 µL); ESR, 0 to 20 mm/h; and CRP, < 28.6 nmol/L (< 3 mg/L).

Contrast-enhanced magnetic resonance imaging (MRI) were obtained of the proximal radius and surrounding soft tissues (Figures 2A through 2C).

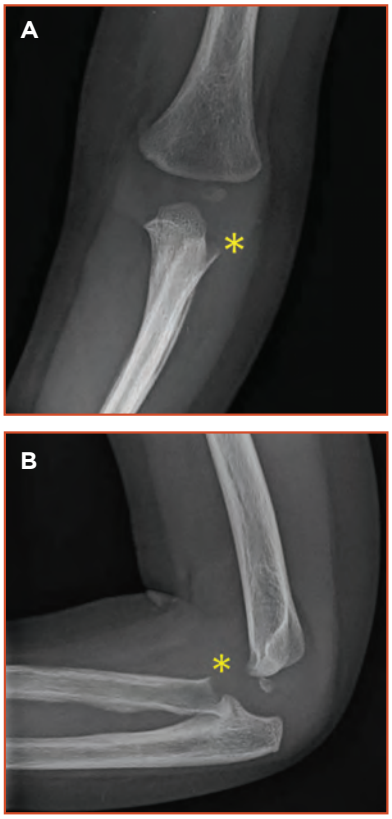

Figure 1. A) Anteroposterior and B) lateral radiographs at time of admission, showing osteolysis of the proximal radius (asterisk).

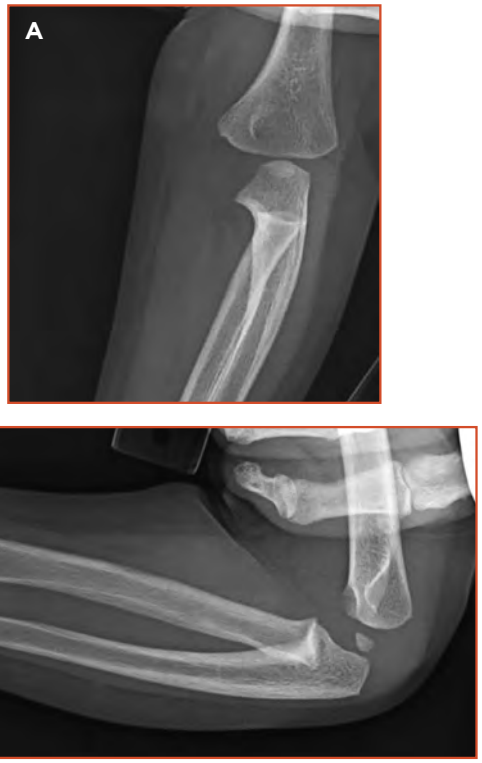

Figure 3. A) Anteroposterior and B) lateral radiographs at 3-month follow-up, showing remodeling of the proximal radius with persistent dysmorphic appearance.

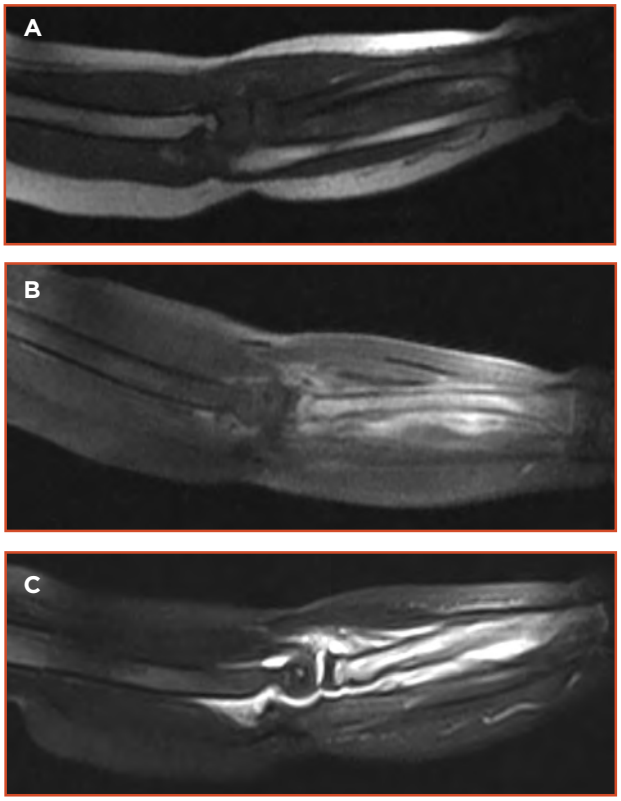

Figure 2. A) T1-weighted, pre-contrast sequence of magnetic resonance imaging showing hypointensity in the proximal radius. B) Hyperintense signal on post-contrast T1 sequences in the proximal radius and surrounding soft tissues, suggestive of osteomyelitis. C) Sort TI-inversion recovery sequences also showing a hypointense signal.

Aspiration of the left elbow joint was performed, which revealed a total nucleated cell count of 4100 with 90% segmented neutrophils and no crystals. Blood and synovial fluid cultures revealed no growth after 14 days. Subsequently, proximal radius osteomyelitis was suspected and the patient underwent a 6-week course of intravenous cefazolin.

The patient followed-up annually, with serial elbow radiographs obtained at each visit to monitor the progression of the lytic destruction of her proximal radius. By 3 months from onset of symptoms, she had complete restoration of elbow motion. There was persistent dysmorphic appearance on radiographs; however, the prior periosteal reaction had mineralized and matured (Figures 3A and 3B). The dysmorphic proximal radius continued to remodel. By 4 years, she had complete resolution radiographically with near symmetric appearance and appropriate radial head ossification compared to the uninjured elbow (Figures 4A through 4D). She had complete active range of motion in her affected elbow (Figures 5A through 5D).

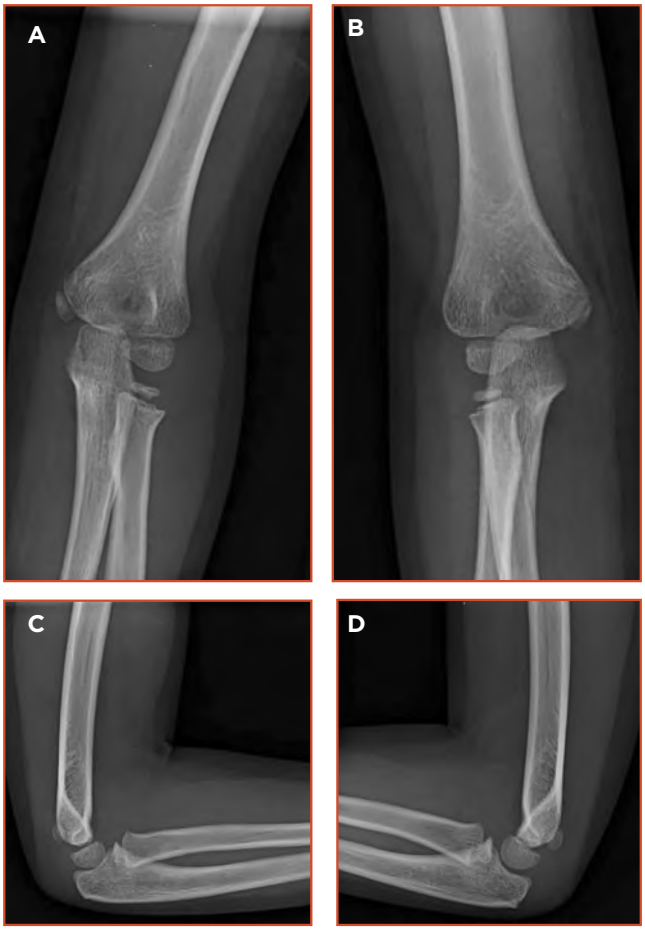

Figure 4. Radiographs of the left elbow at 4-year follow-up, showing remodeling and ossification of the radial head in A) anteroposterior view and B) lateral view. The uninjured right elbow is shown in C) anteroposterior view and D) lateral view.

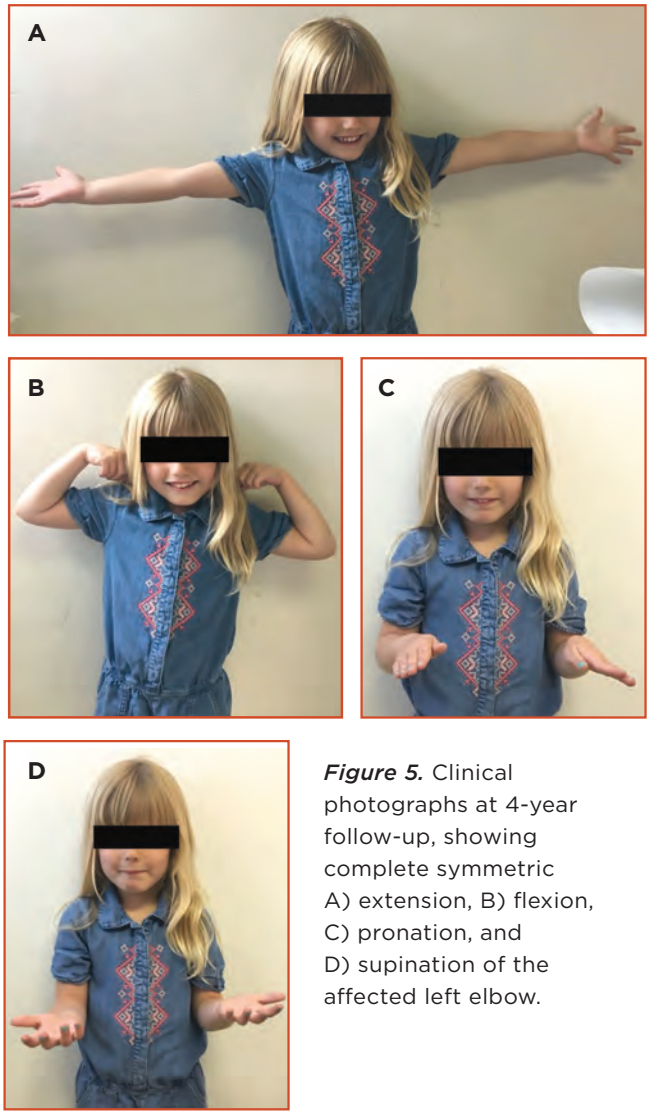

Figure 5. Clinical photographs at 4-year follow-up, showing complete symmetric A) extension, B) flexion, C) pronation, and D) supination of the affected left elbow.

DISCUSSION

Spontaneous osteomyelitis in children is uncommon.[2] Acute forms present with rapid onset and progression, whereas subacute forms are defined by symptoms lasting more than 2 weeks without acute symptoms.[3,4] The pathological features are multifactorial and develop from a combination of decreased host resistance and increased bacterial virulence.[1] Children are theoretically more susceptible owing to their rich periosteal vasculature, potentially resulting in higher risk of infection from transient bacteremia compared to adults.[5]

Up to 63% of pediatric cases are preceded by blunt trauma, which suggests that a subperiosteal hematoma may act as a nidus for infection or subperiosteal abscess.[5] Direct inoculation of bone has also been described.[6] Spontaneous osteomyelitis tends to affect long bones. The tibia is most commonly affected (39% to 83%) followed by the femur, radius, ulna, and humerus.[5,7] However, Spyropoulou et al[1] found that the spine was most often affected in a series of 65 patients in Switzerland.

Several pathogens have been implicated in primary osteomyelitis. Children between the ages of 6 months and 4 years have a higher prevalence of *Kingella Kingae,* whereas children older than 4 years tend to present with *Staphylococcus aureus.*[1] *Mycobacterium tuberculosis, Streptococcus, Pseudomonas, Haemophilus influenzae,* and coagulase-negative *Staphylococcus aureus* are less common but have been implicated in hematogenous osteomyelitis.[1,8,9] Negative blood cultures are not uncommon, however, and the incidence varies widely in studies.[1,3-5,7,8,10] In the series by Labbé et al[5] of 450 children followed for 20 years, blood cultures were negative for osteomyelitis in 20% of patients. In a review by Ezra et al[10] of 16 patients, 100% of cases had negative blood cultures while other series have reported 1.7% incidence of negative blood cultures. Soft-tissue and intramedullary cultures can also be collected, but were found to grow *Staphylococcus aureus* in 25% of patients.[4]

Diagnosis of osteomyelitis in children can be challenging. Patients frequently present with vague extremity pain that progressively worsens with time.[7]

Pain with weight bearing or passive range of motion can make differentiating osteomyelitis from septic arthritis difficult, although both can occur simultaneously.[3,7] Laboratory studies including WBC, ESR, and CRP should be obtained with all patients. Multiple case series have demonstrated that ESR and CRP can be within normal limits in primary osteomyelitis.[4,5,7,8,10-12] Ezra et al[10] noted 5 and 2 patients of 16 total had elevated ESR and CRP, respectively. Similarly, Spyropoulou et al[1] found that 48% of patients (n = 65) presented with an elevated CRP, whereas 72% presented with an elevated ESR. In the current case, our patient presented without leukocytosis and normal ESR and CRP. The results of these studies call into question the sensitivity of systemic inflammatory markers in primary osteomyelitis in children.

In the early stages of primary osteomyelitis, radiograph findings may be normal. As the disease progresses, osteolysis at the site of infection and periosteal reaction become apparent.[3] Cortical thickening and a central radiolucent nidus are also frequently seen.[4] Osteomyelitis can be radiographically classified by location (ie, epiphysis, metaphysis, and diaphysis), periosteal reaction, and sclerotic margins.[12] MRI findings remain the gold standard for diagnosing osteomyelitis and are characterized by suppression of fatty marrow on T1 sequences with contrast enhancement following administration of gadolinium.[7] High intensity in the marrow and surrounding soft tissues observed on short TI-inversion recovery and T2 sequences are also common. Advanced imaging and ultrasound findings can also be helpful in determining the presence of a subperiosteal or Brodie abscess.

Intravenous antibiotics are the mainstay of treatment of primary hematogenous osteomyelitis. When a pathogen is identified, organism-directed therapy can be administered. However, cultures can be negative in many cases as discussed previously. Debridement should be considered in patients with a subperiosteal abscess, Brodie abscess, or septic arthritis, which can occur in up to 50% of cases with primary hematogenous osteomyelitis.[2,3,5,7,8]

Although the diagnosis and treatment have been frequently described, few case studies have discussed the recovery of patients with primary hematogenous osteomyelitis in children. In a study by Kao et al,[3] one patient presented with *Salmonella* Enteritidis that caused osteomyelitis of the distal formal epiphyseal. Treatment involved intravenous ceftriaxone and debridement, which resulted in complete healing and no growth arrest at 16 months postoperatively.

In the current case, our patient presented with primary hematogenous osteomyelitis of the proximal radius associated with normal laboratory findings of WBC, ESR, and CRP. It is unclear whether her infection was preceded by trauma or misdiagnosed as nursemaid's elbow. Radiograph findings revealed osteolysis of the proximal radius, which eventually remodeled to near-symmetric anatomical morphological features compared to her uninjured elbow. Healthcare professionals may benefit from the long-term findings of our patient, which show the healing and remodeling potential of children with this condition.

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Open Reduction and Internal Fixation for Treating Pertrochanteric Femoral Fracture Below a Hip-Resurfacing Implant in a 65-Year-Old Man: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Periprosthetic proximal and pertrochanteric femur fractures around a well fixed hip resurfacing implant present a challenge to orthopaedic surgeons, as they do not allow the most biomechanically favorable fixation constructs in patients with otherwise high-demand levels of physical activity. A 65-year-old man hit a tree while skiing. He presented to our emergency department with a right-sided pertrochanteric fracture of the proximal femur beneath an implant used in prior hip resurfacing. The patient underwent open reduction and internal fixation with intraoperative fluoroscopy-assisted manipulation to ensure fixation of the hip resurfacing. At 6-week follow-up, a slight varus collapse at the fracture was noted. We continued to monitor our patient and the fracture healed with no further complications. Proximal femur fractures distal to a hip resurfacing may progress to mild varus collapse with promising outcomes after 5 months.

Keywords: Femur, Trochanteric Fractures, Hip Resurfacing, Skiing

INTRODUCTION

Total hip arthroplasty is generally thought to have many disadvantages for treating younger, active patients with severe hip arthritis. Hip resurfacing has been proposed as an improved alternative procedure because it preserves the bone stock, has a large diameter head allowing for greater stability, improves biomechanics across the proximal femur with less stress shielding of bone, and allows patients to return to higher levels of physical activity.[1]

The most common proximal femoral fractures are extracapsular fractures. Most patients with this problem undergo surgical treatment. In the United States, about 125,000 extracapsular proximal femur fractures occur annually.[2] These fractures are generally categorized as stable versus unstable, based on the Jensen and Michaelson classification.[1] Unstable fractures can include an affected lateral wall, reverse obliquity pattern, and instability of the posteromedial cortex.[3]

Owing to the increasing number of hip resurfacing procedures performed to treat these younger, more active patients, we would predict an increase in periprosthetic fractures seen around implants placed in the proximal femur. However, few studies have reported on the subject. We present a 65-year-old man who underwent ORIF for treating a pertrochanteric femoral fracture distal to the implant used in hip resurfacing.

CASE REPORT

A 65-year-old man presented to our emergency department with a right-sided pertrochanteric femoral fracture. The patient struck a tree while skiing and was initially evaluated at an outside facility. Findings of radiographs revealed a pertrochanteric femoral fracture beneath the implant used in a prior hip resurfacing (Figure 1). He was transferred to our level 1 regional trauma center for definitive treatment. Before the ski-related injury, the patient's pain had improved since his index procedure. Normal findings of motor and sensory neurological functions were noted. He had returned to all activities, including skiing and riding his motorcycle. Regarding the patient's index hip resurfacing, no radiographs of his pre-, intra-, and postoperative treatment were available.

On physical examination, he held his right-sided hip in external rotation with a flexed knee, with a well-healed posterolateral incision. Motor and sensory

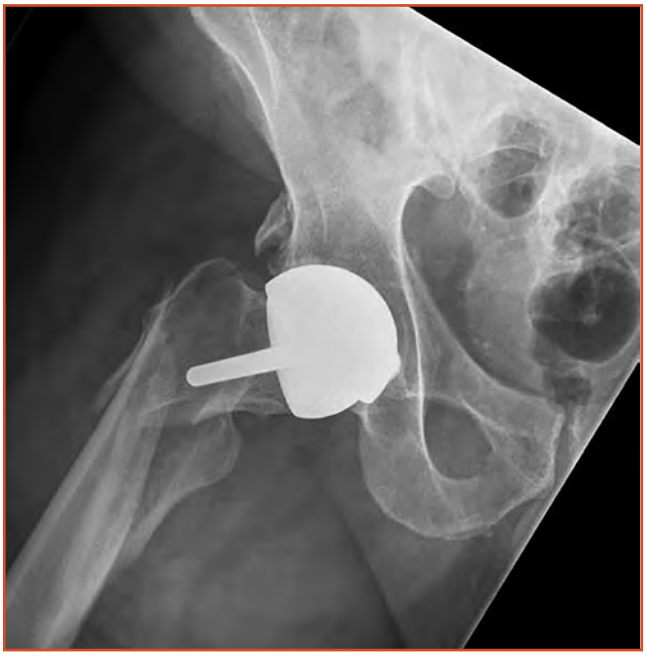

Figure 1. Anteroposterior radiograph of a right hip obtained at an outside facility, showing a displaced pertrochanteric femoral fracture distal to a well-fixed, hip-resurfacing implant.

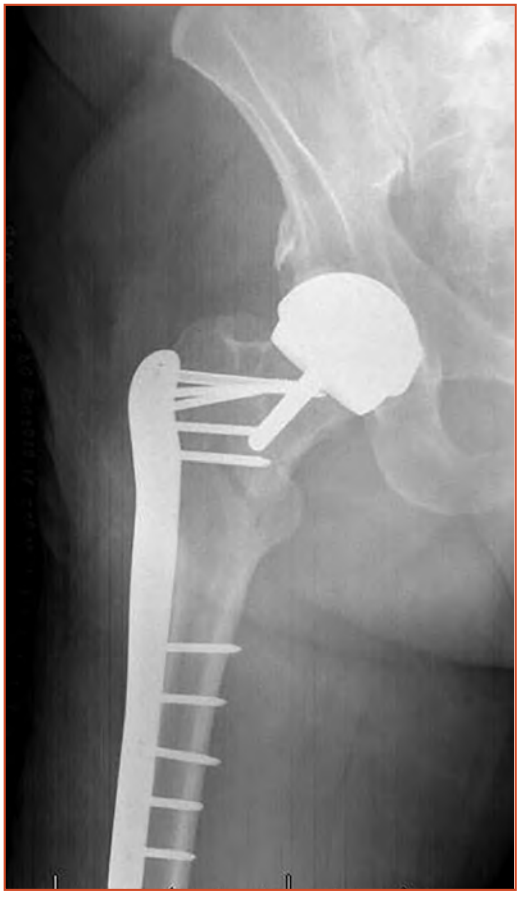

Figure 2. Immediate postoperative anteroposterior radiograph of the right femur, showing a well-reduced fracture with a lateral proximal femoral locking plate in place.

neurological functions were intact, and findings of vascular examination were normal. Radiographs revealed an unstable intertrochanteric femoral fracture, involving the lateral cortex and the lesser tuberosity, with the degree of comminution somewhat appreciated. The hip resurfacing implant was well aligned, with a slight level of valgus noted.

The patient was taken to the operating room and underwent ORIF in the lateral position. Fluoroscopy-assisted manipulation of the hip was used to ensure no loosening or instability of the hip-resurfacing implant. The hip was extended by pulling manually on the leg. The hip-resurfacing implant did not reveal any subluxation, dislocation, or play within the proximal femur. A standard lateral approach to the femur was used to ensure the hip capsule was not violated. Near-anatomical fixation was achieved by using a proximal femoral locking plate.

Because the hip-resurfacing implant was not loose and the patient was happy with his prior level of function, extramedullary fixation was performed to treat the fracture. Owing to the presence of the hip-resurfacing implant, intramedullary and cephalomedullary nailing or other fixation techniques placing large diameter fixed angle implants into the femoral neck were not possible. Total hip arthroplasty was not recommended because the patient functioned well after his prior fracture and the implant did not appear loose. The most proximal screws were drilled and placed free-handedly with nonlocking screws to avoid the hip-resurfacing implant (Figures 2 and 3). Postoperatively, the patient was discharged with posterior hip precautions and no weight bearing on his right leg.

At 2-week follow-up, he reported that he was doing well and radiographic findings were promising. His weight bearing progressed to touch down. At his 6-week follow-up, he reported he was still doing well, with no falls or complications at home. Findings of radiographs revealed mild varus collapse of his fracture without evidence of the hip-resurfacing implant loosening or dislocating (Figure 4). The patient maintained touch-down weight bearing until his 3-month follow-up, at which time the radiograph findings revealed a stabilized fracture. He also reported that he had been putting full weight on his leg. As such, he was progressed to full weight bearing. At 5-month follow-up, the patient had returned to all activities, including riding his motorcycle, and had no concerns. Radiograph findings showed stabilization of his varus collapse, no implant complications, and healing of his fracture (Figure 5).

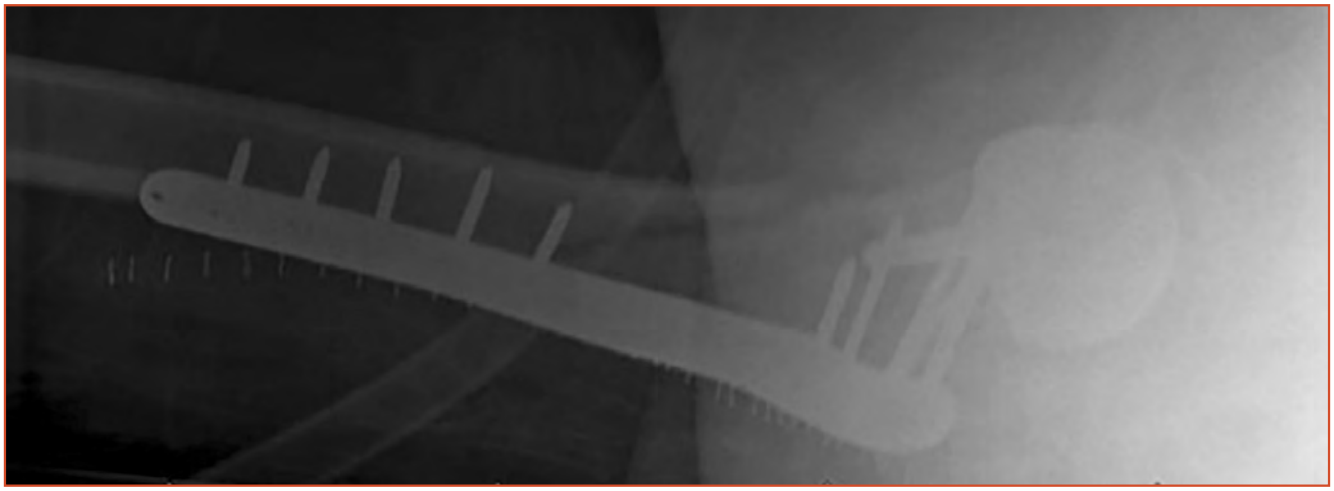

Figure 3. Immediate postoperative lateral radiograph of the right femur, showing a well-reduced fracture with a lateral proximal femoral locking plate in place.

Figure 4. At 6 weeks postoperatively, anteroposterior radiograph of the right femur shows mild varus collapse of the fracture without implant complications.

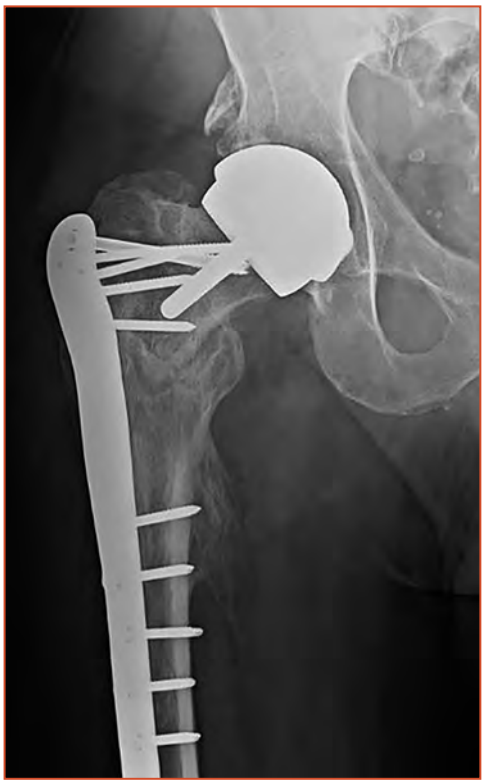

Figure 5. At 5 months postoperatively, anteroposterior radiograph shows a healing fracture, stabilization of varus collapse, and no implant complications.

DISCUSSION

Femoral neck fractures are known complications after hip resurfacing.[4] However, few cases of pertrochanteric femur fractures distal to a hip-resurfacing implant have been reported.[5-7] In one study, the fracture was in the diaphysis and treated using an intramedullary device.[4] Another case reported that the proximal fracture resulted in loosening of the prosthesis, which was treated using cerclage wiring and conversion to a revision total hip arthroplasty.[7]

In only two available reports, the implant was retained and the fracture was treated using a lateral femoral locking plate.[5,6] Interestingly, both of these cases included early and mild varus collapse, although still within acceptable alignment, without lateral cortex gapping and keeping the neck-shaft angle between 125˚ and 135˚. Neither case reported failure of either fracture fixation or hip-resurfacing implant. The patients successfully healed with no complications and returned to their levels of activity before the injury.

It is unclear why these periprosthetic fractures seem to settle into varus deformity and then heal. Our current case and the other two cases[5,6] all involved relatively unstable femoral fractures. Ideally, patients with fracture types are treated with intramedullary devices.[2,3] However, in patients with periprosthetic fractures around a well-fixed, hip-resurfacing implant, using an intramedullary device may not be a reasonable option to maintain the hip resurfacing. In the one fracture that resulted in a loose implant, conversion to revision total hip arthroplasty was performed to stabilize the fixation.[7] Using nonlocking screws proximally to avoid the hip-resurfacing implant changes the lateral proximal femoral locking plate from a pure-fixed angle device to somewhat of a hybrid-type construct, which may result in a varus collapse.

In our case and the other two,[5,6] these fractures settled early into an acceptable amount of varus deformity, healed, and all patients returned to previous levels of activity. However, more studies are needed on ORIF with lateral femoral locking plates for treating pertrochanteric fractures distal to a well-fixed hip-resurfacing implant. Further findings can help assess the biomechanical stability and long-term outcomes of the procedure. We believe the results of the current case can help guide research on appropriate treatment of these rare fractures.

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Recurrent Trigger Finger in the Early Postoperative Period: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

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

Postoperative complications of trigger finger, a type of tendon entrapment, are low, and there is little information regarding evaluation after a complication occurs. Recurrent trigger finger is a rare occurrence, but often requires additional procedures to relieve symptoms. Here we present a case of recurrent trigger finger in the immediate postoperative period after the patient developed a cyst distal to the A1 pulley and synovitis. The first procedure demonstrated a thickened and tight A1 pulley as well as synovitis around the tendon. The patient developed continued clicking and trigger symptoms distal to the A1 pulley at the level of the proximal interphalangeal (PIP) joint postoperatively. Findings of magnetic resonance imaging (MRI) revealed further synovitis distal to the A1 pulley and a cyst. After a second procedure, the patient's trigger symptoms resolved. Imaging, such as MRI, can be useful in the diagnosis of recurrent trigger finger and help identify the location of the recurrence.

Keywords: Trigger Finger Disorder, Synovitis, Hand, Postoperative Complications

INTRODUCTION

Trigger finger is a type of tendon entrapment in which the tendon experiences mechanical impingement owing to changes around the tendon or narrowing of the retinacular sheath.[1] The reported incidence is 2.6% in the American population and increases to 10% in patients with type 2 diabetes mellitus.[1-3] Complication rates in studies range from 1% to 40%, but the procedure is generally seen as low risk.[4] Recurrence rates have been between 0.3% and 2.6%, and slow recovery of motion is the most common complication.[2-5]

Patients with recurrence of trigger finger usually undergo a second procedure to resolve symptoms. Often the cause of the recurrence is unknown.[5-7] Magnetic resonance imaging (MRI) scans can be useful in the workup of patients with postoperative complications, and the findings may suggest potential recurrence.[7,8]

CASE REPORT

A 58-year-old, right-hand dominant woman presented with symptoms of trigger finger in her right index finger. She reported symptoms had been occurring for 2 months before presentation. The patient's relevant medical history included type 2 diabetes mellitus that was treated with insulin, hyperlipidemia, and hypothyroidism. Her surgical history included carpal tunnel release of both hands and release of the first dorsal extensor compartment for treating de Quervain's tenosynovitis of both hands. Her medications included insulin aspart, empagliflozin, metformin, atorvastatin, and levothyroxine. The patient had no reported allergies to medications or family history of chronic illness or trigger finger. The patient worked part-time and reported no tobacco or alcohol use.

She initially elected to undergo conservative management to treat trigger finger in the index finger of her right hand, with non-steroidal anti-inflammatory drugs (ibuprofen), rest, ice and observation. The patient's pain, caused by locking of the index finger, worsened; subsequently, open A1 pulley release was recommended. Intraoperatively, the pulley was thickened and a considerable amount of synovitis around the flexor tendons was observed. Tenosynovectomy was performed as a part of the procedure. During the procedure, the patient was asked to actively flex and extend her finger. No catching or locking was noted intraoperatively after the A1 pulley was released.

At 2 weeks postoperatively, her incision was healing. She reported no pain and could fully flex the finger; however, when the finger was extended completely, some clicking was noted at the level of the proximal interphalangeal (PIP) joint. The patient was instructed on range of motion exercises and scheduled a follow-up appointment 4 weeks later. During this second postoperative visit, the patient's incision was healed but

she developed pain along the dorsum of her finger and described continued catching and clicking at the PIP joint with extension. Physical examination findings were notable for right index finger swelling, catching and clicking at the PIP joint, and crepitus when the flexor sheath was palpated. No signs of infection were noted. A plain-film radiograph showed soft-tissue swelling but no other abnormalities. Findings of an MRI scan showed fluid from the mid-palm to the mid-portion of the middle phalanx and possible mass around the tendon at the level of the A2 pulley and the proximal third of the proximal phalanx (Figure 1).

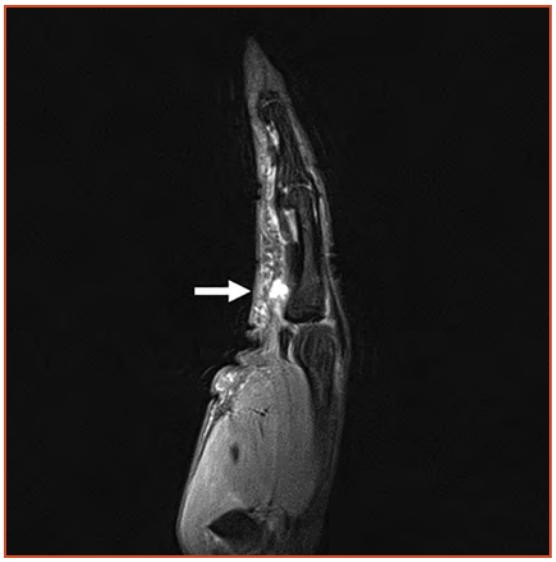

Figure 1. Magnetic resonance imaging of sagittal view depicting the location of the synovial cyst (white arrow) in the region between the A2 and A3 pulleys. There is also increased signal intensity around the tendon corresponding to the fluid and synovitis seen intraoperatively.

At 2 months postoperatively, the patient's symptoms persisted. Owing to that and the MRI findings, she agreed to undergo surgical exploration of the area with extension distally. Intraoperatively, a small incision was placed in the A2 and A3 pulleys to further examine the tendons. A synovial cyst was found along the radial border of the tendon, and synovitis was noted proximally and distally in the region corresponding to the fluid seen on the MRI (Figure 2). The synovitis and cyst were debrided and sent for permanent pathological examination. The A1 pulley was still divided, with some scar formation.

At 2 weeks after the second procedure (10 weeks after the first), the patient reported minimal pain in the area. She reported no locking or clicking of the digit. Results of the final pathological report showed synovial tissue with mild chronic inflammation. At about 8 weeks after the second procedure, the patient reported no recurrence of triggering symptoms and improved range of motion of the digit.

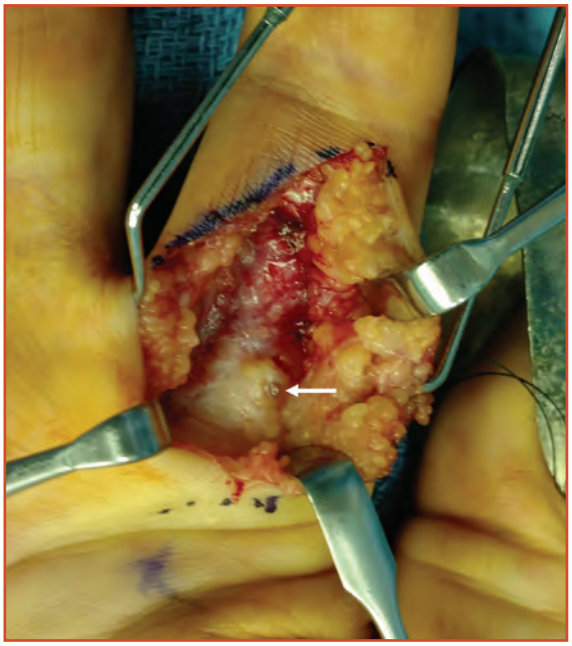

Figure 2. Intraoperative photograph, showing synovial cyst (white arrow) adherent to the flexor tendons on the radial aspect, under the A2 pulley.

DISCUSSION

Recurrent trigger finger is rare but can occur in the immediate postoperative period.[1,4] Younger age and insulin-dependent diabetes are risk factors for recurrence.[4] In addition, percutaneous release, compared to open release, has resulted in higher recurrence rates.[9] The most commonly cited reason for recurrence is idiopathic; however, other reasons include incomplete release, distal mechanical obstruction, and further development of scar or synovitis around the tendon or remaining, released A1 pulley.[5,10]

Our patient developed synovitis and a cyst around the tendon that caused triggering symptoms distal to the A1 pulley. Although synovial tissue was present and debrided in the first procedure, the timing of the development and presence of the cyst is unknown. Further synovitis had developed in the area that had been previously debrided. The A1 pulley is the most commonly implicated pulley in trigger fingers, but mechanical obstruction can also occur either proximal or distal to the A1 pulley.[1] Often there is no clear reason for recurrence, yet patients may require a second procedure to treat symptoms.

Although MRI findings have been used to diagnose primary trigger finger, results of the current case show its usefulness in patients with symptom recurrence.[7,8] Furthermore, the imaging findings can help plan the location and direction of the second procedure.

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Delayed Below-Knee Amputation for Treating Open Pantalar Dislocation With Extruded Talus: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Pantalar dislocation occurs when the talus is dislocated from the ankle, subtalar, and talonavicular joints. An extruded talus is seen when the talus protrudes out of an open wound with little or no soft-tissue attachment. We describe a 62-year-old man who underwent debridement and irrigation for treatment of a pantalar dislocation with an extruded talus. About 1 year postoperatively, he underwent a below-knee amputation. This case highlights the difficulties and complications associated with this injury.

Keywords: Talus, Pantalar Dislocation, Amputation, Foot

INTRODUCTION

Diagnosis of pantalar dislocation, also termed dislocation of the talus, is disputed amongst physicians. This injury is characterized by talus dislocation from the ankle, subtalar, and talonavicular joints. The dislocation can occur without fracture or, more commonly, with minor fracture fragments. Pantalar dislocations are frequently open injuries, referred to as an extruded talus when the bone comes out of the open injury with little or no soft-tissue attachment.

Open pantalar dislocation with talus extrusion is rare. In 2010, Burston et al[1] found between 27 and 45 cases in English-language studies. According to the authors, a precise number of talus extrusions could not be determined because the diagnosis may not have been correct in some reports. This further shows the confusion about what constitutes this injury. For instance, a Hawkins type III talar neck fracture with an extruded talus body is not equivalent to a pantalar dislocation in which there is no major talus fracture.

When the talus is extruded, treatment options include talectomy, fusion, or reimplantation of the bone with internal or external fixation. Studies have also described talus prosthetic replacement.[2] Considerable rates of morbidity are frequently associated with open pantalar dislocation, with common reports of infection, posttraumatic arthritis, and osteonecrosis. In the current case, we describe open pantalar dislocation in a 62-year-old man who underwent reimplantation of the talus.

CASE REPORT

A 62-year-old man fell 20 ft when the wing detached from his ultralight glider. He was transported in stable condition to our hospital with an open pantalar dislocation and extruded talus. The patient had adequate circulation to the foot and a palpable pulse of the dorsalis pedis artery. He had a tingling sensation in the foot but no obvious sensory deficit. Little soft-tissue was attached to the talus, which was grossly contaminated with dirt and grass (Figures 1 and 2A through 2C). On arrival to the emergency department,

Figure 1. A clinical photograph shows the patient's ankle wound and contaminated talus extruded posteromedially.

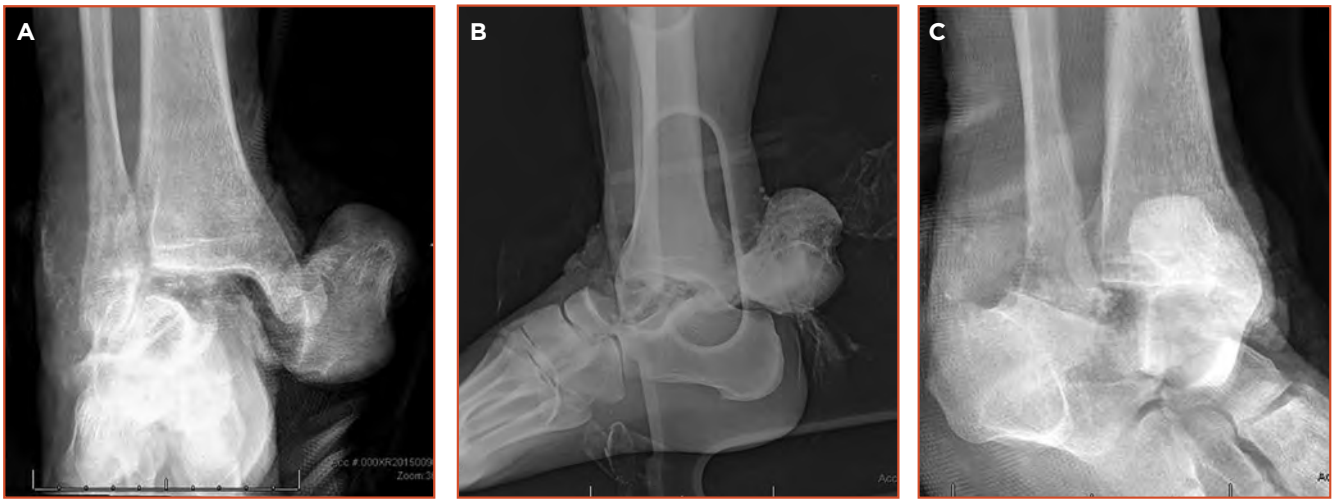


Figure 2. Ankle radiographs show dislocated and extruded talus. A) Anteroposterior view. B) Lateral view. C) Mortise view.

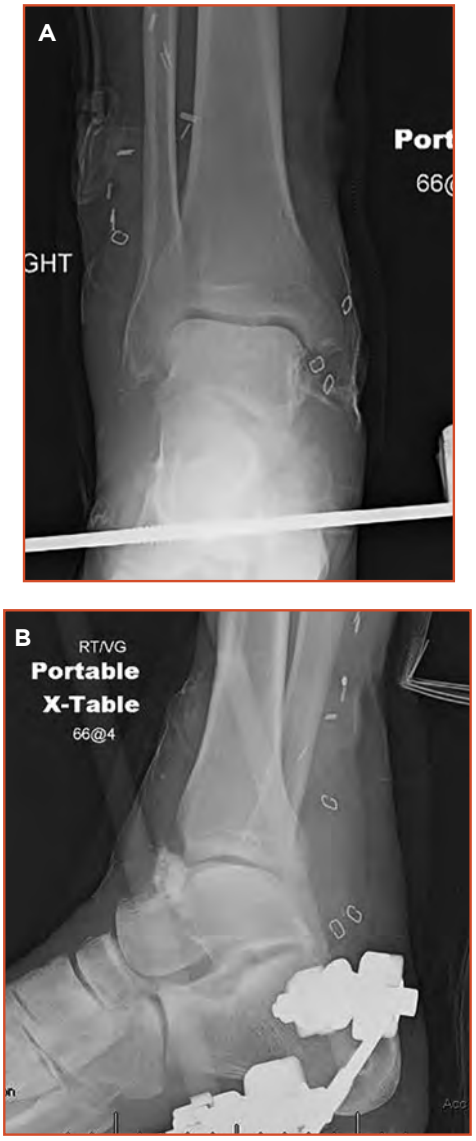


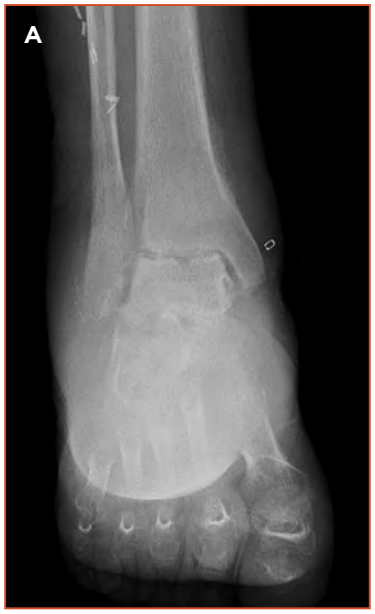
Figure 3. The talus has been reduced and an external fixator applied. Antibiotic beads are visualized anterior to the joint on the lateral view. A) Anteroposterior view. B) Lateral view.

he received intravenous gentamicin, penicillin, and cefazolin. We performed debridement and irrigation to treat the wound and bone. Ten liters of saline was used for irrigation, during which we immersed the bone briefly in a dilute betadine solution. The talus bone protrusion was reduced, and an external fixator was placed (Figures 3A and 3B). Because the 12-cm wound could not be completely closed, a 2 cm by 2 cm area of exposed bone and joint remained.

For the next 9 days, the patient returned to the operating room to undergo irrigation and debridement (one every 3 days). Antibiotic-infused cement beads (Simplex P Bone Cements, Stryker, Kalamazoo, MI) containing vancomycin and tobramycin were placed in the wound to prevent infection.

At 14 days after his injury, the patient underwent a fifth operation. A plastic surgeon applied a sural fasciocutaneous reverse flap to cover the remaining defect. Because the flap was unsuccessful, the patient underwent a rotational flap procedure. The external fixator was also removed. After 2 months, he required one more debridement to treat a small area of wound breakdown. Ultimately, the patient underwent eight surgical procedures after the injury.

At 11 months after his injury, he continued to have a stiff, swollen foot. He had undergone physical therapy and a trial of an ankle-foot orthosis. Radiographic findings did not reveal a Hawkins sign, suggesting avascular necrosis (Figures 4A and 4B). Results of clinical evaluation revealed chronic skin changes from lymphedema (Figure 5). No evidence of infection, drainage, or erythema was noted. Laboratory studies showed the following values: white blood cell count, 6.6 x 10^9/L; erythrocyte sedimentation rate, 22 mm/h; and C-reactive protein, 2.8 nmol/L (0.3 mg/L). Owing to postoperative pain, the patient had difficulty wearing shoes and bearing weight without crutches. After treatment options were discussed, he underwent a below-knee amputation. At 1-year follow-up, he could walk using a prosthesis, hike, and ride his bike (Figure 6).



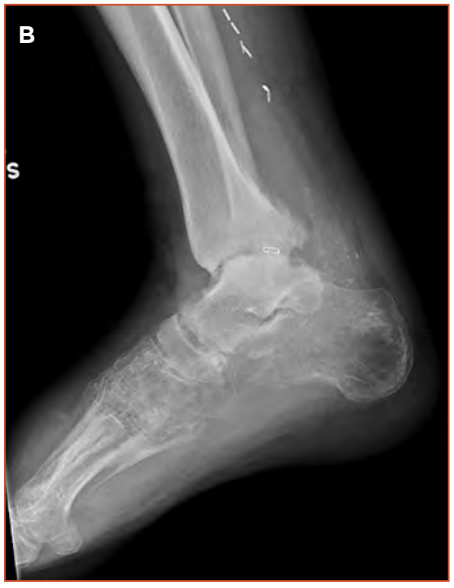


Figure 4. Radiographs of the ankle show joint-space loss and periarticular erosions involving the ankle, talonavicular, and subtalar joints. A) Anteroposterior view. B) Lateral view.

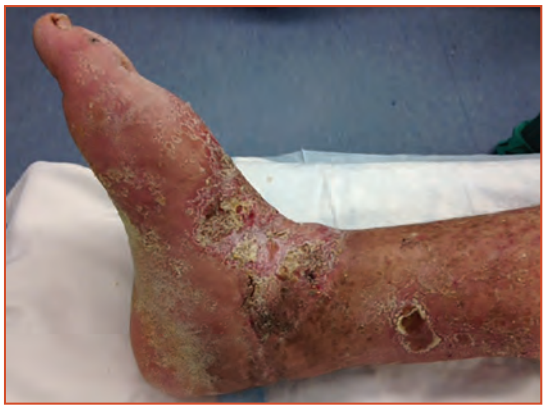


Figure 5. A clinical photograph of the patient's foot at the time of amputation.

Figure 6. The patient riding a bicycle with his temporary prosthesis, several months after the amputation.

DISCUSSION

The talus is a large curved bone of the foot, with 60% of its surface covered by cartilage. This amount of cartilage limits the area for blood to enter the bone. Although the talus lacks any tendinous attachments, stability is provided through ligamentous connections and bony articulations with the tibia, fibula, calcaneus, and navicular.[1,3,4]

Pantalar dislocation with an extruded talus is an uncommon injury, usually resulting from high-energy trauma. Treatment should include meticulous wound care. Owing to the rarity of this injury, no standard treatment exists and no methods have been definitively more successful than another. Options for treating the extruded bone include reimplantation of the talus, talectomy, and primary arthrodesis. Below-knee amputation is usually reserved for patients with associated mangled foot or ankle injuries.[5] The soft-tissue attachment to the talus is often contaminated and lacking. Complications such as infection, osteonecrosis, decreased range of motion, and posttraumatic arthritis are common.

In one long-term study, eight patients were followed during 6 years. Of the seven patients with consistent follow-up data, osteonecrosis developed in five and infection occurred in one.[1] Boden et al[5] reported on 16 patients with open and closed pantalar dislocation during a 12-year period. The authors did not distinguish which patients had bone extrusion. In this study, treatment was primary reimplantation of the talus. Osteonecrosis developed in 88% and arthritis in 44% of patients.[5]

Smith et al[6] reported on 27 patients with an extruded talus during 9 years. Only 11 of these injuries were because of a pantalar dislocation. The other patients had talus neck or body fractures. The extruded talus

was reimplanted after immersing it in bacitracin solution and scrubbing the bone. Only one patient developed an acute infection. Follow-up radiographs at 1 or more years postoperatively were obtained for five of the eleven patients with a pantalar dislocation. Two of the five patients had osteonecrosis, collapse, or arthritis. The remaining three had no radiographic abnormality. The authors concluded that reimplantation was an effective option for architectural salvage, maintaining bone stock, biomechanics, and leg length.

Talus reimplantation after emergent irrigation and debridement is the most common treatment reported. Marsh et al[7] reported on major open injuries of the talus in 17 patients seen over a 22-year period. Only four of these had a pantalar dislocation, and only two of the four were extruded. There was a 38% infection rate in their series. There was a higher percentage of infections in the group with a talus extrusion, and those patients who developed an infection had a worse clinical outcome.

In the current case, our patient presented with a severely contaminated, open pantalar dislocation with extruded talus. He underwent a total of eight operative procedures before the below-knee amputation. Results of his treatment reveal many of the difficulties associated with this injury, including multiple operations and soft-tissue coverage. Although infection did not develop, the patient experienced chronic swelling, limited motion, pain, and osteonecrosis. Postoperatively, the amputation successfully allowed ambulation without crutches. Although primary amputation is commonly discussed in patients with mangled extremities, few data exist regarding treatment of open pantalar dislocation with primary lower-extremity amputation. When technically feasible, salvage of the talus has been more commonly reported.[7] Reimplantation of the talus can preserve the architecture of the foot and successfully treats many patients. If reimplantation fails, surgeons should consider talectomy, arthrodesis, or amputation. Careful discussion about treatment outcomes and complications between limb salvage and amputation techniques should be undertaken for this severe injury.[8-11]

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Orthopaedic-Based Treatment of Laurin-Sandrow Syndrome in a 13-Month-Old Child: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Laurin-Sandrow syndrome (LSS) is a rare condition with only a few published cases in studies. This syndrome, originally described by Laurin in 1964 and again by Sandrow in 1970, can involve digit duplication with mirror hand and foot deformity, ulnar and tibial dimelia, and abnormalities of the knee, ankle, and nasal passages. A 7-month-old male infant presented to our clinic with limited function of his hands and feet due to multiple abnormalities. Results of clinical and radiographic examinations were suggestive of LSS, confirmed by a geneticist. Amputations through the knees, reconstructive pollicization of the right hand, and surgical removal of supernumerary digits on both hands led to successful treatment at 13 months of age, with promising findings at 2-year follow-up. Laurin-Sandrow syndrome may be treated successfully using orthopaedic-based techniques. Amputation can be considered depending on the noted severity of LSS.

Keywords: Laurin-Sandrow Syndrome, Child, Amputation, Abnormalities, Birth Defects

INTRODUCTION

Polydactyly is a common condition seen in children. However, the presence of mirror duplication of the digits with associated nasal anomalies, or Laurin-Sandrow syndrome (LSS), is rare. LSS involves mirror hands and feet, ulnar and fibular dimelia, and may include nasal abnormalities.[1-4] In 1964, Laurin et al[5] described a boy with mirror deformities of the hands and feet, with fibular and ulnar dimelia. Sandrow et al[6] later noted a familial association of the same disorder between a father and daughter. He found a connection between the mirror hand and foot deformities with ulnar and fibular dimelia described by Laurin and nasal defects. With a description of a fifth case with similar anomalies, Martínez-Frías et al[2] suggested that this entity be named Laurin-Sandrow syndrome.

The disorder typically involves overlapping on chromosome 7q36, involving the zone of polarizing activity (ZPA) regulatory sequence (ZRS). During embryogenesis, the anteroposterior axis of limb development is determined by sonic hedgehog expression in the zone of polarizing activity. Its expression is driven by ZRS. Studies indicate that ectopic expression of Hoxb-8 causes duplication of ZPA in the forelimb and homeotic transformation of axial structures.[3] This embryonic disruption of limb-bud formation, typically occurring between week five and six of gestation, may result in the observable anomalies.[4] Otherwise, LSS can be inherited, likely in an autosomal dominant transmission pattern.[6-8]

In total, about 16 cases of LSS have been reported.[9] Although a description of treating hand deformities has been published,[9] no one has described comprehensive treatment by pediatric orthopaedists. Because of infrequent occurrences, current understanding of the disorder is limited. We describe an orthopaedic-based approach to diagnosis and surgical treatment of lower- and upper-extremity abnormalities suggestive of LSS in a 13-month-old child.

CASE REPORT

A 7-month-old male infant presented to our facility with lower- and upper-extremity abnormalities, which limited basic use of his hands and feet. The mother's pregnancy was uncomplicated, with spontaneous vaginal delivery, and the patient weighed 3.4 kg at birth. His mother and father were nonconsanguineous and at the time of birth were aged 33 and 31 years, respectively. His mother was self-reported as Latina-Mexican and had two older children without limb defects. Neither parent had a personal or family history of limb defects. The noted deformities of the patient were not detected until birth, at which time he was referred to a pediatric orthopaedist and hand surgeon for evaluation. Findings of workup were negative for cardiac, visceral, and neuroaxial abnormalities.

On physical examination, five fully formed digits were noted on each hand. A duplicated terminal phalanx was found at both distal interphalangeal joints on the most ulnar digit; thumbs were absent. The patient had full strength and motion at the shoulders and elbows, with limited motor strength and diminished passive range of motion at the wrists. He held each hand in radial deviation at the wrist (Figure 1). Additionally, normal development of the hip and femur was observed, with instability and severe deformity at both knees. The patient had absent active-knee flexion and extension. Each knee had a fixed-flexion deformity, including associated translational and rotatory instability. On palpation, his knee and ankle joints were grossly irregular and had a limited passive range of motion. Distally, the patient had mirrored duplication of the toes and an absent hallux on each foot (Figure 2).

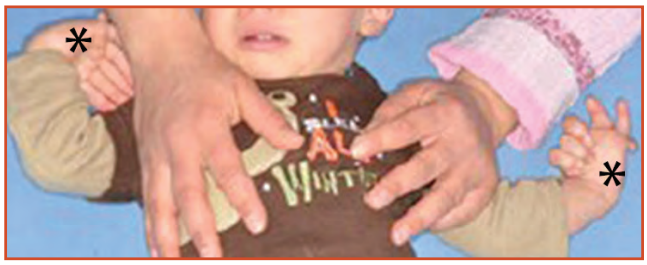

Figure 1. The patient, aged 7 months, with mirror hands (asterisk) and absent thumbs.

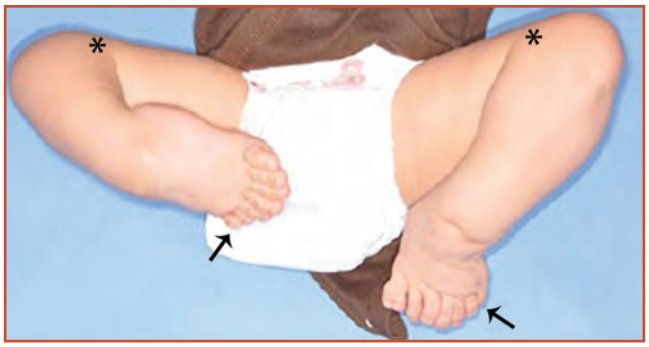

Figure 2. The patient, aged 7 months, with fixed knee flexion deformities (asterisk) and mirror duplication of the feet (arrow).

In addition, a wide nasal tip was noted with a subtle groove and wide columella.

Radiographs revealed five similar metacarpals on each hand, without a definite thumb. The most radial rays had a triphalangeal digit and duplicated distal phalanx attached with soft tissue. A supernumerary digit, located on the ulnar side of the most ulnar ray (Figure 3), had constricted soft-tissue attachments without appreciated bony fusion. Radiographs of each forearm showed normal appearance and relationship of the radius and ulna. Radiographs of the lower extremities revealed normal hip osteology but indicated

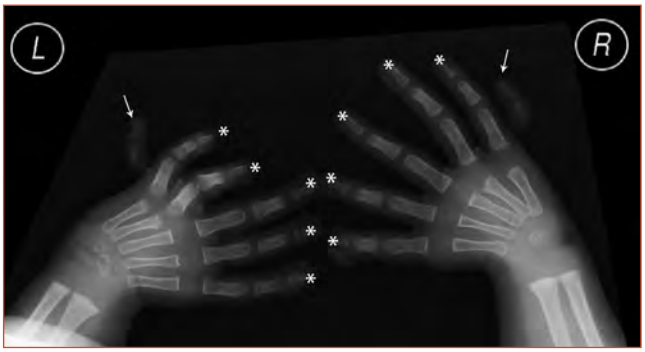

Figure 3. Preoperative radiograph of anteroposterior view shows both hands with five similar digits, absent thumbs, preaxial triphalangeal digits (asterisk), and mirror duplication (arrow).

an abnormal knee joint articulation. Furthermore, the tibias were absent on both lower limbs, with duplicated fibulae. The talus and calcaneus were in equinus, with posterior and superior displacements relative to the distal fibulae (Figures 4, 5A, and 5B). Both feet had seven digits. Axial-view magnetic resonance imaging of his brain and spine did not reveal additional abnormalities.

The patient was referred to a geneticist who made the clinical diagnosis of LSS. Reconstructive procedures for treating the lower extremities were felt to be insufficient owing to the observed severity of limb deficiency at and below the knee (including deficient knee articular and gross knee instability). Subsequently, amputations through both knees for treating knee instability and dysfunction was discussed with the parents. The procedure was performed when the patient turned 13 months, after which he was fitted for lower-extremity prostheses for both legs. In follow-up with the hand surgery service, surgical removal of radial- and ulnar-sided supernumerary digits was performed, as well as right-sided reconstructive pollicization.

At 2 years after the operation, the patient walked using his prostheses. On physical examination, he sat with a clinically straight spine and no obvious deformity. A radiograph of his pelvis was obtained and indicated normal hip development (Figure 6). Additionally, results of the hand examination suggested successful function of the right hand, whereas pollicization was indicated for further treatment of the left hand.

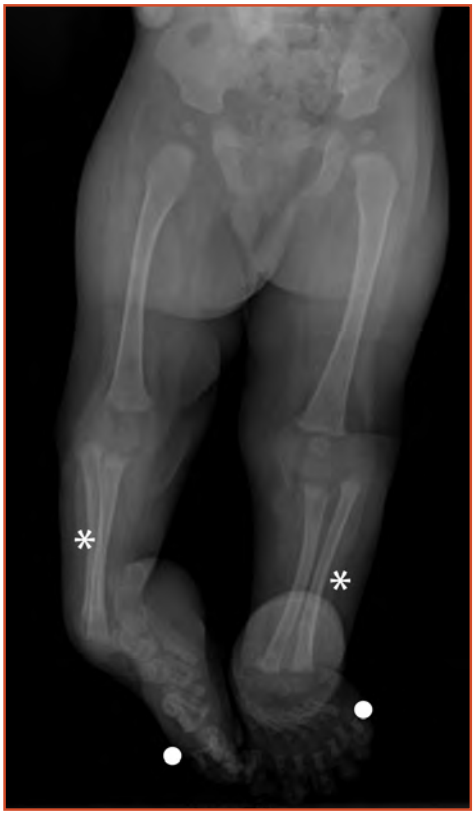

Figure 4. Preoperative radiograph of anteroposterior view shows the knee-to-ankle region with a duplicated fibula, absent tibia, and mirror duplication of the feet (asterisk).

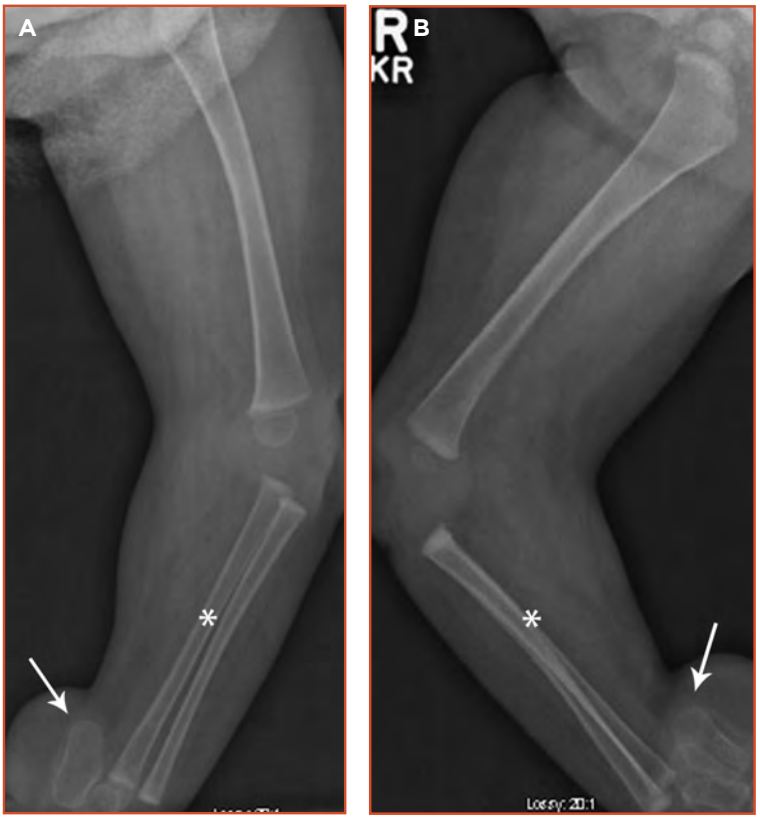

Figure 5. Preoperative radiographs of lateral view shows the A) left and B) right lower extremities, with a duplicated fibula (asterisk). Notably, the talus and calcaneus are displaced posteriorly and superiorly (arrow).

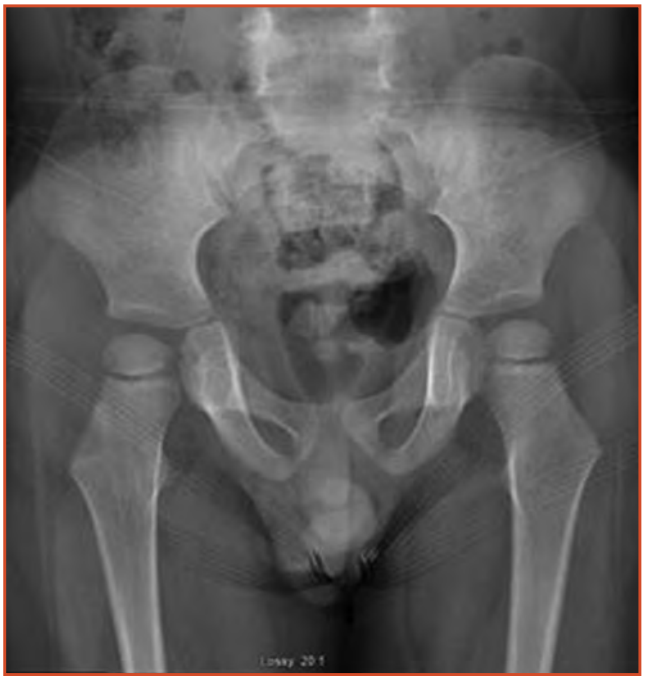

Figure 6. At 2 years after the operation, radiograph of anteroposterior view shows the pelvis with normal hip development.

DISCUSSION

The incidence of LSS is rare. Patients typically present with multiple anomalies of upper and lower extremities. In the current case, we performed amputation through both knees for treating severe knee dysfunction and instability. Additionally, operative removal of supernumerary digits and a pollicization procedure were indicated to improve hand function. To our knowledge, this is the first report of LSS to describe comprehensive orthopaedic-based evaluation, diagnosis, and treatment, which were overseen by a pediatric orthopaedic surgeon.

Fourteen other patients have been identified with LSS.[2,5-15] Studies have also reported "segmental" or "partial" LSS, which primarily involves the upper extremities.[16-19] The results of most studies indicate three signs suggestive of LSS, with the first being the most common[2]: 1) mirror duplication of the digits of the hands and feet, which may be the only constant anomaly in LSS[8]; 2) ulnar and fibular dimelia with absence of the radius and tibia; and 3) nasal abnormalities. We noted all characteristics in our patient except the last, in which only minor deficiencies were found.

In the current case, we used reconstructive techniques for treating the abnormal hand development and performed amputation for treating severe knee deformity. This decision was based on radiographic severity of LSS at and below the knee and the desire to restore lower-extremity function for long-term ambulation. Ultimately, orthopaedic-based treatment can help provide function for upper and lower extremities in patients with LSS at an early age. For successful treatment, amputation may be considered on an individual basis, depending on the severity of the disorder.

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Acute Gluteus Medius and Minimus Intramuscular Tear in a 59-Year-Old Half-Marathon Runner: A Case Report

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Funding The authors received no financial support for the research, authorship, and publication of the article.

Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Acute gluteus medius and minimus tears are an infrequent and possibly underdiagnosed cause of lateral hip pain. When reported, they most commonly occur at the distal tendinous attachment at the insertion on the greater trochanter or at the musculotendinous junction. It is rare for muscle belly or proximal muscle tears to occur. They are more prevalent in the setting of degenerative joint disease, but cases have also been described in previously healthy athletes without preexisting joint or muscle disease. We describe a 59-year-old man who developed considerable pain and swelling on the left side of the hip during a half-marathon race. We subsequently diagnosed acute intramuscular tears of the gluteus medius and minimus muscles. Acute tears of the gluteus medius and minimus are rare, and to our knowledge this is the first reported acute intramuscular rupture with an intact tendinous attachment.

Keywords: Gluteus Minimus, Gluteus Medius, Muscle Tears, Running Injuries

INTRODUCTION

The gluteus medius and minimus muscles are the main abductors and internal rotators of the hip and thigh, which are important stabilizers during running and walking. Weakness or tearing of these muscles or tendons can result in decreased range of motion of the hip and alterations in gait. Tears of the gluteus medius and minimus muscles, especially at their tendinous insertion on the greater trochanter, have been compared to a rotator cuff injury of the shoulder and were originally described by Bunker et al[1] in 1997.

Similar to rotator cuff injuries, tears of the gluteus medius and minimus have most commonly been described as the result of progressive degenerative hip disease.[2,3] Acute tears of the gluteus medius and minimus tendons are infrequently described,[4-8] and it is even more uncommon to have acute intramuscular tears of these muscles. This case describes an acute gluteus medius and minimus intramuscular tear in a 59-year-old half-marathon runner.

CASE REPORT

A 59-year-old male runner visited a sports medicine clinic and reported a 5-day history of pain and swelling on the left side of the hip, which had an acute onset early during a half marathon, a 21-km (13.1-mi) race. He was an experienced long-distance runner and prepared for the race with a 3-month progressive training program before the event. He reported some soreness on the left side of the hip about 2 days before his race, which occurred before flying to the race site. He was unsure of the cause of the discomfort but on race day he had no symptoms. At the start of the run, he joined the group that averaged 7 minutes and 45 seconds per mile. About 1.6 km (1 mi) into the race, he said he felt a popping sensation in the left lateral side of his hip, followed by notable shooting and stabbing pains radiating down the left thigh.

Owing to the pain and hip dysfunction, he almost fell during the race. He reported that he tried to continue with the pacing group for the next 8 km to 9 km (5 mi to 6 mi), but at 10 km (7 mi) he was unable to continue.

The man said he decided to complete the 21-km (13.1-mi) race by alternating between walking and running, which resulted in notable ecchymosis and swelling in his left-sided hip at the end of the race. He underwent evaluation in the post-race medical tent and was advised to use a cane or crutches to assist ambulation. Three days later, he returned home and visited the sports medicine clinic for further evaluation.

At this visit, he reported he experienced severe pain and difficulty in walking, but no paresthesia or loss of sensation. Findings of his physical examination were suggestive of an antalgic, Trendelenburg gait and difficulty standing on his left foot. While standing only on his left leg, he exhibited balance issues and the right side of his hip dropped, indicating a Trendelenburg gait. While in supine position, the patient underwent a left-sided straight leg raise test. Results were normal, without pain or weakness noted. On the left side of the hip, he had flexion to 115°, internal rotation to 30°, and external rotation to 50°. The flexion-adduction-internal and abduction-external rotation maneuvers caused no pain. Weakness was present during active and resisted hip abduction while in both supine and lateral positions. He had tenderness to palpation over the proximal left greater trochanter.

Findings of radiographs of the pelvis and the left side of the hip were notable for moderate hip joint osteoarthritis, with joint narrowing and osteophyte formation. No fractures or dislocations were noted, but a small calcific density was present in the soft tissues of the lateral thigh, consistent with a dystrophic calcification. Soft-tissue edema was also noted (Figure 1).

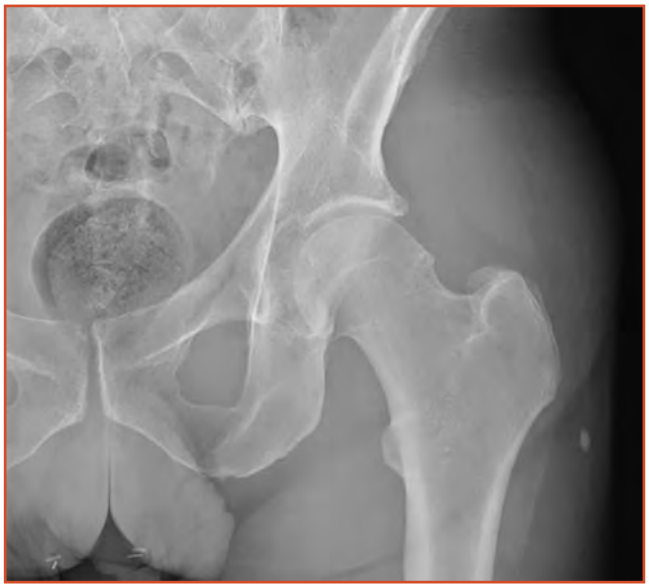


Figure 1. Anteroposterior radiograph of the left side of the hip, showing moderate osteoarthritis with joint space narrowing and osteophyte formation. Incidental note of dystrophic calcification in lateral soft tissues.

We obtained magnetic resonance imaging (MRI) of the pelvis and left side of the hip without contrast. Findings on the MRI revealed mild degenerative joint disease of both sides of the hip, as well as edema of the left gluteus minimus and medius muscles, with partial interruption of the fascia of both muscles consistent with an intramuscular tear (Figures 2A and 2B). The tendon at the greater trochanter was noted to be intact, and edema was present over the greater trochanter (Figures 3A and 3B). No fractures were noted.

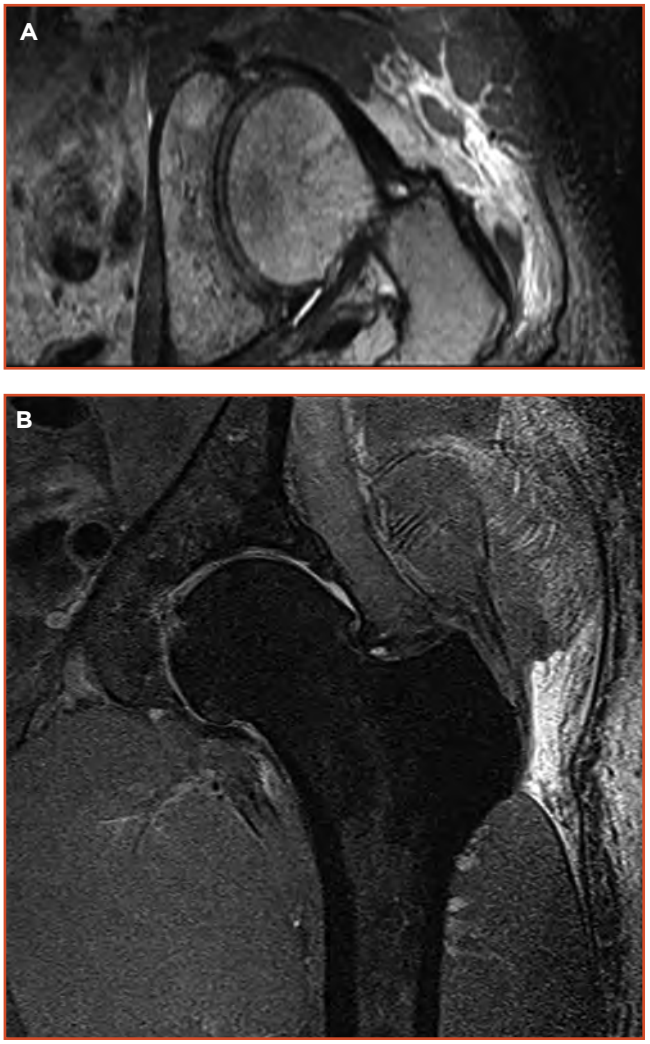
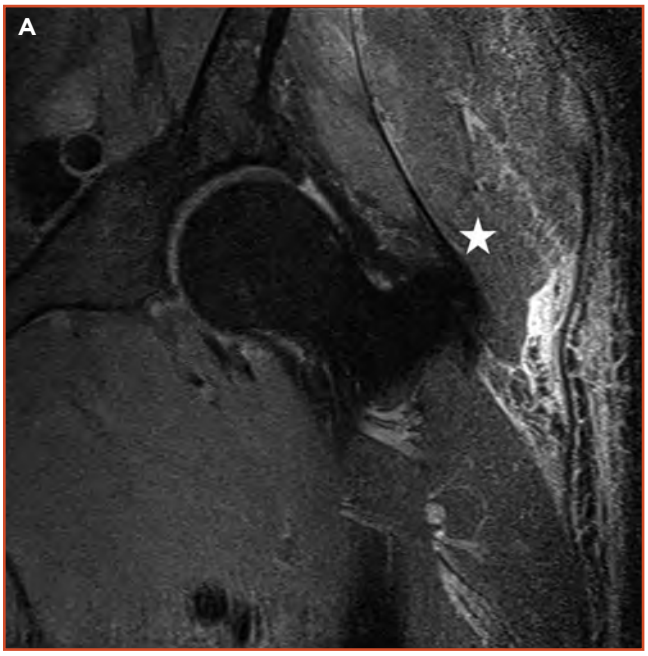


Figure 2. A) Axial and B) coronal magnetic resonance imaging of the left side of the hip, showing gluteus minimus and medius muscle edema consistent with an intramuscular tear.



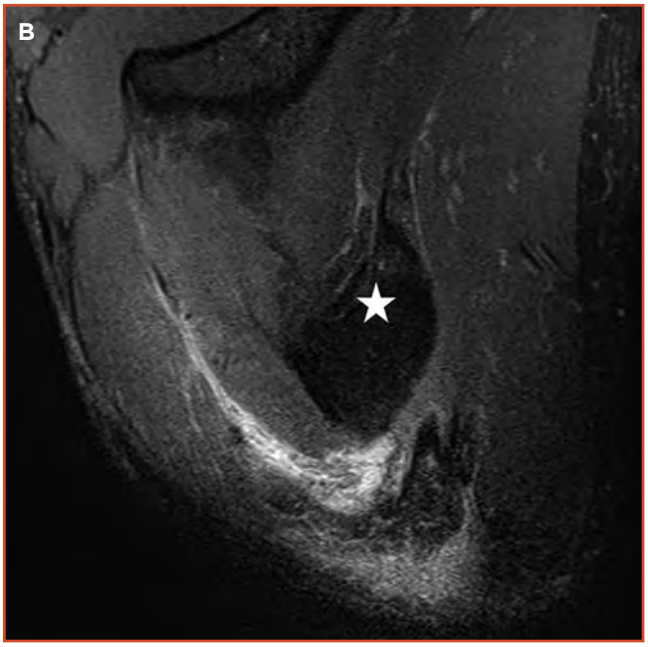


Figure 3. A) Coronal and ***B)*** sagittal magnetic resonance imaging of the left side of the hip, showing an intact gluteus tendon insertion (star) on the greater trochanter.

The patient's muscular tears were treating conservatively with physical therapy and a temporary discontinuation of running. He underwent an intensive 10-week rehabilitation program involving open- and closed-chained exercises and cross training on a rowing machine and bicycle. After physical therapy, the symptoms were resolved and the patient returned to running at 12 weeks postoperatively. At 9 months after the injury, he was averaging 40 km to 48 km (25 mi to 30 mi) per week in preparation for another half marathon and will not likely require any surgical intervention.

DISCUSSION

Lower-extremity injuries in runners are quite common, with an incidence ranging from 19.4% to 79.3% in a 2007 systematic review.[9] Of these, only 3.3% to 11.5% were classified as hip and pelvis injuries, whereas the knee was the most commonly injured. Gluteus medius and minimus tears should be considered in patients with acute lateral hip pain.[10] Although distal tears at the tendinous insertion on the greater trochanter are most common, intramuscular or more proximal tears may occur.

Patients with this injury frequently experience sudden onset of severe, sharp pain and difficulty walking after forceful hip abduction.[8] Physical examination findings reveal weakness with hip abduction maneuvers and tenderness to palpation over the greater trochanter on the affected side. Symptoms include the classic Trendelenburg gait or sign. Tearing of the hip abductor muscles is frequently associated with degenerative joint disease, which was consistent with the radiographic findings of this patient.

Treatment is generally conservative, involving rest from strenuous activity and physical therapy to rehabilitate the injured muscles and tendons. The methods focus on hip range of motion and strength and core strengthening, with emphasis on abductor strength to ensure pelvis stability when walking. In cases in which physical therapy does not improve mobility, surgical procedure is recommended. Open and endoscopic repair techniques have been described, but these are typically reserved for distal tendon tears or avulsions in patients with more severe, refractory pain.[11]

In a 2018 case series, the outcome of patients who underwent isolated transtendinous gluteus medius repairs improved considerably across all subjective and objective measures.[12] A total of 86% of patients showed improvement in gait measured by subjective decrease in presence of a limp, and 64% showed objective improvements in strength testing. Their results are similar to that of other studies that have evaluated efficacy of full-thickness repairs.[13] Given the varied and sometimes inconclusive clinical presentation of acute lateral-sided hip pain in athletic patients, a high index of suspicion and thorough workup are critical to guide appropriate treatment. Unlike distal avulsions and tendinous tears, intramuscular tears of the hip abductors can be successfully managed with conservative treatment.

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Hosting Two Programs of the Perry Initiative in Albuquerque: Inspiring New Generations of Women Engineers and Orthopaedists

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Funding The Perry Outreach Program was generously funded by Acumed and supported by material donations from Summit Medical, AxoGen Inc, Acumed, and Össur.

Acknowledgments We thank the following volunteers from the Perry Initiative, Summit Medical, Acumed, AxoGen Inc, UNM Department of Orthopaedics & Rehabilitation, School of Medicine, School of Engineering, Marketing & Communications, Office of Diversity, BA/MD Degree Program, and the many individuals whose time and efforts dedicated to the two programs made the events not only possible but enjoyable. Special thanks to: Karen Zaderej (guest speaker at the Perry Outreach Program), Grecthen Hinton, Nicole Ray, Kelsey Neal, Laurie Meszaros Dearolf, Quincy Gonzales, Orlando Merced-O'Neill, Ryan Wood, Melanie DeLorenzo, Aditi Majumdar, Angelina Rodriguez, Amber West, Kris Battaglini, Kristen White, Kavita Vakharia, Kourosh Kolahi, Robert C. Schenck Jr (guest speaker at the Medical Student Outreach Program), Jasmin Regalado, Priscilla Mendoza, Bridgette Love, Christy Kurnik, Krish Khalsa, Hannah Groves, Michaela Granados, Emma Garcia, Darielys Meijias-Morales, Christopher Buksa, Shaina Aguivre, Jennifer Bishop, Gail Case, Gene Passariello, James Perea, Amy Rosenbaum, George Griego, Kim Delker, Amanda Bassett, Janea Dickson, Marcos Romero, Theresa Sherman, Tamara Clover, and Teresa Madrid.

Female leaders in the fields of orthopaedic surgery and engineering are sparse. Women comprise only "6.1% of fully-accredited practicing orthopaedic surgeons" and "12.4% of the faculty at engineering schools."[1] To inspire women leaders in both fields, the Perry Initiative runs more than 40 outreach programs nationwide and has influenced more than 7500 high school, college, and medical students.[1] At The University of New Mexico (UNM) Department of Orthopaedics & Rehabilitation, we host two Perry Initiative programs annually to help change these numbers: the Perry Outreach Program (POP) and Medical Student Outreach Program (MSOP).

Each event provides participants with a unique opportunity to network with local female physicians, residents, fellows, engineers, and colleagues. The POP invites young women in high school to explore careers in medicine and engineering, and the MSOP helps foster a sense of community between new medical students and UNM Orthopaedics. The goal of the POP is to inspire women to pursue careers in orthopaedic surgery and engineering—particularly mechanical engineering—whereas the MSOP is focused mainly on encouraging female students to pursue specialties in orthopaedic surgery. Overall, UNM Orthopaedics has led six POPs since 2013 and two MSOPs since 2016.

Our team of faculty, staff, and volunteers is honored to be among the national sites that host POPs and MSOPs. We are also proud to reach out to young women in the rural state of New Mexico, who might not otherwise be exposed to orthopaedic surgery and engineering. At the end of both programs, we hope our participants embark with new ideas and insights about lifelong careers in engineering and medicine—careers that are readily attainable.

DIFFERENCES BETWEEN PROGRAMS

At both free-of-charge events, female participants join open discussions, dive into hands-on workshops, and have the chance to directly network with orthopaedic surgeons, healthcare professionals, and engineers—guided by women leaders in both fields. Notably, the POP and MSOP have a few differences.

Perry Outreach Program

- All-day event created by the Perry Initiative in 2009 and held at various locations across the United States
- Recruits 40 female high-school students through a competitive application process overseen by the Perry Initiative
- Representatives from the Perry Initiative fly out to the host city to help lead the program
- Comprises six hands-on activities in orthopaedic surgery and engineering, two lectures, and a questions-and-answers (Q&A) session
- Includes free lunch and breakfast
- UNM-specific workshops include a cadaver component and engineering competition

Medical Student Outreach Program

- Half-day event introduced in 2016 to select sites across the United States
- Recruits 30 medical students through an application process overseen by UNM Orthopaedics
- Self-run by UNM Orthopaedics, with material shipments from the Perry Initiative
- Comprises two hands-on workshops in orthopaedic surgery, one lecture, and a Q&A session
- Includes free breakfast
- Mirrors the program set forth by the Perry Initiative

SIXTH ANNUAL PERRY OUTREACH PROGRAM ON MARCH 17, 2018

At the sixth annual POP, about 40 volunteers and 39 high-school students participated in all-day activities. Our guest speaker from Axogen Inc—the president, Karen Zaderej—opened up our morning lecture with an insightful talk about biomedical engineering and life balance. Afterward, we began the first set of hands-on workshops and helped the high-school students apply arm casts, suture pig feet, and implant intramedullary (IM) nails into fractured femurs (Figures 1 and 2).

After the morning workshops, Dr. Christina Salas led the bone-breaking competition—an innovative engineering component to the program. Participants watched wide-eyed and laughed excitedly as a custom-made device applied load until it broke the bones of the IM nail workshop. With new understanding of how the type of surgical repair affects the strength of the repaired bone, students transitioned into the final set of hands-on workshops: repairing fractures of the distal radius, repairing a fractured femur using external fixation techniques (Figure 3), and observing a live dissection of a cadaveric hand-and-forearm.

Before the program concluded, all volunteers gathered together to answer any questions posed by participants (and by the participants' parents). The young, aspiring women departed with personalized diplomas, goodie bags, mentors, internship opportunities, and a newfound passion for medicine and engineering (Figure 4).

Figure 1. At the Perry Outreach Program, participants suture pigs feet.

Figure 2. At the Perry Outreach Program, from left to right: Christina Salas, PhD, and Deana Mercer, MD (The University of New Mexico site directors for the Perry Initiative programs) pose for a quick shot with Karen Zaderej (our guest speaker and president of AxoGen Inc) and Robert Schenck Jr, MD (chairperson of the Department of Orthopaedics & Rehabilitation) before joining participants in the intramedullary nail workshop.

Figure 3. At the Perry Outreach Program, participants repair fractures of the femur using external fixation techniques.

SECOND ANNUAL MEDICAL STUDENT OUTREACH PROGRAM ON SEPTEMBER 16, 2017

Dr. Robert Schenck Jr, Chairman of UNM Orthopaedics, began our second MSOP with an informative talk on the success of women leaders in orthopaedic surgery, work-life balance, and shadowing opportunities (Figure 5). After the morning discussion, the medical students participated in two hands-on workshops: applying techniques using IM nailing and performing external fixation, both for treating fractured femurs (Figure 6). Dr. Mercer captivated all listeners with her story on choosing orthopaedics as a lifelong career, persevering

Figure 4. At the Perry Outreach Program, a group photograph shows all fantastic participants and volunteers.

Figure 5. At the Medical Student Outreach Program, Robert Schenck Jr, MD, speaks with the participants about orthopaedic-related careers.

Figure 6. At the Medical Student Outreach Program, Deana Mercer, MD, helps a medical student in the intramedullary-nail activity.

Figure 7. At the Medical Student Outreach Program, participants and volunteers pose for a fun group photograph after the event.

through residency and fellowship experiences, and overcoming the many obstacles along the way. In conclusion, the volunteers formed a panel discussion and invited all participant inquiries. Before the program ended, each of the participants received a shiny certificate of completion and—of course—posed for a group photograph (Figure 7).

FUTURE

Thanks to these two amazing programs created by the Perry Initiative, many young women of New Mexico can reap the benefits of networking and participating in medical- and engineering-related fields. UNM Orthopaedics is grateful for the opportunity to continue hosting these much-needed outreach events in our effort to educate New Mexican women on the collaboration between medicine and engineering—and on pursuing your ambitions.

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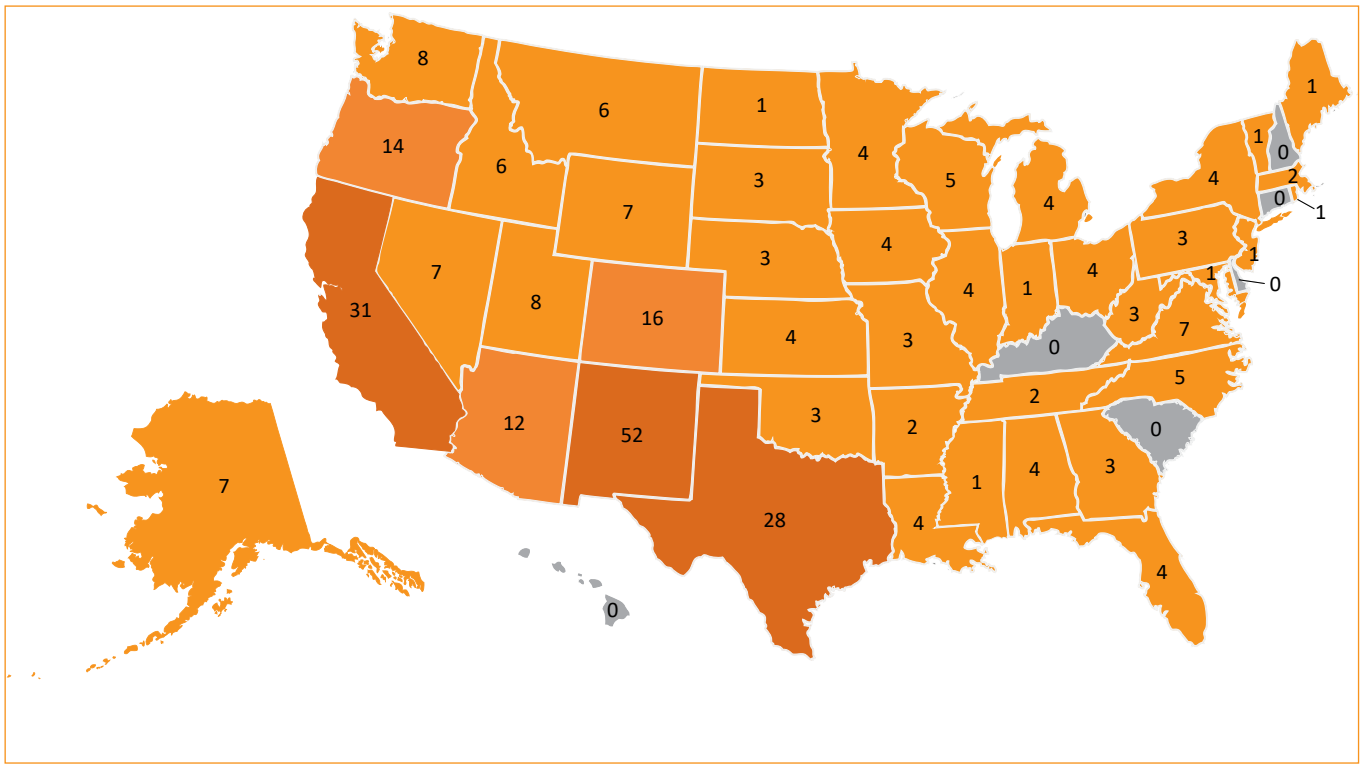

Alumni in each state. Map reprinted with permission from Vexels (https://goo.gl/QtSLq5).

THE UNIVERSITY OF NEW MEXICO DEPARTMENT OF ORTHOPAEDIC SURGERY ALUMNI

Hand Surgery Fellows

Damon Adamany (AZ)	2007
Ahmed Afifi (OH)	2008
Jeffrey Aldridge (OR)	1987
Valdemar Ascencio (CA)	1984
John Bax (WI)	1985
William Blair (TX)	1979
John Bolger (WI)	1980
Daniel Boudreau (TX)	1973
Boyd Bowden*	1972
Bradlet Britt*	1984
Mark Buchman (NE)	1989
Randy Bussey (CO)	1980
David Capen (TX)	1975
Cory Carlston (MN)	2014
Alex de Carvalho (KS)	2005
Edwin Castaneda (IA)	1988
James Clark (NM)	2013
Anthony Dalton	1980
William Doherty (MA)	1993
Gregory Duncan (CA)	1992
Thomas Eiser (OK)	1979
Edgardo Espirtu (TX)	1985
Hani Fahmy (EG)	1993
Ronald Ford (MI)	1997
Bruce Freedman (VA)	1988
Eric Freeh (NM)	1983
Bonnie Fraser (NV)	2007
Jeffrey Garst (IL)	1994
David Gerstner (MI)	1988
Richard Gobeille (NM)	1985
Douglas Gordon (OH)	1987
Matthew Green (UT)	2012
Dominic Gross (ID)	1997
Robert Hamas (TX)	1974
Conrad Hamilton (NM)	2011
Terry Happel (AZ)	1986
John Hayden (AZ)	1983
Aaron Hoblet (OR)	2013
Karl Hofammann (AL)	1983
Thomas Howey (SD)	1992
Jing Hsien (CA)	1986
Patrick Hudson (NM)	1978
Davis Hurley (CO)	2003
Tariq Hussain (NY)	2002
Perry Inhofe*	1994
William Irey (IA)	1982
Glenn Johnson (MN)	1998
Jann Johnson (CA)	1984
David Johnston (CANADA)	1995
Terrell Joseph (CO)	2006
Jon Kelly (CA)	1993
Alan Koester (WV)	1995
Shankar Lakshman (CA)	2004
Scott Langford (MO)	2000
Kenna Larsen (UT)	2009
Dusting Larson (OR)	2016
Thomas Lehman (OK)	2002
Charles Leinberry (PA)	1990
Andrea Lese (WV)	2015
David Long (OR)	1971
Paul Luce (MI)	1999
Joseph Mann (CA)	1981
Matthew Martin (MI)	2014
Deana Mercer (NM)	2010
Elizabeth Mikola (NM)	2001
Gary Miller (MO)	1986
Steven Miller (AZ)	2009
Robert Morrow (LA)	1980
Anastasos Mourikas (GR)	2004
Louis Murdock (ID)	1996
Abdul Mustapha (OH)	2000
Thomas Narsete (TX)	1981
William Niedermeier (WI)	1979
Gavin O'Mahony (OK)	2012
Gerald Olmstead (WA)	1971
Don Oschwald (NC)	1985
Larry Patton (UT)	1979
Ralph Pennino (NY)	1986
Erik Peterson (UT)	2016
Charles Phillips (FL)	1971
Jeffrey Pokorny (NC)	2002
Ram Prabhakar (CA)	1980
Charles Pribyl (NM)	1989
Milos Radwick (MD)	1971
Michael Ravitch (NV)	1974
Allison Richards (NM)	2008
Hector Rosquete*	1990
John Russin (NM)	1984
Robert Saide (AZ)	1983
Ehab Saleh (MY)	2005
Scott Schemmel (IA)	1987
Joseph Serota (CO)	1983
Swati Shirali (VA)	1999
Victoria Silas (WA)	1996
Richard Sleeper	1988
Duret Smith (OH)	1982
Osama Suliman (FL)	1985
Scott Swanson (CO)	2010
Steven Taylor (WI)	2006
Ronald Tegtmeier (KS)	1976
Kenneth Teter (KS)	1993
Norfleet Thompson (TN)	2015
Erik Torkelson*	1984
James Trusell (AR)	1973
Gregory Voit*	1996
Catherine Walsh (CA)	2011
Howard Weinberg	1978
InSok Yi (CO)	1998
Robert Yoo (MA)	1977
Steven Young (IL)	2001
Elmer Yu	1979

Sports Medicine Fellows

Roy Abraham (IA)	2006
Tamas Bardos (HUNGARY)	2015
Brandee Black (NM)	2016
Todd Bradshaw (TX)	2014
Blake Clifton (CO)	2015
Lindsey Dietrich (TX)	2014
Matthew Ferguson (TX)	2013
John Jasko (WV)	2010
Ray Jenson (SD)	2016
Adam Johnson (NM)	2012
A. John Kiburz (NM)	2009
John Mann (AL)	2010

Ben Olson (OR)	2002
Toribio Natividad (TX)	2011
Ralph Passerelli (PA)	2007
Brad Sparks (AK)	2008
Brad Veazey (TX)	2007
Jonathan Wyatt (AR)	2012

Trauma Fellows

Stephen Becher (GA)	2014
Shahram Bozorgnia (GA)	2008
Max de Carvalho (MN)	2011
Seth Criner (CA)	2016
Fabio Figueiredo (ME)	2007
Shehada Homedan (NY)	2006
Victoria Matt (NM)	2005
Gary Molk (WY)	2010
Urvij Modhia (NM)	2013
Leroy Rise (NM)	2012
Ahmed Thabet (TX)	2015
Zhiqing Xing (AL)	2009

Residents

Alexander Aboka (VA)	2011
Christopher Achterman (OR)	1977
Brook Adams (TX)	2011
Zachary Adler (NV)	2007
Amit Agarwala (CO)	2002
Owen Ala (AK)	2013
Lex Allen (UT)	2002
Alan Alyea (WA)	1986
Frederick Balduini (NJ)	1981
Adam Barmada (OR)	2001
Jan Bear (NM)	1991
Jeremy Becker (OR)	1997
Kambiz Behzadi (CA)	1994
Robert Benson (NM)	1973
Eric Benson (NM)	2007
Ryan Bergeson (TX)	2008
Thomas Bernasek (FL)	1986
C. Brian Blackwood (CO)	2011
David Bloome (TX)	2001
Dustin Briggs (NM)	2013
Luke Bulthuis (CA)	2016
William Burner (VA)	1980
Dwight Burney (NM)	1980
Dudley Burwell (MS)	1987
Dale Butler (CA)	1973
Everett Campbell (TX)	1973
Bourck Cashmore (AZ)	1997
Richard Castillo (NM)	1988
Zachary Child (NV)	2011
Joel Cleary (MT)	1985
Mitchell Cohen (CA)	1992
Harry Cole (WI)	1992
Matthew Conklin (AZ)	1988
Clayton Conrad (NM)	2009
Geoffrey Cook (AZ)	1988
David Cortes (WA)	2005
Mark Crawford (NM)	1994
Aaron Dickens (NV)	2013
Grant Dona (LA)	1993
Daniel Downey (MT)	1992
Shakeel Durrani (NC)	2010
Paul Dvirnak (CO)	1996
Paul Echols (NM)	1978
Daniel Eglinton (NC)	1983
Scott Evans (VA)	2015
James Fahey (NM)	1978
James Ferries (WY)	1995
Thomas Ferro (CA)	1990
Judd Fitzgerald (TN)	2016
Jennifer FitzPatrick (CO)	2010
John Franco (NM)	2003
John Foster (NM)	1974
Orlando Garza (TX)	1977
Jan Gilmore (NM)	2012
Jenna Godrey (CA)	2014
Robert Goodman (CO)	1980
Stan Griffiths (ID)	1989
Speight Grimes (TX)	2004
Christopher Hanosh (NM)	2001
Gregg Hartman (CA)	1997
Robert Hayes*	1975
William Hayes (TX)	1996
David Heetderks (MT)	1990
Thomas Helpenstell (WA)	1991
Fredrick Hensal (AL)	1982
Bryon Hobby (MT)	2012
Daniel Hoopes (UT)	2013
Mischa Hopson (TX)	2016
David Huberty (OR)	2005
Sergio Ilic (CA)	1977
Kayvon Izadi (NE)	2008
Felix Jabczenski (AZ)	1989
Taylor Jobe (TX)	2014
Robert Johnson (ND)	1981
Orie Kaltenbaugh (ID)	1978
Daniel Kane (IL)	1977
David Khoury (WY)	2007
Roger Klein (CA)	1984
Dennis Kloberdanz (NM)	1988
Ken Korthauer (TX)	1985
John Kosty (TX)	1983
Reilly Kuehn (CA)	2016
Sean Kuehn (UT)	2015
Letitia Lansing (WA)	2010
Loren Larson (WA)	2006
Earl Latimer (NM)	1993
Robert Lee (ID)	1995
Corey Lieber (CA)	2006
Peter Looby (SD)	1995
Joel Lubin*	2001
Norman Marcus(VA)	1983
Charley Marshall (UT)	2005
Roberto Martinez (FL)	1984
Victoria Matt (NM)	2002
Timothy McAdams (CA)	2000
Victoria McClellan (OR)	1984
Seth McCord (AK)	2014
Thomas McEnnerney (NM)	1984
Kevin McGee (NM)	2008
Laurel McGinty*	1991
Michael McGuire (NE)	1995
Matthew McKinley (NM)	1998
Heather Menzer (VA)	2016
Deana Mercer (NM)	2008
Richard Miller (NM)	1990
Brent Milner (WY)	2003
Frank Minor (CA)	1982
Rosalyn Montgomery (OR)	1991
Kris Moore (OR)	2008
Nathan Morrell (RI)	2014
Ali Motamedi (TX)	1998
David Munger (AZ)	1969
Fred Naraghi (CA)	1981
Joseph Newcomer (IL)	1998
Lockwood Ochsner (LA)	1986
Charlotte Orr (IN)	2014
Andrew Paterson (NM)	2004
L. Johnsonn Patman (NM)	2012
William Paton (AK)	1977
Matt Patton (NM)	2002
Chris Peer (MO)	2005
Eugene Pflum (CO)	1976
Dennis Phelps (CO)	1985
Gregg Pike (MT)	2004
Mario Porras (NV)	1977
Julia Pring (PA)	2009
Jeffrey Racca (NM)	2000
Shannah Redmon (AZ)	2009
Stephen Renwick (OR)	1994
Jose Reyna (NM)	1983
Allison Richards (NM)	2002
Dustin Richter (NM)	2015
Brian Robinson (NM)	1998
Peter Rork (WY)	1984
Kenneth Roth (CA)	1967
Michael Rothman (NM)	1974
David Rust (MN)	2012
Peter Schaab (AK)	1990
Ted Schwarting (AK)	2003
Jonathan Shafer (WA)	2006
Sanagaram Shantharam (CA)	1992
Paul Shonnard (NV)	1995
Selina Silva (NM)	2010
Robert Simpson (NY)	1976
James Slauterbeck (VT)	1993
Christopher Smith (WY)	1974
Dean Smith (TX)	2000
Jason Smith (LA)	2007
Robert Sotta (OR)	1987
Richard Southwell (WY)	1980
Daniel Stewart (TX)	2012
Greg Strohmeyer (AK)	2015
Christopher Summa (CA)	1995
Kenneth Teter (KS)	1993
Eric Thomas*	2004
Gehron Treme (NM)	2006
Krishna Tripuraneni (NM)	2009
Randall Troop (TX)	1989
William Tully (CA)	1972
Cathleen VanBuskirk (CO)	1999
Tedman Vance (GA)	1999
Andrew Veitch (NM)	2003
John Veitch*	1978
Edward Venn-Watson (CA)	1975
Eric Verploeg (CO)	1987
Joseph Verska (ID)	1994
David Webb (TX)	1977
Richard White (NM)	1979
John Wiemann (CA)	2011
Michael Willis (MT)	2000
Bruce Witmer (CA)	1982
Heather Woodin (AZ)	2015
Jeffrey Yaste (NC)	2009

*Deceased

The University of New Mexico Orthopaedics Research Journal 2018

Volume VII

SCHOOL OF MEDICINE

DEPARTMENT OF ORTHOPAEDICS & REHABILITATION