Western Journal of Orthopaedics

2025
volume XIV

THE UNIVERSITY OF NEW MEXICO

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With thanks to
Ryan Wood

Thank You from the Co-Editor

Welcome to the 14th volume of the *Western Journal of Orthopaedics* (*WJO*) published in conjunction with the Research Division of The University of New Mexico (UNM) Orthopaedics & Rehabilitation Department. This edition updates educational and research activities from the Department and features 13 articles that focus on orthopaedic innovations and cases of interest to the readership. Many of the articles are authored by UNM alumni, faculty, fellows, residents, students, and staff, but we also receive several external submissions from around the nation and the globe that contribute to the overall scientific quality of *WJO*. We are delighted to offer authors the opportunity to share their research and perspective on a wide variety of orthopaedic topics and invite you to submit to next year's 15th volume.

I would like to extend my heartfelt congratulations to our graduating residents and fellows. Their steadfast dedication and hard work have brought them to this exciting milestone, and we wish them continued success and growth in their journeys as surgeons. I would like to acknowledge the outstanding work of our research team, with special thanks to Dr. Laurie Wells – an expert statistician and clinical researcher. Her unwavering commitment to advancing the department's capabilities in data analysis is deserving of the highest recognition. To further support the department's research efforts, Dr. Wells pursued and completed a Master's degree in Data Science. We are deeply appreciative of Leorrie Watson, our Sports Medicine Research Manager, for her support and dedication to furthering the department's research endeavors. I would like to express my appreciation for Gail Case, Administrative Supervisor, for her continued leadership and support of our research efforts. We are all appreciative of our Interim Chair, Dr. Gehron Treme, for his leadership and support of the department, and especially for his commitment to advancing our research initiatives.

In this edition, I want to express my deepest appreciation for our dear friend and colleague, Joni Roberts, whom we sadly lost late last year. Her professional and personal contributions to our department will be deeply missed. I am grateful for Arianna Medina, our managing editor, for her publication support in gathering, copyediting, and formatting submissions to *WJO*. My thanks as well to Angelique Tapia, our layout editor, for her work in producing this volume of *WJO*.

I look forward to the work we will all continue to create together in the coming years.

Deana Mercer, MD
Professor
Department of Orthopaedics & Rehabilitation
The University of New Mexico

CALL FOR SUBMISSIONS

WJO 2026; Volume 15

YEARLY DEADLINE: NOVEMBER 1

***WJO* highlights the following types of articles relevant to orthopaedic surgery and engineering:** clinical and basic-science original research, case reports, reviews, technical notes, new technology, pilot studies, education articles, and reflections.

Peer-Reviewed, Annual Biomedical Publication
WJO employs a meticulous double-blind review process, ensuring anonymity between authors & reviewers

Open Access
Articles featured in *WJO* are freely accessible from *WJO's* website, allowing anyone to read, download, and share

No Submission Fee
WJO does not accept submission fees as a way to stay committed to fostering accessibility and collaboration in academia

International Research Submissions
WJO welcomes and publishes submissions from researchers around the globe, reflecting our commitment to diverse and broad perspectives

Short (1-Page) Instructions for Authors:
https://orthopaedics.unm.edu/research/research-journal.html

Email your Title Page, Blinded Manuscript, Figures, and Tables to WJO@salud.unm.edu

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INSTRUCTIONS FOR PEER REVIEWERS

WJO follows a double-blind peer review process to maintain the highest standards of academic quality. Reviewers participate in the following steps:

STEP 1

The *WJO* Editorial Team sends the Reviewer a PDF of the submission, a Response Form, and assessment guidelines.

STEP 2

The Reviewer submits their initial review within two weeks, including an overall assessment, author-specific feedback, and a publication recommendation for the Co-Editors.

STEP 3

The *WJO* Editorial Team sends the Author a blinded copy of the review, and the Author has two weeks to respond to Reviewer comments.

STEP 4

The *WJO* Editorial Team returns the revised submission and Author responses to the Reviewer for final approval or disapproval.

Reviewers will not be asked to review more than two submissions for a given volume. We understand that reviewer's time is limited and valuable. If the request is not possible, or if you believe that the content does not align with your expertise, please let us know immediately. A prompt review helps encourage authors to submit future work and allows our team to meet printing and publication deadlines.

PEER REVIEWERS: *WJO* 2025

The Co-Editors and Editorial Team of *WJO* extend our thanks to our peer reviewers, whose generous contributions of time, insight, and expertise play a vital role in shaping the scientific integrity and relevance of our content. Your thoughtful reviews uphold the standards of academic excellence we strive for.

Together, we continue progressing on our shared journey toward official indexing in PubMed and expanding the reach and impact of *WJO*.

Justin Bartley
Patrick Bosch
Trevor Crean
Thomas DeCoster
Rebecca Dutton
Shawn Duxbury
Rick Gehlert
Mischa Hopson
Samer Kakish
Eric Kruger
Eric Lew
Richard Miller
Beth Moody Jones
Drew Newhoff
Blake Obrock
Laura Shevy
Andrew Veitch
Adam Walsh

SHORT INSTRUCTIONS FOR AUTHORS

Western Journal of Orthopaedics

The Western Journal of Orthopaedics (WJO) is a peer-reviewed (double blinded) publication of the UNM Department of Orthopaedics & Rehabilitation. *WJO* publishes annually in June and highlights original research relevant to orthopaedic-focused surgery and engineering, with the goal of MEDLINE indexing.

The submission deadline for *WJO* volume 15 is November 1, 2025. Manuscripts submitted afterward will be considered for volume 16. Email questions to WJO@salud.unm.edu.

Submit the Title Page, Blinded Manuscript, each table, and each figure to **WJO@salud.unm.edu.**

General Formatting: Title Pages and Blinded Manuscripts must be submitted as Microsoft Word documents. *WJO* follows the style and format of the *AMA Manual of Style* (11th 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, $P = 0.05$, $P < 0.01$).

Title Page: State the paper’s title. List authors’ names in the desired order of appearance. For authors, include their highest academic degree, current affiliations, and any changed affiliations since the time of the study. Identify the corresponding author’s name, physical address, and email. Include five informative statements: 1) funding, 2) conflict of interest, 3) informed patient consent for case reports *OR* your Institutional Review Board approval number if the research involved humans, 4) preferred subspecialties of reviewers for your submission (eg, pediatric spine), and 5) acknowledgments of any non-authors who contributed.

Blinded Manuscript: Excluding the references, abstract, tables, and figure legends, we will accept ≤3200 words for reviews; ≤2500 for scientific articles, pilot studies, education articles, and new technology; ≤1200 for case reports and technical notes; and ≤1000 for reflections. For scientific articles and education articles, include the following headings: Abstract, Introduction, Methods, Results, Discussion, References, and Figure Legends if figures are used. For reviews, use the same headings but replace Discussion with Conclusion. For case reports, the headings are Abstract, Introduction, Case Report, Discussion, References, and Figure Legends. Email us about headings for other submission types. Subheadings may vary but are generally not included in the Introduction, Discussion, or Conclusion sections.

Abstract: ≤250 words for scientific articles, structured into four paragraphs: Background, Methods, Results, Conclusions. ≤150 words for education articles, case reports, technical notes, new technology, and pilot studies (≤250 for reviews) in an unstructured paragraph format. At the end, list 3 to 5 keywords using terms searchable in the MeSH database (https://meshb.nlm.nih.gov/search).

References: List in order of appearance (not alphabetically) and cite in the text using superscript numbers. Format all references in *AMA Manual of Style* (11th ed). All listed references must be cited in the text and vice versa.

Tables/Figures: Create tables using only the Microsoft Word table function. Number each table and include a descriptive title. Place each table on a separate page after the References section in the Blinded Manuscript. For figures, place each one at the end of the Blinded Manuscript and also email us each one as an EPS, TIFF, PPT, or JPEG file in 300 DPI. Provide a brief description of each figure in the last page of the Blinded Manuscript, under a Figure Legends heading. When submitting a figure 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 *WJO* as an avenue to feature your research.

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Letter from the Chair of Orthopaedics

What an exciting time of year! The Alumni conference and the publication of the *Western Journal of Orthopaedics (WJO)* are celebrations of another successful year for our team – treating patients, exploring research questions, and training the next generation of orthopaedic surgeons.

Summer is a time to welcome our newest class of residents and to cheer on our graduating chiefs as they continue their journeys as orthopaedic surgeons into fellowship and beyond. Time always seems to fly – it seems like just yesterday that our graduates were rotating with us and interviewing for residency.

With Match Day 2020 coming just nine days after the World Health Organization declared COVID-19 a global pandemic, Nick, Tyler, Will, Solomon, and Audrey embarked on an already uncertain and challenging journey during one of the most uncertain and challenging times in our country's recent history. With a style that has been the calling card of their class throughout their time here at UNM, they rose to meet and conquer these challenges, leaving all of us better than they found us five years ago.

Every year seems to bring a sense of transition, and this past year has been no exception. Since our last edition of *WJO*, we lost our long-term friend and colleague, Joni Roberts. Joni faced her cancer diagnosis with remarkable courage and her characteristic grace. Her absence has left an unfillable void, especially as we celebrate our graduates without her for the first time in nearly 20 years. We miss you dearly, Joni, and wish you were here to share this time with us. We dedicate this year's Alumni Conference and *WJO* to your memory.

I am so grateful and proud to be part of the UNM Orthopaedic Family, and it is an honor to congratulate our residency and fellowship graduates. We are all fortunate to have participated in your training and to now count you among our colleagues. We are incredibly proud of each and every one of you.

Gehron P. Treme, MD
Interim Chair
UNM Department of Orthopaedics & Rehabilitation

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Camille Aubin-Lemay MD


Attlee Benally DPM


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Beau Shelton
PA-C


Amber West
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PA

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Shannon Lopez CNP
Antonio Marquez PA
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Sydney Slenes PA-C
Amanda Stratmoen, CNP

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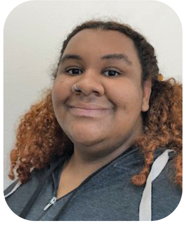

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2024 Alumni Conference Highlights

The 43rd annual UNM Orthopaedic Alumni Conference was held on June 7, 2024, at the Sandia Resort Event Center. This conference is intended to provide an update in current orthopaedic practices. Our audience comprises of practicing orthopaedic surgeons, advanced practice providers, therapists, and other professionals who work in the orthopaedic realm. This year's conference topic was "Orthopaedic Spine Surgery, Practice Management, and Diversity in Orthopaedics," with four main objectives:

1. **Understand emerging concepts in spine injuries and deformities and appropriate treatment options**
2. **Identify injuries and patients appropriate for surgical intervention**
3. **Understand choosing a career path as a spine surgeon: academia vs. private practice**
4. **Understand emerging concepts in orthopaedics: hand, sports, and trauma**

We had the honor of hearing presentations from two talented orthopaedic surgeons, Dr. Evalina Burger, from the University of Colorado Anschutz Medical Campus, and Dr. Supriyah Singh, from the London Health Sciences Centre Victoria Hospital, our 2024 invited speakers. The conference was followed by a graduation dinner for the chief residents and fellows where our interim chair of orthopaedics, Dr. Gehron Treme, delivered a thoughtful keynote speech.

Evalina Burger, MD

Evalina Burger, MD, is a Professor and the Chair in the Department of Orthopaedics at the University of Colorado Anschutz Medical Campus. Dr. Berger earned her undergraduate degree from the University of the Orange Free State, South Africa where she also completed her MB ChB. She completed residency at the University of Pretoria Academic Hospital, South Africa, after which she completed the American-British-Canadian Traveling Fellowship, where she became the first female orthopaedic surgeon from South Africa and only the third woman ever to receive this prestigious fellowship program awarded to highly accomplished young surgeons from English-speaking countries. Dr. Burger specializes in complex spinal surgery, adult deformity, and scoliosis.

Supriya Singh, MD

Supriya Singh, MD, is an Assistant Professor in the Division of Orthopaedic Surgery at London Health Sciences Centre's Victoria Hospital, Ontario. Dr. Singh earned her medical degree and completed her orthopaedic surgery residency at the Schulich School of Medicine and Dentistry, Western University, Ontario. She completed her fellowships in Adult and Pediatric Spine Surgery at The University of British Columbia, Canada. During her time in residency and fellowship, Dr. Singh was involved with Team Broken Earth, doing spine surgery outreach work in Haiti. Dr. Singh specializes in orthopaedic surgery with a focus on adult and pediatric spinal injuries.

Letter from the Residency Director

As we celebrate the publication of the 14th edition of *WJO*, I remain profoundly impressed by our residents' unwavering dedication to advancing research. Their contributions extend far beyond articles published in our journal, with many residents' research being showcased in other prestigious journals as well. While our department houses extensive talent, I would like to take this opportunity to acknowledge the extraordinary achievements within our Residency program.

Our Residency program continues to grow, offering several research opportunities for both faculty and staff, and residents excelling in their individual research interests. We take pride in the fact that a number of our residents exceed the two-project minimum for graduation, with many taking on additional projects within the department. Our focus is not only on developing residents into skillful surgeons and clinicians, but also on fostering overall personal and professional growth. I am honored to be part of a program that provides residents with the educational and clinical foundation that will guide them throughout their careers as orthopaedic surgeons.

Lastly, I would like to recognize the outstanding work of the *WJO* co-editors, Dr. Deana Mercer and the Vice Chair of Research and fellow *WJO* co-editor, Dr. Dustin Richter. I also want to express my gratitude for Dr. Christina Salas, former *WJO* co-editor. Dr. Salas' support and dedication have been instrumental in the journal's growth and success. The co-editors' commitment to project completion, involving medical students, and supporting residents during their didactics is greatly appreciated. In my 19 years at UNM, I have witnessed tremendous growth within the department, much of which is owed to our amazing research team. Monthly research meetings, dedicated staff supporting project completion across divisions, and the growth of *WJO* have played a key role in our success. As our department continues to grow and evolve, I have confidence that with Dr. Dustin Richter's leadership our research will continue to thrive.

Thank you to the entire research team and to *WJO* for supporting our residents and faculty.

Selina Silva, MD
Orthopaedic Surgery Residency Program Director
The University of New Mexico School of Medicine

Orthopaedic Residents

PGY 4

Cesar
Cardenas MD

Colin
Carroll MD

Taylor
Gurnea MD

Kate
Parker MD

Ryan
Price MD

PGY 3

Carolyn
Ardizzone MD

Tomas
Holy MD

Hayley
Urreiztieta MD MPH

Kylan
Larsen MD

Nicholas
Newcomb MD

PGY 2

Cory
Alford MD

Mathew
Gremillion MD

Naomi
Kelly MD

Hernan
Lebensohn MD

Lauren
Nun MD

PGY 1

Lorena Fuentes
Rivera Lau MD

Matthew
Gasparro MD

Johnathan
Jensen MD

Hoang
Nguyen MD

Tobi
Odeneye MD

Chief Residents

Audrey Wassef, MD

Medical School: Baylor College of Medicine
Fellowship: The Ohio State University - Spine

Many surgeons say that even as children they dreamed of becoming surgeons. As a child, I would have confidently said that I would be a WNBA star or a professional food taster. Luckily, neither of those options played out and I ended up in the greatest profession possible.

I grew up in Houston, Texas and attended Rice University for my undergraduate studies. At Rice, I ran cross country and track, an experience that honed the work ethic that would carry me through long call weekends in the years to come. Throughout this time, I lived with my twin sister, Chrissy, who pushed me to become the best student and athlete I could be, while also being my best friend.

I attended Baylor for medical school, only venturing out to do my orthopaedics sub-internships. The first of those sub-internships was at UNM, which very quickly felt like the place I wanted to pursue residency. Around this time, I also met Raf, who I somehow convinced to marry me during my fourth year of residency after over three years of long distance.

Leaving Texas, my family, and my friends behind for residency was a tough decision but was ultimately the right one. I am tremendously grateful for the patience, encouragement, and time that all of our attendings have invested in my development as a surgeon. I have enjoyed learning from you all more than I can express.

None of this would be possible without my family and friends who supported me along the way. My parents spent hours helping me and my siblings with homework, driving all over Texas for track meets, and encouraging us through medical school. Thank you for believing in me when I did not believe in myself. My siblings have been in busy residencies as well but always take the time to talk. Thank you for cheering me on as we all navigated this experience together. Thank you to Kate Parker, who has been the best roommate, friend, and cat aunt I could ever ask for. Finally, my husband Raf has been my rock, never wavering in his faith in me. Thank you for your patience, willingness to jump on hundreds of flights to see me, and for single handedly planning our entire wedding.

I look forward to my spine fellowship at The Ohio State University, where I hope to make you all proud. I am forever grateful for my years here in New Mexico.

Tyler Chavez, MD

Medical School: Harvard Medical School
Fellowship: Harborview Medical Center - Trauma

I was born and raised in Las Cruces, New Mexico. I grew up surrounded by a big New Mexican family and spent most of my free time playing and watching sports. Baseball was my first love, filling my early summers with competitive games and fun times with friends. I also loved music from a young age, playing both trumpet and guitar.

I completed my undergraduate studies at New Mexico State University (Go Aggies!), where I majored in Genetics & Biotechnology in the college of agriculture. There, I found life-changing mentors who saw my potential before I did and pushed me to pursue it. In my spare time, I developed a passion for medicine while working as a medical scribe in our local Las Cruces emergency department. I then attended Harvard Medical School, where my world view expanded exponentially, and I was fortunate to connect with people who remain some of my best friends and greatest supporters to this day. I discovered my excitement for the operating room and the fulfillment that comes with caring for injured patients. This led me to pursue a career in orthopaedic trauma surgery.

Choosing UNM for residency was an easy decision. I knew the program was special from the day I arrived as a visiting student. The supportive culture, excellent mentorship, and hands-on surgical training have remained top notch throughout my five years. I will be forever grateful for all of the outstanding surgeons I have had the privilege of learning from within the department. Outside of work, I continue to enjoy all things sports related. On my days off, you can typically find me in the gym, on the pick-up basketball court, or on the golf course. I also enjoy trail running in the New Mexican high desert, good food, live music, and country dancing.

I would like to thank all of my supportive family and friends who have helped and encouraged me along the way. I certainly could not have made it this far without their support and guidance. Most of all, I would like to thank my loving mother, Rebecca, for being an unwavering source of inspiration, love, and support.

Next year, I will complete a fellowship in orthopaedic trauma surgery at Harborview Medical Center in Seattle, Washington. After fellowship, I hope to return to the Southwest to fulfill my lifelong mission of increasing access to specialty trauma care in my community.

Chief Residents

Nicholas Brady, MD

Medical School: University of Texas, San Antonio
Fellowship: Robotics Institute at Ortho Rhode Island - Joint Reconstruction

My path to becoming an orthopaedic surgeon has been unconventional. After earning my undergraduate degree in economics and an MBA from The University of New Mexico, I began my career in the investment industry here in my home state, New Mexico. Early on, I realized that my true calling was in medicine. I was fortunate to have incredible mentors who guided me toward a new path, ultimately leading me to orthopaedics.

I attended the University of Texas at San Antonio for medical school and had the privilege of rotating at UNM as a medical student. During my rotation, I worked with Drs. Treme, Silva, Miller, Chafey, Gehlert, Kakish, and Richter. From the outset, I knew that this was where I wanted to train as an orthopaedic surgeon. I feel lucky to have learned from them and all the faculty at UNM over the past five years.

Growing up as a competitive golfer, I developed a particular passion for joint reconstruction, as the surgeries often require a similar thought process needed to compete in golf: patience during challenging moments, developing a reliable routine, and the ability to adapt. Both are highly technical and elusive, yet appear very simple on the surface. Next year, I will continue my passion for robotic joint replacements with a fellowship in adult joint reconstruction at the Robotics Institute at Ortho Rhode Island.

I am profoundly grateful to The University of New Mexico Orthopaedics & Rehabilitation Department for providing me the opportunity to train and grow as an orthopaedic surgeon. To my parents, Bill and Yoshiko, thank you for always believing in me and supporting me; none of this would be possible without you. I would also like to thank my sister, Christina, an unwavering role model and friend, and my brother-in-law, Zach, who helped me realize that I could become a physician—your support means the world to me. Most importantly, thank you to my wife, Emily, for standing by my side and supporting me throughout the last five years. To Nora, my little nugget, you made my journey every bit worth it.

William Curtis, MD

Medical School: University of Southern California
Fellowship: Columbia University - Shoulder/Sports Medicine

I grew up just outside San Francisco in San Rafael, CA with my mother Tina-Lise, father David, and younger brothers Wes and Sam. Growing up in an outdoorsy household, I spent most of my free time mountain and road biking with my dad, skiing, and hiking with the family dogs. In high school, I began racing mountain bikes at an international level, raced with the National Team in Europe, and represented the United States at the World Championships.

I completed my undergraduate studies at University of California at Santa Cruz, where I lived all four years with future co-resident, Nick Newcomb, and continued to race mountain bikes professionally while completing a degree in human biology. My parents soon followed me down to Santa Cruz County, where they still live today with their dog, Millie. Following a series of injuries and surgeries after college, I became passionate about a career in orthopaedic surgery. I then attended University of Southern California for medical school, where I graduated Summa Cum Laude and rotated at UNM as a fourth-year student. I was lucky enough to match at UNM for residency and have loved living in New Mexico since.

I currently live in Albuquerque with my lovely fiancée, Emi, and our husky, Jackson. We enjoy riding bikes on the many trails around the Sandias, resort and backcountry skiing, exploring New Mexico, and walking Jackson in the trails by our house (although never as much as he would like). We are excited to spend the next year in New York City, where I will complete a fellowship at Columbia University in shoulder and sports medicine. We hope to return to New Mexico following fellowship.

I would like to thank my family for their endless support throughout the many phases of my career. Emi, thank you for your unwavering love despite many missed dinners and altered plans. I would also like to thank my co-residents for making work fun every day, and all my mentors at UNM who have embodied what it means to be a compassionate, skilled, and well-rounded physician.

Chief Residents

Solomon Oloyede, MD

Medical School: University of Oklahoma
Fellowship: New England Baptist Hospital - Spine

I was born in Nigeria and raised in Edmond, Oklahoma. I earned my bachelor's degree in biology from the University of Central Oklahoma before attending the University of Oklahoma School of Medicine, where I graduated in 2020. Completing residency at The University of New Mexico has been an incredible journey, allowing me the chance to pursue my orthopaedic surgery training.

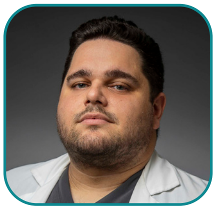
The past five years have been a transformative experience, and I am indebted to the exceptional attendings who have mentored me. Their unwavering support, constructive feedback, and invaluable wisdom have been instrumental in my growth. After completing my orthopaedic surgery residency, I will be pursuing a fellowship in spine surgery at New England Baptist Hospital in Boston, Massachusetts. Outside of the hospital, I enjoy playing soccer, weightlifting, and exploring the beautiful state and national parks nearby.

To my parents, thank you for the innumerable sacrifices that changed the trajectory of my life forever; this is for you. To my amazing wife, thank you for your unwavering love and support. You have been my rock through the highs and lows of this journey. I love you.

Fellows

Christopher Canario, DO
Fellowship: Sports Medicine
Residency: Rocky Vista University of Osteopathic Medicine
Medical School: Good Samaritan Regional Medical Center

Matthew Eads, MD
Fellowship: Hand
Residency: University of Kentucky
Medical School: University of Kentucky



Gabriel Echegray, MD
Fellowship: Hand
Residency: University of Puerto Rico School of Medicine
Medical School: University of Puerto Rico School of Medicine

Robert Mercer, MD
Fellowship: Trauma
Residency: University of Nevada Las Vegas
Medical School: The University of New Mexico School of Medicine

Dustin Richter, MD
Fellowship: Sports Medicine
Residency: Medical College of Wisconsin
Medical School: Medical College of Wisconsin

SAGITTAL ALIGNMENT CONCEPTS

Audrey Wassef, MD

Sagittal alignment refers to the balanced relationship between the cranium, spine, and pelvis. It is not just relevant to deformity surgeons, but should be a fundamental consideration for all spine surgeons to avoid creating unintended deformities. Recent advancements have led to a better understanding of what constitutes normal anatomy and how surgical interventions can preserve or restore it.

Lordosis refers to the natural inward curvature of the lumbar spine. Pelvic incidence (PI) is a static measure that remains unchanged regardless of surgery or posture. Sacral slope represents the angle between the sacral plate and the horizontal plane, while pelvic tilt describes the angle formed between the vertical axis and the line connecting the sacral midpoint to the femoral heads. The sagittal vertical axis measures how far the upper body shifts forward or backward relative to the pelvis. Additionally, T4 Pelvic Angle (T4PA) and L1 Pelvic Angle (L1PA) have emerged as critical angles for determining alignment goals in surgical planning.

Historically, several classification systems have attempted to provide a structured approach to sagittal alignment. The SRS-Schwab classification was useful for correlating radiographic findings with quality of life outcomes, but was not developed from a disease-free population. The Roussouly Classification, based on sacral slope and the apex of lumbar lordosis, recognized individual variability in alignment, but proved difficult to use intraoperatively with poor interrater reliability. The global alignment and proportion score introduced a predictive formula for mechanical failure risk, but it remained challenging to reproduce and still relied heavily on pelvic incidence.

Recent findings have helped establish more precise surgical targets. The equation for L1-S1 lordosis is given as Lordosis = 0.60(PI) + 30, while the L1PA goal is calculated as L1PA = 0.5(PI) - 20. Furthermore, the T4PA goal should be maintained within -3° to +1° of L1PA to minimize the risk of mechanical failure. These new parameters allow for more objective and standardized alignment targets in surgical planning.

Ultimately, sagittal alignment should be considered in every spinal surgery, even in cases involving only one or two degenerative levels, because changes at one level affect the entire spine. Failing to account for proper alignment may lead to progressive complications like Proximal Junctional Kyphosis or catastrophic implant failure, requiring multiple future surgeries. The field is continuously evolving, and while recent research has provided new insights, current data only extend to two-year follow-ups, leaving many long-term outcomes yet to be determined.

THE INS AND OUTS OF SHOULDER INSTABILITY

William Curtis, MD

Anterior shoulder instability is a relatively common orthopaedic condition that affects 1.0% to 2.0% of people in their lifetime. It is seen more frequently in men and in military populations, and leads to chronic instability in up to 90.0% of patients experiencing their initial instability episode at under 20 years old. It is normally caused by an anterior-directed force to an abducted, externally-rotated shoulder, but can also be secondary to generalized ligamentous laxity and/or repetitive microtrauma. Glenohumeral instability has been associated with increased risk of future shoulder arthropathies.

The stabilizing elements of the native glenohumeral joint can be separated into static and dynamic stabilizers. The static stabilizers include the glenoid fossa, joint capsule, glenoid labrum, glenohumeral ligaments, and synovium. Dynamic stabilizers include the rotator cuff muscles, which create a concavity-compression effect.

Work up of anterior glenohumeral instability includes a history focused on risk factors for chronic instability (eg, age, previous instability, mechanism, daily activities) and exam that focuses on range of motion, rotator cuff strength, and apprehension. Radiographs will commonly show a Hill-Sachs lesion (HSL) at the posterior humeral head and anterior-inferior bone loss at the glenoid. Magnetic resonance imaging (MRI) is used in initial work up to evaluate the labrum, cartilage, and rotator cuff. Computed tomography scan can be used to better characterize bone loss, although recent literature has demonstrated efficacy of MRI in characterizing bone loss. Advanced imaging can be used to calculate the glenoid track and HSL, from which “on-” (non-engaging) versus “off-track” (engaging) lesions can be determined.

Treatment is based on the amount of bone loss at both the glenoid and humeral head. Nonoperative management with physical therapy focused on rotator cuff and periscapular strengthening can be attempted for first-time dislocations but has a high failure rate, especially in young and athletic populations. Patients with glenoid bone loss of less than 13.5% with an on-track HSL can be treated with arthroscopic labral repair, while those with an off-track HSL can be treated with labral repair with Remplissage, open capsular shift, or a bone-block procedure, such as Latarjet or distal tibial allograft. Patients with greater than 25.0% glenoid bone loss should be treated with a bone-block procedure, regardless of whether the HSL is on-track or off-track. Treatment of patients with moderate glenoid bone loss (13.5%-25.0%) is less well defined, but includes labral repair with Remplissage, open capsular shift, or bone-block procedures. Allograft procedures to address large HSLs (>30.0%) have also been described with promising early results.

Future research should focus on timing of return to sport, definition and treatment of “subcritical” glenoid bone loss, prevention of future arthropathy, and treatment of shoulder instability in the setting of global hyperlaxity.

THE ROLE OF ROBOTICS IN TOTAL KNEE ARTHROPLASTY

Nicholas Brady, MD

The field of joint arthroplasty faces two critical challenges: 1) rising costs due to advanced technologies, and 2) increasing demand for joint replacements, while Center for Medicare and Medicaid Services reimbursement rates decline. Surgeons must do more with fewer resources. The introduction of expensive, disruptive technology without long-term outcome data naturally sparks controversy.

Patient dissatisfaction with total knee replacements stems from various factors, including component malpositioning, poor soft-tissue balancing, overlooked pain sources, aseptic loosening, and infection. Compared to patients who undergo total hip replacements, those who undergo total knee replacement report lower satisfaction rates. This discrepancy likely arises from the complexity of the knee. While sports medicine literature has extensively documented native knee biomechanics, total knee replacement alters these biomechanics by removing stabilizing ligaments and modifying soft tissue. Since the introduction of the total condylar knee in the 1970s, surgeons have sought to replicate native knee mechanics with various implant designs. No single design has definitively prevailed, but advancements in materials have significantly reduced aseptic revisions.

How does robotics improve outcomes? First, it's crucial to distinguish between technologies. "Passive" systems require the surgeon to manually cut with a hand-held saw, whereas "semi-autonomous" systems use a robotic arm to control the saw blade. Another distinction is whether the system uses a computed tomography (CT) scan. Navigation systems rely on the surgeon to map bone architecture, while CT-guided systems integrate anatomic landmarks with a CT scan, providing a three-dimensional view of the bone.

The paradigm shift in knee arthroplasty comes from the ability to balance the knee before making bone cuts. Traditional manual techniques involve cutting the bone first to restore mechanical alignment, then adjusting soft tissues to balance the knee—akin to forcing a square peg into a round hole. Robotic-assisted CT-guided systems allow for precise bone cuts with minimal soft-tissue manipulation.

Robotics should be seen as a tool that enhances surgical precision, particularly in achieving accurate bone cuts. However, two key challenges remain: 1) objectively assessing soft-tissue tensioning, and 2) determining each patient's ideal constitutional alignment and joint line obliquity. Regardless of whether a surgeon favors mechanical or kinematic alignment, robotics can help achieve the desired outcome.

The next phase of robotics holds exciting potential, particularly in complex primary cases, conversions, and revisions. This is where robotics may prove most valuable, demonstrating significant cost savings and improved outcomes.

NAVIGATING THE EMERGENCE OF NEW TECHNOLOGY IN SPINE SURGERY

Solomon Oloyede, MD

Recent innovations in spine surgery are drastically reshaping how procedures are planned and executed. The integration of advanced imaging technology, robotics, and artificial intelligence (AI) have paved the way for more precise interventions. Surgeons are now able to leverage real-time, three-dimensional images for meticulous preoperative planning and precise implant placements, thereby significantly reducing complications and improving patient outcomes.

Computer-assisted navigation (CAN) has been a transformative force in spine surgery since its emergence in the mid-1990s. By leveraging advanced imaging systems—such as the O-arm® and Ziehm Vision FD—that provide real-time operative feedback, this technology empowers surgeons to achieve exceptional precision. CAN has fundamentally altered the surgical landscape, allowing for more consistent implant placement and enhancing overall procedural safety by minimizing potential complications.

Robotic systems represent another critical evolution in the field. Various robotic platforms assist surgeons by offering enhanced control and precision during both the preoperative and intraoperative phases. These platforms employ rigid robotic arms that provide precise guidance for surgical instrumentation based on detailed preoperative plans. As a result, surgeons can accurately predict the ideal trajectory of pedicle screws, determine the optimal rod length and contour, select the appropriate cage size, and estimate the necessary deformity correction before entering the operating theatre. Notably, patient-specific precontoured rods enable surgeons to efficiently manage large deformity cases.

The evolution of minimally-invasive techniques, particularly those using endoscopic methods, has further advanced spine surgery. Modern endoscopic strategies—including full endoscopy, biportal, and microendoscopy approaches—allow for targeted interventions that minimize tissue disruption and promote faster recovery times. Concurrently, emerging augmented reality (AR) technologies, such as the Augmedics Xvision headset, offer real-time anatomical overlays and hands-free navigation, potentially improving outcomes by reducing line-of-sight interruptions and attention shifts associated with traditional navigation setups.

In exploring the future trajectory of spine surgery, new platforms that are built on the synergy of robotics, CAN, AR, and AI promise to refine and personalize procedures, heralding a new era of technology-driven, patient-centered care.

THE EVOLUTION OF ORTHOPAEDIC TRAUMA SURGERY CARE FOR THE MULTIPLY-INJURED PATIENT

Tyler Chavez, MD

Emergency surgical care of the polytrauma patient is a complex and evolving concept. Overall mortality from polytraumatic injuries has decreased in recent years due to advancements in critical care, resuscitation protocols, and the development of comprehensive trauma systems. As survival rates improve, the orthopaedic management of these patients has become increasingly relevant and crucial in driving positive outcomes and reducing both morbidity and mortality.

Poly-traumatic events pose significant risks to patients, especially in the setting of major chest, abdominal, or brain injuries. While most of these body systems are managed by other surgical services, research has identified the presence of a femur fracture in a polytraumatized patient as an independent risk factor for pulmonary complications, acute respiratory distress syndrome, and mortality. Given this relationship, the orthopaedic trauma surgeon plays a critical role in providing safe surgical care at the appropriate point in the treatment timeline.

Historically, management of femur fractures in the polytrauma setting involved immobilization with splints, casts, or skeletal traction. The invention of the intramedullary nail in the mid 1900s changed orthopaedic trauma practice entirely. Naturally, this raised questions about the most appropriate timing for bony surgical fixation. The earliest guidance within the trauma community was to delay surgical intervention until the traumatized patient was completely clinically stable and had recovered from their other injuries before proceeding with intramedullary instrumentation. However, the complications of prolonged immobilization with this approach were quickly realized.

A major prospective study by Bone et al[1] demonstrated a trend towards increased complications in patients who underwent fixation more than 48 hours after injury. Despite lacking statistical significance, this result led the orthopaedic trauma community to push for definitive fixation as early as possible. Retrospective literature from the 1980s, though limited by confounders, supported the notion that early definitive fixation reduces complications. These studies led to an era defined by "Early Total Care," with emphasis on definitively fixing bony injuries within six hours of injury, despite the majority of studies evaluating time frames between 24 and 48 hours.

The 1990s and 2000s then refuted the benefits of "Early Total Care" by demonstrating increased rates of complications and mortality in the very early care groups. This was especially true in the setting of severe lung or brain injuries and the newer concept of secondary lung or brain injury as a result of early surgery. The concept of a "Damage Control" external fixator was also shown to be a viable option as a safe bridge to definitive fixation.

With much conflicting evidence up to this point, the critical question remained: which orthopaedic trauma patients should be treated in an early versus delayed fashion? Fortunately, important work was also being done to better define hemodynamic resuscitation, using pH, lactate, and base excess values. Vallier et al[2] evaluated these factors in a predictive model to define cut-offs that would predict a patient's resuscitation status and readiness for safe surgery. A follow-up prospective study using these defined parameters then demonstrated significant benefit when adequately resuscitated patients underwent surgery to fix unstable extremity, spine, and pelvic injuries less than 36 hours after injury.[3] This important work has come to define our current era of orthopaedic polytrauma practice as "Early Appropriate Care." This better stratifies patients based on resuscitation status and recommends early fixation (less than 36 hours after injury) for adequately-resuscitated patients and "Damage Control" for clinically unstable or under-resuscitated patients.

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Letter from the Chief of The Division of Physical Therapy

As we move into the 51st year of the Division Physical Therapy (DPT) at The University of New Mexico (UNM) School of Medicine, I would like to highlight the advancements we have made as a team. In 1968, when a small group put together our charter proposal, there were less than 40 PTs in the state. Today there are over 1,200 physical therapists statewide, and our program has graduated over 1,000 PTs in its short history. We quickly developed and adapted, transitioning from an entry-level bachelor's program to a Doctor of Physical Therapy program. We have now graduated students with a DPT degree for nearly 13 years.

A one-of-a kind research lab is now open at The University of New Mexico DPT program, paving the way for new and innovative research in physical therapy that will improve patient care across the state. The Gait and Motion Analysis Lab conducts cutting-edge research focused on understanding how people move and walk. Using advanced technology, including camera systems and various types of sensors, the lab tracks the movements of muscles, joints, and limbs to gather detailed data on walking mechanics. This research not only helps identify abnormalities, but also contributes to developing better rehabilitation methods and tools. The Gait and Motion Analysis Lab has been pivotal to the Physical Therapy program's success and a cornerstone of its research.

Over 70.0% of the Physical Therapy program's core-faculty at UNM use the lab for their research. In addition to faculty research, the lab will continue to increase research learning experiences for students. Physical Therapy students take part in faculty-led research projects, learning how to gather, export, analyze, and report data. The lab is also used by undergraduate and graduate School of Medicine students, medical residents, and UNM students studying engineering, statistics, and exercise science. The lab's modernization was made possible through a federal Health Resources and Services Administration grant, which allowed for significant renovations, including new cameras and the installation of advanced equipment like the Zeno Walkway. The Zeno Walkway provides critical data on gait and safety. The Gait and Motion Analysis Lab's expansion is not just a technological upgrade; it also represents a broader evolution in the field of physical therapy.

I would like to express my gratitude and appreciation for the hard work and dedication of our students and faculty in the Division of Physical Therapy. As a team, the DPT now averages over 12 peer-reviewed publications per year, close to 20 national and local professional presentations, and participation in grants valuing over $3 million. As we look toward our next 51 years, we will continue working toward funding scholarships for our students, growing our research agenda, and offering pro-bono physical therapy services to our community.

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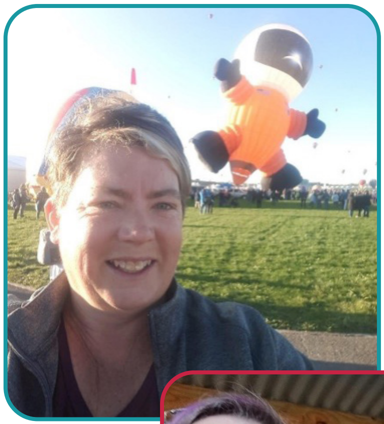
REMEMBERING
Joni Roberts

Joni's impact on us all is immeasurable. She was more than just a colleague – she was a friend, a mentor, and guiding light in our office. We are honored to share some of our favorite memories of Joni that exemplify the kindness, generosity, and dedication that defined her time with us.



"Joni was the best supporter, not just in work but in *life*."

Joni started with the department as a Program Coordinator in 2005. From the beginning of her tenure, Joni was dedicated to our mission and the teammates she worked with. She quickly became our go-to-person for everything office-related, supporting not only the residents but faculty and staff as well. Although her responsibilities continued to grow, she never once complained. She always showed up with a smile, ready to help, and participated fully in every department event. In her 19 years with the department, Joni contributed greatly to several department projects, including our research journal, the *Western Journal of Orthopaedics* (*WJO*) - previously The University of New Mexico Orthopaedic Research Journal. She served as one of the managing editors for 12 of the journal's 13 volumes. We would not have been able to build *WJO* into the successful, peer-reviewed journal that it is today without Joni's many contributions and efforts.

Joni went above and beyond by crocheting blankets for the new babies, babysitting when asked, and even lending an ear during tough times. She had a wealth of knowledge regarding UNM policies and procedures and took on several roles, including being the department notary and our "Chrome River Champion." Joni also contributed to the more mundane tasks, like clearing a copier jam and helping navigate Banner and P-card transactions. We relied on Joni for lots of things, including smaller, non-office-related reminders, like Valentine's Day and Administrative Assistants' Day to name a few. She always knew how to make those days special, sharing cards and gifts with the staff. One of our most cherished memories of Joni is her love for Christmas, specifically her Christmas Countdown Calendar, which brought joy and excitement to us all. We will continue to honor her love of Christmas by displaying her miniature Christmas tree on the front desk. Every time we see it, we will remember her during the holidays. Joni will also be remembered for the small bowl of candy she kept stocked at her desk for anyone who wanted to stop by for conversation and candy. Her candy bowl served as a token of appreciation and an effort to bring a smile to her colleagues; something she did without fail.

Joni's love for her family was obvious for those who knew her. She was the best aunt anyone could ask for, and her love for the Broncos was palpable. Joni was the best supporter, not just in work but in life. We are forever thankful for Joni's contributions to our lives and she will be missed dearly.

A Brief History of Opioid-Use Disorder in the United States, Effect on Orthopaedics, and Current Management Options

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ABSTRACT

Declared a public health emergency in 2017 and leading to 11 million years of life lost worldwide, the American opioid crisis has impacted millions of people, with up to 7 million experiencing opioid use disorder. In orthopaedic surgery, opioid analgesia has been associated with various complications, including infections, deep vein thrombosis, prolonged hospital stays, and overall inferior outcomes after surgical procedures. Orthopaedic surgeons commonly rely on opioids to provide postoperative analgesia and may frequently encounter patients with opioid use disorder. It is therefore essential that orthopaedic surgeons understand opioid use disorder, its effect on orthopaedic outcomes, and management of opioid use disorder in the context of surgical procedures. This review provides a background on opioid use disorder, a brief history of the American opioid epidemic, an overview of medications used to manage opioid use disorder, and recommendations on the management of these medications in the perioperative period.

Keywords: Buprenorphine; Methadone; Naloxone; Opioid, Opioid-Related Disorders

INTRODUCTION

Defined as the chronic use of opioids that causes significant stress or impairment, opioid use disorder (OUD) affects 7 million people in the United States and up to 26.8 million people worldwide.[1-3] It impacts people of all socioeconomic, ethnic, and educational backgrounds, is associated with a 20 times greater risk of early death, and has led to a cumulative 11 million years of life lost worldwide.[4] The United States accounts for only 4.4% of the world's population, but 80.0% of its opioid consumption. More people in the United States have died as a result of opioid overdose than any other drug class in the nation's history, increasing six-fold between 1999 and 2021. Gomes et al[5] performed a cross-sectional study to evaluate opioid-related mortality before and after the COVID-19 pandemic, from 2011 to 2021. They found a 63.0% increase from 2019 to 2021, highlighting the alarming interplay between the pandemic and OUD. In 2021 alone, 107,000 people died from an opioid overdose in the United States, accounting for 75.0% of the nation's overdose deaths and leading to a decrease in national life expectancy of 0.67 years in 2022.[3]

Orthopaedic surgery is the third highest opioid-prescribing specialty, accounting for 7.7% of the United States' opioid prescriptions.[6-9] Multiple studies have demonstrated that opioids are overprescribed postoperatively following orthopaedic procedures, with patients often using less than half of their prescribed amount.[6-9] Furthermore, a majority of patients report that they are unaware of how to safely dispose of their unused opioids, which can lead to increased risk of misuse.[6-8] Even when used within normal prescribing guidelines, preoperative and postoperative opioid use has consistently been associated with inferior postoperative outcomes after orthopaedic surgeries, including longer length of stay, higher rates of infection and deep vein thrombosis, increased long-term pain, worse functional scores, and other complications.[10-13] Given these associated risks, various studies have examined non-opioid multimodal pain protocols, reporting promising results.[14,15]

As opioids have become more commonly prescribed, and with OUD rising in prevalence, it is not infrequent that the orthopaedic surgeon will encounter patients with OUD. An increasing number of these patients may be prescribed medication for opioid use disorder (MOUD), such as buprenorphine, methadone, or Suboxone™, among others. While these medications effectively reduce mortality in OUD patients by curbing cravings, little research has explored their optimal management in the perioperative orthopaedic setting, including preoperative and postoperative care.[1,16] Therefore, there are very few established guidelines for managing pain and maintenance medications for patients with OUD who undergo either elective or nonelective orthopaedic procedures.

The purpose of this review is to provide an overview of the American opioid crisis, its impact on orthopaedic patients, and to review available guidelines for the management of patients with OUD undergoing orthopaedic surgery.

A BRIEF HISTORY OF THE OPIOID CRISIS

Morphine, a natural opioid derived from the opium poppy, was first manufactured during the American Industrial Revolution in the 1830s and quickly became a mainstay of acute and chronic pain control.[17] It was not until the 1870s that the first widespread concerns were raised regarding the potential for morphine addiction. By 1898, heroin was developed and marketed as a cough suppressant and treatment for morphine addiction. After heroin, other semi-synthetic opioids including hydrocodone, methadone, and combinations with acetaminophen, were introduced. In 1971, the Food and Drug Administration (FDA) approved naloxone, a potent opioid antagonist, for treatment of opioid overdose.

In the 1990s, the American pharmaceutical market became flooded with newly formulated opioids, including OxyContin™ by Purdue Pharmaceuticals in 1995, which was heavily marketed as a safe and potent pain reliever.[18] Just one year after the release of OxyContin™, the American Pain Society promoted pain as the "fifth vital sign," encouraging pain to be addressed with the same importance as basic vital signs such as heart rate, blood pressure, and temperature.[19] This was quickly adopted by major medical systems including the American Veterans Health Administration, the National Pharmaceutical Council, and the Joint Commission for the Accreditation of Healthcare Organizations.[20] These factors all contributed to a sharp rise in the prescription and sale of opioids, which quadrupled between 1999 and 2010. This was accompanied by a dramatic increase in opioid-related deaths, rising from 2.9 to 6.8 deaths per 100,000 people.[18] This rise in prescription-opioid deaths has since been labeled the "first wave" of the American opioid epidemic.[18]

In the early 2010s, the cost of heroin dropped as its production shifted from China and South America to Mexico. This resulted in decreased production costs, increased supply, and contributed to a nearly five-fold increase in heroin-related deaths between 2010 and 2018.[18] In this "second wave," heroin remained the leading cause of American opioid-related deaths until 2016 when fentanyl, a fully synthetic opioid, surpassed it for the first time. Fentanyl supply increased due to advances in illicit manufacturing process; this rise in supply resulted in the "third wave," and consequently, opioid overdoses soared from 10.4 to 21.4 deaths per 100,00 people between 2015 and 2020.[18] The United States government declared the opioid crisis a public health emergency in 2017, leading to a series of congressional initiatives, including dedicated funding for harm reduction strategies, naloxone access, and MOUD.[17,18] These efforts have led to a decrease in overall opioid-related deaths from 2023 to 2024, reaching their lowest since 2020.[21] Most recently, a "fourth wave" of challenging substance-use disorders has emerged with the rise of easily derived synthetic stimulants and tranquilizers (eg, methamphetamine, xylazine) packaged in combination with synthetic opioids.[22,23]

OPIOIDS IN ORTHOPAEDIC SURGERY

In recent years, there has been particular focus on the impact of opioid use on outcomes following orthopaedic procedures. This literature has consistently demonstrated that preoperative and/or prolonged postoperative opioid use is associated with greater postoperative analgesic needs, increased postoperative pain, less functional improvement from surgery, and a higher rate of complications across all orthopaedic subspecialties.[10,11,24-27] While not comprehensive, a summary of relevant literature can be found in Appendix 1.

MEDICATION FOR OPIOID USE DISORDER

Many treatments, including medications, behavioral therapies, harm-reduction strategies, and symptomatic treatment of withdrawal symptoms have proven beneficial for OUD.[4] The optimal treatment of OUD for many patients likely encompasses multiple or all of these modalities. The focus of this review is on common medications used in the treatment of OUD, and the way that they should be managed preoperatively and postoperatively in orthopaedic surgery. It is important to note that given the scarcity of research specific to orthopaedics, most of the recommendations are derived from other surgical specialties. The primary findings of this section are summarized in Appendix 2.

Methadone

Used in the treatment of OUD since the 1950s and proven to reduce the risk of overdose death by 59%, methadone is likely the longest-standing MOUD still routinely encountered by healthcare providers today.[28] As a synthetic, full opioid agonist, methadone fully activates mu-opioid receptors in the brain and functions by reducing cravings.[29] Methadone's long half-life reduces withdrawal symptoms and blunts the euphoria of short-acting opioids like heroin and fentanyl. Unlike some treatments, it can be initiated without prior withdrawal, even during hospitalization. As a full agonist, missed doses can still cause withdrawal, and excessive doses may lead to respiratory depression. Methadone requires days to weeks to reach a therapeutic dose and therefore must be carefully adjusted to avoid withdrawal or overdose. Methadone can only be prescribed to patients enrolled in state and federally-certified opioid treatment programs.[29] However, exceptions are made for patients admitted to a hospital for other conditions.

In most situations, methadone should be continued at the patient's standard dose throughout the perioperative period when undergoing surgical procedures. If the patient is unable to tolerate oral medications, intravenous methadone can be administered at one half to two thirds of their normal maintenance dose.[30] Additional opioid and non-opioid analgesics can be added as needed for uncontrolled pain. It should be noted that attempting to replace methadone with other opioids based on morphine-equivalents is often inaccurate given its longer half-life compared to shorter-acting opioids.[30]

Buprenorphine-Based Therapies

Buprenorphine was first released in the United Kingdom in 1978 as a pain reliever and was approved for treatment of OUD in the United States in 2002. This medication has a high-affinity partial agonist at the mu-opioid receptor as well as a weak kappa-receptor antagonist and delta-receptor agonist. Receptor interactions lead to reduced opioid cravings in patients who experience OUD while offering a safe treatment that has been shown to decrease overdose deaths in patients experiencing OUD by 38.0%.[28] Unlike methadone, it exhibits a "ceiling effect," meaning that respiratory and cardiac depression does not change with doses exceeding 24 milligrams, making it less likely to lead to overdose.[31] In higher doses, buprenorphine also exhibits greater antagonistic qualities, leading to a plateau effect on analgesia. However, it may still lead to respiratory depression, dependence, and other side effects related to opioids, especially when taken in high amounts for acute pain. Also in contrast to methadone, patients are required to abstain from using all long-acting opioids for at least 48 hours to 72 hours, and short-acting opioids 12 hours prior to initiating buprenorphine, as it can precipitate withdrawal.[32] This makes buprenorphine difficult to initiate in the inpatient setting. Buprenorphine is often prescribed as a formulation with naloxone, named Suboxone™. Because naloxone, a potent mu-opioid receptor antagonist, is inhibited when taken orally but fully active when injected, Suboxone™ may have a lower rate of misuse versus buprenorphine alone.

For patients taking buprenorphine prior to surgery, recommendations depend on the dose taken pre-operatively and the level of pain expected post-operatively. If the surgery is relatively minor and expected pain is low, it is recommended that patients continue buprenorphine at their baseline dose through the perioperative and postoperative period.[33] Rather than adding additional opioids, providers should use adjuncts such as anti-inflammatories, regional anesthetics, and acetaminophen if possible. If surgery is expected to cause relatively higher pain and is elective, the procedure should be postponed until the patient is weaned to 8 milligrams to 12 milligrams of buprenorphine daily. In emergent surgical cases for patients taking less than 8 milligrams to 12 milligrams of buprenorphine daily, providers should continue the normal buprenorphine dose, but may also consider adding supplemental opioids if pain control is inadequate.[30] Providers should keep in mind that the patient may have a high opioid requirement to overcome the buprenorphine mu-receptor blockade. In patients taking higher doses of buprenorphine preoperatively, providers may consider lowering the postoperative dose but should not decrease to fewer than 8 milligrams to 12 milligrams per day, as this may precipitate opioid overdose by flooding receptors with stronger agonists.[33] Finally, some authors have recommended replacing buprenorphine with methadone in the perioperative period, due to the stronger analgesic effect of the latter.[30]

Naloxone

Naloxone is a potent, fast-acting nonselective opioid receptor antagonist used to quickly reverse opioid overdose that has been approved by the FDA since 1971, available as a prescription since 2015, and available over the counter since 2023.[34,35] It is not used in maintenance treatment of OUD, but orthopaedic surgeons should still be knowledgeable of naloxone in case of need for emergent use in opioid overdose. As previously discussed, it is often combined with buprenorphine to limit misuse.

Naltrexone

Naltrexone is a mu-opioid receptor antagonist as well as a weaker kappa and delta-opioid antagonist that was developed in 1963 and approved for use in the United States in 1984.[36] It is also commonly used in treating alcohol use disorder. It functions by creating a blockade at mu-opioid receptors, therefore preventing opioid intoxication, and comes in both standard and extended-release intramuscular injection.[36,37] However, as a mu-opioid receptor antagonist, it can quickly precipitate severe withdrawal symptoms. For this reason, patients must stop all short-acting opioids (ie, fentanyl, oxycodone) for at least seven days prior to beginning naltrexone, and 14 days for long-acting opioids (ie, methadone).[37] Patients undergoing surgery that is likely to cause significant pain should stop taking naltrexone 48 hours prior to their procedure to allow for adequate postoperative opioid analgesia.[36] Patients taking a long-acting intramuscular naltrexone formulation should stop it 28 days prior to surgery.[36] However, providers should be very cautious in dosing opioids post-operatively, as these patients are at risk for opioid overdose after the mu-opioid receptor blockade is removed.[36] Patients requiring emergent surgical procedures will need to discontinue naltrexone, and may need higher doses of additional opioids postoperatively during the naltrexone wash-out period.[36]

MEDICATION MANAGEMENT

The authors want to acknowledge the difficulty patients may face with discontinuing MOUD in preparation for surgery. Naltrexone, methadone, and Suboxone™ have been credited with offering significant support for patients who struggle with substance use and improving their quality of life. When undergoing an elective orthopaedic procedure, it is important for the prescribing physician and surgeon to work together to provide education and plan accordingly for the surgery. For example, stable patients who are on long-acting injectables of naltrexone can be switched to an oral formulation, which can be discontinued 48 hours before the procedure.

CONCLUSION

OUD is an increasingly common condition that will be encountered more frequently by orthopaedic surgeons. It is important that orthopaedic surgeons understand how opioids may affect postoperative outcomes in patients with or without opioid use disorder, and become comfortable managing MOUD in the preoperative, perioperative, and postoperative periods. This review discusses a brief history of the opioid epidemic, the effect of opioids and OUD on outcomes following orthopaedic procedures, and basic recommendations for the management of MOUD in the context of orthopaedic surgery.

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Appendix 1. *Summary of Literature on Effects of Opioids on Postoperative Outcomes.*

Author(s)	Population of Interest	Findings
Cozowicz et al[10]	National Premier Perspective Database, containing over 1,000,000 lower extremity arthroplasty and 220,000 patients undergoing a spinal fusion	Patients who received the highest amounts of prescribed opioids (the top quartile) had higher rates of DVTs, postoperative infections, urinary, gastrointestinal, and respiratory complications, longer hospital stays, and increased healthcare cost
Brandner et al[11]	Patients undergoing total shoulder arthroplasty	Chronic opiate use led to a higher rate of hospital readmissions, revision surgeries, dislocations, bleeding, and gastrointestinal complications
Brandner et al[11] & Hills et al[12]	Patients undergoing spine surgery	Preoperative opioid use was associated with higher rates of postoperative pain, worse functional outcomes, decreased satisfaction, and increased disability
Curtis et al[24]	Patients undergoing orthopaedic surgery	Higher pain scores reported despite increased opiate medication use perioperatively
Johnson et al[25]	77,573 patients undergoing hand surgery	13.5% of previously opioid-naïve patients continued to take opioids at 90 days following hand surgery
Okoli et al[26]	Patients undergoing common elective orthopaedic surgery	6.0% of previously opioid-naïve patients continued to take opioids at six months postoperatively
Basilico et al[27]	17,961 opioid-naïve patients	The risk of prolonged opioid use after hospital discharge (defined as 90 days) was associated with the quantity of opioids included in the patients' discharge medications, highlighting the need for sparing use of these medications postoperatively

Deep Vein Thrombosis, DVT

Appendix 2. *Common Medications for Opioid Use Disorder and Management Recommendations.*

Medication	Mechanism	Advantages	Disadvantages	Recommendation
Methadone	Long-acting mu-opioid agonist	• Most proven to reduce overdose deaths in OUD • No opioid cessation required prior to initiation	• Can still lead to respiratory depression and death in high doses • Certification required to prescribe	Continue preoperative dose through the perioperative and postoperative period. IV methadone should be dosed at one half to two thirds the home dose in settings where patient is unable to tolerate oral medications. Control of postoperative analgesia can be achieved with the addition of opioids and non-opioids.
Buprenorphine/ Suboxone™	High-affinity partial mu-opioid agonist, weak delta-opioid, weak kappa-opioid antagonist	• "Ceiling effect" limits respiratory and cardiac side effects • Suboxone™ limits misuse • Prescribed without additional certification	• Can still lead to respiratory depression • Can precipitate withdrawal symptoms in patients actively using other opioids • Need to cease opioid use for 12 hours to 72 hours prior to initiation	For minor procedures, patients can continue their usual preoperative daily dose. For more extensive procedures, limit the dose to 8 milligrams/day to 12 milligrams/day, with gradual tapering to this level for elective surgeries when possible. In nonelective surgeries, reduce the postoperative dose to 8 milligrams/ day to12 milligrams/day. Breakthrough pain can be managed with additional opioids, non-opioid analgesics, anti-inflammatories, regional anesthetics, and acetaminophen.
Naltrexone	Strong mu-opioid antagonist, weak delta- and kappa antagonist	• Prevents opioid intoxication • Not an opioid, does not cause opioid side effects	• Can precipitate withdrawal • Must be off opioids for 7 days to 14 days prior to initiation	Discontinue naltrexone a minimum of 48 hours before surgery. Long-acting injectables should be discontinued 28 days in advance of elective procedures. Use caution when prescribing opiates postoperatively, due to increased risk of overdose.
Naloxone	Fast-acting nonselective opioid antagonist	• Quickly reverses opioid overdose • Over the counter	• Precipitates acute severe withdrawal	Recommend providing educational resources and a prescription of naloxone to all patients on opiates.

Intravenous, IV

Introducing The University of New Mexico 12-Level Functional Scale: A Novel Approach for Assessing Functional Recovery in Orthopaedic Trauma Patients

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ABSTRACT

The University of California at Los Angeles (UCLA) Activity Scale and other common activity scales are primarily used for patients undergoing joint reconstructive surgery. However, no such scale exists for musculoskeletal trauma patients. The authors propose The University of New Mexico (UNM) 12-Level Functional Activity Scale to address this gap in assessing functional activity and managing postoperative care for orthopaedic trauma patients. A comprehensive review of existing scales led to the development of the UNM Scale, emphasizing simplicity, objectivity, and potential benefits in patient education and interdisciplinary collaboration. The UNM Scale provides a structured approach to assess and monitor functional activity levels, relying less on subjective input and incorporating surgeon assessments. It enhances patient comprehension, facilitates surgeon-patient communication, and helps tailor rehabilitation protocols. The proposed UNM Scale may fill a critical gap in orthopaedic trauma care, potentially improving treatment outcomes and patient-provider communication. Further research is needed to validate its efficacy and feasibility in clinical practice.

Keywords: Orthopaedics; Orthopaedic Surgery; Patient Reported Outcomes; Trauma

INTRODUCTION

Quantifying patient baseline functional activity is important for orthopaedic trauma surgeons to define distinct treatment goals in the setting of traumatic musculoskeletal injury. Assessing subjective baseline function offers surgeons an insight into how well their patients recover postoperatively. One approach to evaluating this is by administering activity questionnaires, which evaluate the patient's ability to perform daily activities, satisfaction, and overall quality of life (QoL).[1] Patient-reported outcomes have become key clinical measuring tools in the field of orthopaedics.[1]

Originally developed in the 1980s, the University of California at Los Angeles (UCLA) Activity Scale has become the most common measure for assessing physical activity in patients with significant osteoarthritis (OA) who underwent hip or knee arthroplasty (HA)/(KA).[2] It is a questionnaire that relies on self-reported data to gauge individuals' engagement in diverse physical activities ranging from sedentary behaviors to vigorous exercise. Due to its widespread implementation, multiple activity scales have also been introduced in recent years aiming to expand upon and improve the foundations of the UCLA Activity Scale.

However, orthopaedic trauma patients present distinct challenges, due to the sudden nature of their injuries and the diverse range of activities involved in their recovery. Therefore, a more specific functional activity scale may be a more appropriate tool tailored to their needs. This review proposes a unique activity scale, one which may prove beneficial in assessing the preoperative and postoperative function for patients sustaining musculoskeletal trauma requiring operative treatment.

OVERVIEW OF THE UCLA SCALE & OTHERS

Assessing activity levels for lower extremity joint reconstructive surgery has become important for evaluating patient outcomes and was initially proposed with the development of the UCLA Activity Scale.[3] This scale was designed in 1984 by Amstutz et al[2] as a means of quantifying physical activity in patients with varying degrees of OA undergoing HA and KA. It is widely recognized that hip and knee OA can cause significant physical impairment to the individual, warranting joint replacement.[4] It is beneficial to both the patient and their surgeon to establish objectivity when quantifying physical activity to set expectations as to what degree a major operation can improve the patient's QoL.[5] The UCLA Activity Scale is a 10-level scale ranging from level 1 (wholly inactive) to level 10 (highly active) [Table 1], and has gained international attention as a clinically

Table 1. *Study Patient Data*

UCLA Physical Activity Scale [2]	
1	Wholly inactive, dependent on others
2	Mostly inactive, restricted to minimal activities of daily living.
3	Sometimes participates in mild activities such as walking, limited housework, shopping.
4	Regularly participated in mild activities.
5	Sometimes participates in moderate activities such as swimming, unlimited housework, shopping.
6	Regularly participated in moderate activities.
7	Regularly participates in active activities such as bicycling.
8	Regularly participates in very active activities such as bowling or golf.
9	Sometimes participates in impact sports such as swimming, unlimited housework, shopping.
10	Regularly participates in impact sports.*

**This table is the authors' original work using data from the cited source. The reference mentioned in the table is the source of the data.*

concise and convenient patient-reported outcome measure (PROM). However, the original scale's development and primary indications remain undocumented, as no true description of this has ever been formally published. To address its shortcomings, countless other modified scales have been proposed since the UCLA Activity Scale's inception.[5]

A similar, subjective and rather popular, scale is the Lower Extremity Activity Scale (LEAS). Originally developed in 2005, the LEAS focuses on arthroplasty patients and further expands upon the UCLA Activity Scale by providing a total of 18 questions ranging from "I am confined to bed all day" to "I am up and about at will in my house and outside. I also participate in vigorous physical activity, such as competitive level sports daily."[6] The LEAS and UCLA Activity Scale have both been widely recognized as the two most rigorously developed and validated scales in orthopaedics to date.[6]

The subjective 42-question comprehensive knee injury and osteoarthritis outcome score (KOOS) and condensed 12-question KOOS-12 are other examples. Both are widely used PROMs that provide overall scores for pain, function, symptomatology, QoL, and an overall knee impact score.[1] Given the sheer number of individual questions, the KOOS is cumbersome to complete in a busy orthopaedic trauma clinic. But unlike the UCLA Activity Scale, which primarily measures a patient's overall physical activity on a wide spectrum, the KOOS-12 assesses the impact of knee OA on the patient's pain, function, and QoL.[1]

Another widely used activity scale is the Western Ontario and McMaster Universities osteoarthritis index, which also serves as a PROM in assessing lower limb OA.[7] This scale has been widely implemented since its original publication in 1988 and has since been utilized as one of the highest-performing outcome measures for patients with knee and hip OA.[7,8] This scale is a 24-item subjective-based questionnaire that assesses patients' functional status based on three primary categories: pain, stiffness, and physical function.[7] Much like the UCLA Activity Scale, it relies on distinct input from patients, which leaves it prone to several forms of bias, including recall bias. Nevertheless, it is widely used in clinical practice today and remains extremely relevant in the field of orthopaedic joint surgery.

Other notable examples include the Short Musculoskeletal Function Assessment, Visual Analogue Scale, Short-Form-36, and Physical Activity Scale for the Elderly.[9-13] These tools are commonly employed for various orthopaedic conditions, each demonstrating high reliability and validity as outcome measures, effectively gathering subjective patient data such as pain levels and general physical function.

Due to the widespread implementation of the UCLA Activity Scale and subsequent development of similar scales, scale validation should be mentioned. Validation of functional activity is crucial for ensuring their reliability and sustained relevance in clinical practice. Validity ensures that the scale accurately measures what it intends to, while reliability ensures consistent and reproducible measurements. For orthopaedic clinicians, validated scales provide accurate assessment of patients' functional status, guiding treatment decisions effectively. Without validation, there remains a risk of misinterpretation and suboptimal patient care; several studies examining the validity of activity scales are routinely performed to address these issues.[14,15] Ongoing validation efforts are essential in upholding the integrity and utility of these scales in orthopaedic practice.

THE NEED FOR A TRAUMA-FOCUSED OUTCOME MEASURE

The original UCLA Activity Scale and many of its later counterparts have proven useful in the field of arthroplasty, specifically in patients with significant OA that warrants surgical intervention. The purpose of these scales is to provide orthopaedic surgeons a means of objectively assessing their patients' activity levels postoperatively. However, to the authors' knowledge, no such scale exists for the orthopaedic trauma population. Traumatic orthopaedic injuries often lead to significant long-term musculoskeletal impairments. Therefore, establishing a trauma patient's functional activity levels and tracking them over the course of the postoperative period may prove beneficial in quantifying patient recovery while managing long-term treatment algorithms and rehabilitation programs.

Table 2. *Proposed UNM 12-Level Function Scale, designed to assess preoperative function and postoperative functional recovery specifically in patients sustaining traumatic orthopaedic injuries, ranging from fully non-ambulatory to increasing degrees of impact activities.*

UNM 12-Level Functional Activity Scale (Trauma-Focused)	
1	Nonambulatory: full assist for transfers (dead lift).
2	Nonambulatory: able to bear weight (upper +/- lower) to assist transfer, needs human assist to complete transfer.
3	Nonambulatory: able to self-transfer with assistive device (eg, walker/cane).
4	Minimal ambulation with walker (takes a few steps).
5	Household ambulation with walker or bilateral devices.
6	Community ambulation with two canes or bilateral devices.
7	Community ambulation with one cane or simple device.
8	Community ambulation with no assist, level surfaces only.
9	Minimal impact: ambulatory on irregular surfaces, stairs with rail, able to lift/carry up to 5 lbs, sedentary work.
10	Light impact: hiking with day pack, stairs without rail, occasional lift/carry up to 20 lbs, light duty.
11	Moderate impact: jogging, backpacking, frequent lift/carry up to 50 lbs, medium duty.
12	High impact: sprinting, jumping, continual lifting up to 100 lbs, heavy labor.

On that account, the authors propose The University of New Mexico (UNM) 12-Level Function Scale, which provides an objective means of monitoring postoperative recovery and is practical for use in high-volume clinic settings (Table 2). This scale is designed to be level-based, with each level encompassing a patient's maximum ambulation. Ideally, the treating surgeon would document a patient's pre-injury function level based on subjective input gathered from the patient and/or their friends/family to establish a functional postoperative goal and gauge recovery. Functional recovery can then be objectively assessed by the surgeon and physical therapists at the bedside, during clinic visits, or throughout rehabilitation sessions during the postoperative period. Using the UNM Scale as a means of objective evaluation would serve two purposes: 1) to quantify the current degree of impairment, and 2) to track progress toward baseline function during the early postoperative recovery period. Special focus on each subsequent level is directed to varying degrees of ambulation and impact activities (eg, non-ambulatory, community ambulation, minimal/light/moderate/high impact). This scale is designed to be both effective and easy to use, aiming to provide orthopaedic trauma surgeons with a framework to objectively assess and measure their patients' activity levels postoperatively.

DISCUSSION

The UCLA Activity Scale and its counterparts have proven to be beneficial in the arthroplasty field. The goal of these scales remains to provide orthopaedic surgeons an avenue to categorize their patients' activity levels postoperatively. However, to the authors' knowledge, no such scale exists for the orthopaedic trauma population. Traumatic orthopaedic injuries can often lead to significant long-term musculoskeletal disabilities. The number of patients surviving major musculoskeletal trauma has doubled in recent years, further necessitating the need for improving QoL in the immediate and late postoperative periods.[16] Given this, a trauma-focused activity scale that quantifies outcome measures and establishes treatment goals and timelines for a reasonable return to baseline function seems to be a suitable approach.

The UNM Scale provides a unique tool for implementation for several important reasons. Similar to previous scales, the UNM Scale will somewhat rely on subjective input from the patients and their friends/family to define baseline function. But more importantly, it will rely heavily on assessment from the treating surgeon and physical therapist throughout the postoperative period. As previously stated, many of the prior activity scales being used today, specifically the UCLA Activity Scale, utilize self-reported questionnaires filled out by the patients to arrive at an overall score. Such subjective input can be limited by the complexity of the questions themselves and self-reporting information bias.[17,18] Therefore, a scale with a more objective aspect may be appropriate when evaluating orthopaedic trauma patients. Although assessing pre-injury function would still require subjective reporting either directly from the patient or their friends/ family, careful clinical examination by orthopaedic surgeons and physical therapists will provide a new level of detailed assessment of their patients' functional status. Their assessment can therefore be correlated to the corresponding UNM score and tracked over time to monitor improvements or setbacks in functional status.

Next, the UNM Scale is designed to focus on simplicity, aiming to underscore its practicality while promoting patient education and understanding. It seeks to streamline the evaluation process, particularly in the setting of a high-volume orthopaedic trauma clinic, by avoiding the cumbersome nature of a multitude of subjective-based questions utilized by many of its predecessors. The ease of use encourages patients to express their concerns and perspectives with their providers, while also ensuring the highest standards of care are maintained throughout the surgical treatment and rehabilitation periods.[16] Integrating feasibility considerations with proper communication and transparent expectations can be initiated from the start of treatment, enhancing patient education and comprehension. Moreover, using a common reference system may help articulate patient preferences with their surgeons, and can be further supplemented by interactive visual aids or charts in a hospital or clinic setting. Such practices have been shown to strengthen the patient-provider relationship and lead to improved overall health outcomes.[17]

Finally, the degree of scale specificity can prove beneficial when surgeons collaborate with their physical therapy colleagues to provide postoperative treatment recommendations. The nature and location(s) of traumatic injury plays a large role in patient outcomes, with high-energy pelvic and lower limb injuries most likely to cause long-term functional impairments after operative intervention.[19] As such, a large portion of orthopaedic trauma patients require prolonged rehabilitation. For example, it is estimated that 90.0% of patients experiencing acute hip fractures require discharge to a post-acute care facility where they can receive the necessary vigorous physical therapy care they need.[20] Therefore, a standardized scale may mitigate communication challenges between the surgeon and the physical therapist by providing objective function assessments, allowing both care teams to arrive at a reasonable, yet quantifiable recovery goal for their patients. In this manner, the UNM Scale could 1) be used to develop rehabilitation protocols based on fracture type, treatment, and elapsed time from injury, and 2) establish an obtainable postoperative goal by estimating the patient's pre-injury level.

To demonstrate how the UNM Scale might be used to achieve these goals, let us consider a 70-year-old man with a UNM preoperative score of 8 who undergoes routine intramedullary (IM) nailing for a femoral shaft fracture. Assuming a relatively uncomplicated postoperative course, a hypothetical improvement in functional status would be expected per the UNM Scale as demonstrated in Table 3. The ultimate treatment goal for this patient would be to eventually achieve a postoperative score of 8, matching the previously established preoperative score. By utilizing the UNM Scale, this postoperative goal can not only can be explicitly defined at the time of surgery, but improvements (or setbacks) in function may be tracked over the course of the recovery period as well.

Overall, the key goal of this scale is to establish objectivity in a patient's functional activity levels, particularly in the early postoperative period. This may prove beneficial in managing long-term treatment algorithms and rehabilitation programs to track improvements of physical function, with the ideal goal of returning patients to their pre-injury baseline. Given this, and the apparent absence of a trauma-focused scale in the current literature, the authors believe this innovative concept is worth proposing at this time.

Table 3. *Rehabilitation protocols and corresponding UNM score, which illustrates the expected functional status at different postoperative intervals based on fracture type in a hypothetical patient scenario. In this example, a femoral shaft fracture treated with intramedullary nailing is illustrated.*

IM Nail for Femoral Shaft Fractures	Corresponding UNM Score
Postoperative day 1 – 7	4
Postoperative week 2 – 6	4
Postoperative week 6 – 12	6
Postoperative week 12 – 18	7
Postoperative week 18 – 36	8
Postoperative week 36 - 54	8

Further research and extensive testing are necessary to evaluate the practicality and validity of the UNM 12-Level Scale in quantifying patient recovery for orthopaedic trauma patients undergoing operative management. This institution is currently conducting a pilot study aimed at validating this scale through a prospective cohort study. The study focuses on a small group of patients with lower extremity fractures who underwent standardized operative treatment per institutional protocols. Adopting an interdisciplinary approach to define the patient's baseline function and subsequent postoperative activity levels may yield the most comprehensive results. One proposed approach involves blinding all parties involved – including the patient, surgeon, patient's spouse/close family members, and a certified physical therapist – at defined intervals throughout the recovery period and collecting their individual assessments. Consistency across multiple blinded observers would greatly contribute to the overall validity of the UNM Scale. Future research with larger study groups and diverse traumatic fracture patterns are essential. The authors anticipate that these studies will demonstrate significant correlations between UNM scores and clinical outcomes, as well as favorable feedback regarding practicality and utility of integrating the scale into modern clinical practice. Only with time will it become clear whether a simplistic 12-level functional activity scale specifically designed for orthopaedic trauma patients will prove beneficial in today's world of musculoskeletal trauma.

CONCLUSION

A trauma-focused functional activity scale may prove beneficial in quantifying recovery and guiding treatment recommendations for patients suffering from acute musculoskeletal injuries. To the authors' knowledge, no such scale currently exists in practice. Previous activity scales, such as the UCLA Activity Scale, have been implemented and modified over many years to guide such recommendations and provide objective baselines to orthopaedic surgeons evaluating their patients, particularly in the arthroplasty field. Such a novel idea may prove substantially beneficial in the trauma population to achieve similar results. The authors propose a 12-level maximum function scale to fill this gap in literature with the goal of implementation into modern clinical practice as a convenient and practical option for future orthopaedic trauma surgeons, physical therapists, and their patients alike.

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Fishtail Deformity Complication of Distal Humeral Fractures in Children

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ABSTRACT

Background: This article examines 10 pediatric distal humeral avascular "fishtail" deformities with an average of eight years follow-up. The authors discuss initial injury classification and treatment, timing to presentation of fishtail deformity, and subsequent treatments for this rare injury pattern..

Methods: A retrospective chart review was conducted at The University of New Mexico Hospital to identify patients aged 18 years or younger diagnosed with a distal humerus "fishtail" deformity from 2008 to 2018. Patient demographics, injury characteristics, physical exam findings, timing of fishtail deformity presentation, follow-up time, and pertinent complications were recorded. Intraoperative fluoroscopic and immediate postoperative imaging studies were also reviewed.

Results: Ten patients met inclusion criteria, eight of which underwent operative management for their initial injury, while two patients with involved fractures were treated in closed fashion. On average, fishtail deformity was diagnosed 3.6 years after the index injury, with mean follow-up time of eight years. At time of diagnosis, common presenting symptoms included pain, limitations in range of motion (ROM), peripheral nerve compressive neuropathies, exostoses, and malunion. Additional operative treatment was performed on three patients, which included debridement of exostoses and ulnar nerve decompression. The arc of ROM at last follow-up was 124.5° (7.5°to 132°).

Conclusion: Given its rarity, the authors concluded that calculating a meaningful incidence proportion of pediatric fishtail deformities remains challenging. Additionally, the severity and fracture type of the initial injury do not concretely predict the eventual development of fishtail deformity. Presentation and long-term complications remain variable regardless of treatment option for distal humerus fractures.

Keywords: Deformity; Elbow; Humerus; Necrosis; Pediatrics

INTRODUCTION

A "fishtail deformity" describes an anatomical and radiographic finding of central epiphyseal deficiency in the distal humerus. This finding is likely secondary to osteonecrosis of the trochlea following a variety of distal humeral fractures, including supracondylar, T-condylar, and medial or lateral condylar fractures, all of which are common injuries in the pediatric population.[1-3] It is estimated that 64.0% of all distal humeral fractures occur in patients younger than 15 years of age, with a peak incidence in children ages five years to nine years, and a sharp decrease after the age of 15.[1]

Among the pediatric population, the incidence of distal humerus fractures is well established in the literature. Supracondylar humerus fractures represent the most frequent type of distal humerus fracture, accounting for 50.0% to 70.0% of all pediatric elbow fractures.[3] In contrast, lateral condyle fractures of the distal humerus account for 12.0% to 20.0% of all elbow fractures in the same population.[3] However, literature regarding incidence rates of the fishtail deformity remain sparse.

Pediatric patients who develop a fishtail deformity can experience significant functional disability, including pain and restricted range of motion (ROM).[4] Despite the prevalence of these fractures, only a limited number of case series are currently available to describe patient presentation and guide subsequent management.[4-10] To bring awareness to a rare, yet disabling condition, this study aims to contribute to the available literature by reporting on the diagnosis, management, and complications associated with fishtail deformities in 10 patients.

METHODS

Approval was granted by The University of New Mexico Health Sciences Institutional Review Board (IRB #20-305). The authors conducted a retrospective chart review using Current Procedural Terminology (CPT) codes to identify patients at this Level I trauma center who were diagnosed with a distal humerus fracture and required surgical intervention from 2008 to 2018. This timing was selected to ensure adequate opportunity for follow-up. The CPT codes 24538 (percutaneous skeletal fixation of supracondylar or transcondylar humeral fracture, with or without intercondylar extension), 24545 (open treatment of humeral supracondylar or transcondylar fracture, with or without internal or external fixation; without intercondylar extension), and 24546 (open treatment of humeral supracondylar or transcondylar fracture, with or without internal or external fixation; with intercondylar extension) were used to identify patients. Using these codes ensured that only operative patients who likely had sufficient follow-up imaging studies were included.

Patients' electronic medical records were reviewed for an additional diagnosis of a distal humerus deformity, fishtail deformity, or avascular necrosis of the trochlea. Additionally, the Picture Archiving and Communications System (PACS) was used to identify patients treated nonoperatively who may have developed a fish tail deformity. PACS was queried for reports of elbow imaging with diagnoses of "avascular necrosis," "trochlear dysplasia," "distal humerus deformity," or "fishtail deformity." Inclusion criteria included patients ages 18 years of age and younger with a confirmed distal humerus deformity, fishtail deformity, or avascular necrosis of the trochlea based on chart and imaging reviews. Exclusion criteria included patients who did not have adequate imaging or those diagnosed with a systemic rheumatological disease with involvement of the elbow. Their records were also reviewed to obtain patient demographics, injury mechanism, medical interventions, physical exam findings, timing of fishtail deformity presentation, follow-up time, and complications.

RESULTS

A total of 854 operatively treated elbow fractures were identified, eight of which met inclusion criteria, suggesting an incidence of 0.94% among surgically managed pediatric elbow injuries. The PACS query identified an additional two cases that arose in patients treated nonoperatively. In total, 10 patients met inclusion criteria (representative patient is demonstrated in Figure 1). Of the 10 patients, five were women with a mean initial injury age of 4.8 years of age (range: two years to eight years) (Table 1). The average elapsed time from initial injury to deformity presentation was an estimated 3.6 years of age (range: two months to eight years). Six patients presented with a type III supracondylar fracture, five of which were treated with closed reduction percutaneous pinning (CRPP) and one treated with open reduction percutaneous pinning. Two patients presented with a type I or type II supracondylar fracture, which were treated with a cast and CRPP, respectively. One patient presented with a lateral humeral condyle fracture and was treated with CRPP. The other patient presented with an unspecified elbow fracture, which was treated with closed reduction and casting at an outside institution within the state.

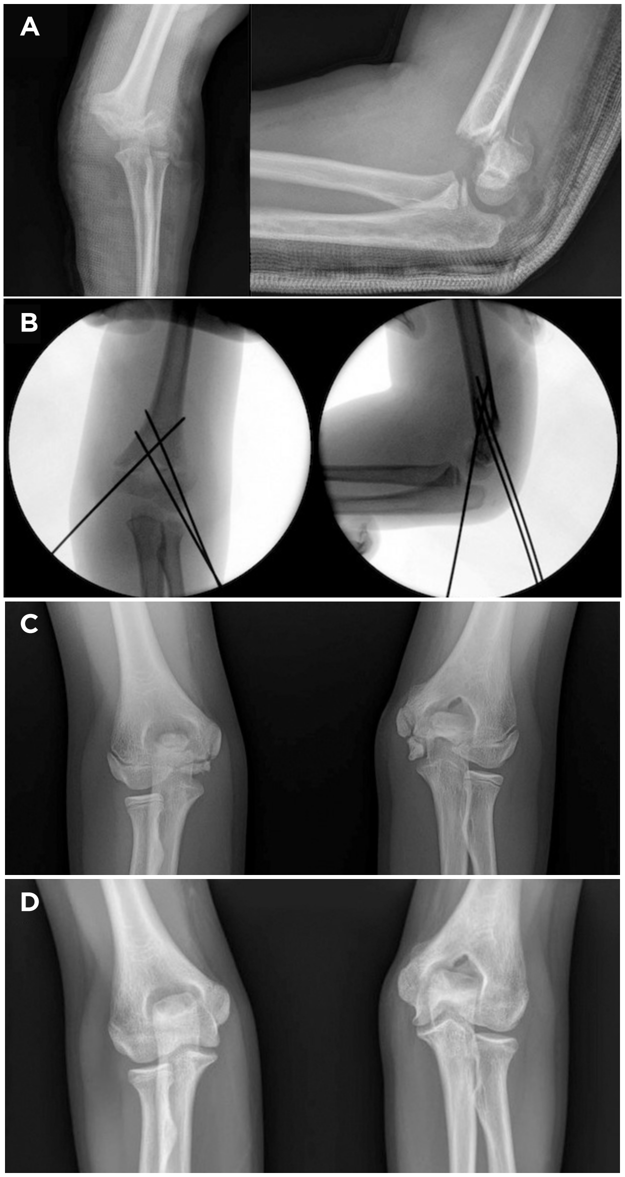

Figure 1. *A) Radiographs of a left Gartland 3 extension type supracondylar humerus fracture (patient age 8); B) Fluoroscopic images of treatment with closed reduction and percutaneous pinning; C) Radiograph of bilateral elbows demonstrating development of contour abnormality of the left distal humerus secondary to lateral trochlear ossification center involvement 2.5 years after injury; D) Radiograph of bilateral elbows, four years after injury with resultant central epiphyseal deficiency and characteristic "fishtail deformity."*

Table 1. *Relevant data for each patient diagnosed with fishtail deformity.*

Age at Initial Injury	Gender	Arm Affected	Initial Injury/ Fracture Type	Initial Treatment	Initial Complications	Time from Initial Injury to Diagnosis of Fishtail	Elbow ROM at Presentation of Fishtail	Treatments	Elbow ROM at Last Follow-up	Total Follow-Up
8 Years	F	L	Type 3 SCH Fracture	CRPP	None	31 Months	20°-140°	Ulnar Nerve Decompression, Open Excision of Exostoses	0°-140°	8 Years
3 Years	F	R	Type 1 SCH Fracture	Closed Reduction and Casting	None	82 Months	20°-140°	Conservative	0°-140°	9 Years
4 Years	M	R	Type 2 SCH Fracture	CRPP	Malreduction	12 Months	10°-90°	Open Excision of Exostoses	0°-125°	4 Years
4 Years	M	L	Type 3 SCH Fracture	CRPP	None	12 Months	30°-140°	Ulnar Nerve Transposition	0°-140°	10 Years
5 Years	M	R	Lateral Condyle Fracture	CRPP	Nonunion requiring ORIF	2 Months	70°-100°	Deferred Contracture Release	45°-110°	9 Years
7 Years	F	L	Type 3 SCH Fracture, Medial Epicondyle Fracture	CRPP and ORIF	Transient Radial Nerve Neuropraxia	12 Months	20°-140°	Conservative	0°-140°	3 Years
5 Years	M	R	Type 3 SCH Fracture	CRPP	Pin Tract Infection Requiring I&D	36 Months	0°-140°	Conservative	0°-140°	3 Years
4 Years	M	L	Type 3 SCH Fracture	ORPP	Transient Median Nerve Neuropraxia	90 Months	5°-120°	Conservative	5°-120°	8 Years
2 Years	F	L	Distal Humerus (Unspecified)	Closed Reduction and Casting	None	96 Months	30°-140°	Conservative	25°-140°	19 Years
6 Years	F	L	Type 3 SCH	CRPP	Malreduction	60 Months	0°-125°	Deferred Removal of Foreign Body	0°-125°	7 Years

ROM: range of motion; SCH: supracondylar humerus; ORIF: open reduction internal fixation; CRPP: closed reduction percutaneous pinning; I&D: irrigation and debridement

A review of the intraoperative fluoroscopic and immediate postoperative imaging revealed slight rotations in two patients treated with CRPP. Another patient treated with CRPP received two lateral pins placed slightly posterior in the capitellum. Two patients received cross pinning in which the entry point was not from the posterior capitellum. Intraoperative imaging otherwise illustrated adequate reductions and pinning.

Following treatment of the initial distal humeral fractures, postoperative complications were noted in six patients. Two patients were diagnosed with neuropraxia, both of which resolved without operative management. Two patients had malunions of their supracondylar humerus fractures, neither of which underwent revision. One patient experienced lateral condyle malunion requiring open reduction and internal fixation (ORIF), and another experienced a pin tract infection and resultant lateral condyle osteomyelitis requiring irrigation and debridement. Four patients reported no complications following the immediate follow-up period.

Presenting symptoms at the time of diagnosis of a fishtail deformity were variable and included stiffness, pain, mechanical symptoms, and ulnar nerve paresthesias. Restrictions in ROM were the most common symptom, occurring in nine patients. The severity of elbow ROM restriction was variable. Eight patients presented with limited elbow extension and demonstrated flexion contractures ranging from 5° to 70°. Additionally, four patients presented with a loss of elbow flexion, ranging from 15° to 50°. Following fishtail deformity diagnosis, seven patients received nonoperative treatments. Two of these patients deferred the offer of contracture releases and intra-articular free body mass removal. Ulnar nerve transposition/decompression was performed in two cases. Open debridement of exostoses was performed in two cases.

Time from initial injury to last follow-up varied in length with an estimated mean of eight years (range: three years to 19 years). Symptoms at time of last follow-up included mild intermittent pain in one patient, valgus deformity of 15° in one patient, limited ROM in five patients, and mechanical symptoms, such as locking, in one patient. The arc of ROM at last follow-up was 124.5° (7.5° to 132°) compared to an initial arc of ROM of 97.5° (20.5° to 118°) on presentation for an average improvement of 27°.

DISCUSSION

The term "fishtail deformity" was first used by Wilson in 1955 to describe radiographic observations following pediatric fractures of the distal humerus.[11] Wilson and more recent authors theorized that the sharp angular deformity was the result of a fracture and persistent gap between the lateral condylar ossification center and the medial trochlear ossification center.[12] This gap is hypothesized to produce a small physeal bar in addition to the malunion. In contrast, physicians have observed a second, less angular deformity that involves the lateral trochlea. The resultant smooth deformity is believed to be associated with osteonecrosis of the trochlear epiphysis and has been associated with supracondylar fractures, medial condyle fractures, and separations of the entire distal humeral epiphysis.[6,13] Osteonecrosis of the lateral trochlear ossification center results in development failure or possible reabsorption of the lateral trochlea, while the medial ossification center continues to grow normally, which results in an inverted V shape resembling a fish tail.[6-7]

Current theories support a vascular etiology with avascular necrosis of the lateral trochlea being the primary pathologic process in producing a fishtail deformity.[7] The trochlea, olecranon fossa, and coronoid fossa are watershed areas, and are therefore vulnerable to injury.[13] The lateral trochlea obtains its blood supply from two distinct end arterioles.[14,15] One arteriole arises from lateral humeral vessels, which supplies the capitellum then cross the physis to supply the lateral trochlea.[7] The other originates from medial humeral vessels and supplies the majority of the medial trochlear epiphysis.[7] Following distal humeral fractures, the described blood supply to the distal humerus and the watershed area between the two arterioles is potentially vulnerable to disturbances and is involved in the development of a fishtail deformity.[7]

In pediatric patients, fishtail deformities have been described as a complication of distal humeral fractures, particularly supracondylar fractures.[7] However, they have also been associated with lateral condylar fractures, T-type distal humerus fractures, medial condylar fractures, and Salter Harris 1 epiphyseal fractures.[8-10] A fishtail deformity can develop following ORIF, CRPP, or conservative treatment of the initial injury. This indicates that the severity of distal humerus fractures or the type of fracture management may not correlate with the risk of developing the deformity.[11]

In their seven-patient case series, Lehnert reported an average of 7.6 years between the initial injury and presentation of fishtail deformity.[9] However, other case series have reported a time to presentation of 4.7 years, which is more consistent with the cohort in this study.[8] Current literature demonstrates that most patients with a fishtail deformity present with stiffness, pain, or decreased ROM, which was consistent in nine out of 10 patients in this study.

The treatment approach to fishtail deformity is often multifaceted and depends on the severity of symptoms. This study demonstrated that conservative management alone provided mild, but improved ROM, with five of the patients demonstrating full ROM following conservative treatment. In patients with persistent or severe symptoms, operative intervention, including open versus arthroscopic debridement and removal of loose bodies, capsulotomy, contracture release, surgical arrest of the remaining physis, and osteotomy for persistent deformity can be indicated.[11] Glotzbecker et al[8] focused on treatment and outcomes in their 15 patients with fishtail deformities. Of the 15 patients, seven received arthroscopic debridement with six experiencing short-term pain relief and all seven reporting improvement in ROM. Moreover, four of seven patients required a second debridement after the initial intervention.[11] In this study, the two patients who underwent open debridement have not undergone repeat debridement after four and eight years of follow-up. Nevertheless, long-term outcomes for debridement and other treatment options are not well described.

Several authors in the literature suggest that fishtail deformity is not a serious clinical condition because there are few symptoms or functional deficiencies in the first few years following its presentation.[7] However, long term follow-up demonstrates that this deformity can result in significant disability, especially in adulthood; severe cases can involve limited flexion, limited extension, radial head subluxation, and osteochondritis dissecans.[6,10] Additionally, underlying fishtail deformity can complicate adult and geriatric trauma management. In a recent case report, an 83-year-old woman with a medial condyle fracture and chronic lateral condyle nonunion with fishtail deformity of the humerus was successfully managed with a semi-constrained total elbow arthroplasty.[16]

CONCLUSION

Fishtail deformities are a rare, but potentially debilitating complication of pediatric elbow fractures. Supracondylar fractures are a frequent elbow injury in the pediatric population and are associated with the development of trochlear avascular necrosis. However, a fishtail deformity can also develop with other elbow fractures, such as lateral condyle fractures and transphyseal distal humerus injuries. Clinical presentation with pain and loss of ROM can vary, and presentation time of these symptoms is likely close to four years following the initial injury. Treatment options can be conservative or operative depending on the patient's symptoms.

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Decoding a Decade: Evolution in Distal Radius Fracture Techniques from Past to Present, Embracing the EFCR Method

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ABSTRACT

Background: Commonly occurring in daily activities, distal radius fractures (DRF) traditionally involve immobilization. With an increasing risk in elderly populations, surgical advancements like volar-locking plates challenge conventional methods. Distinguished orthopaedic surgeon, Dr. Deana Mercer, demonstrates expertise in the extended flexor carpi radialis (ECFR) approach, aiming to mitigate surgical complications and improve DRF treatment outcomes.

Methods: Institutional Review Board approval permitted a retrospective chart review of 815 adult patients aged 18 to 58 who underwent open reduction and internal fixation for DRF by Dr. Deana Mercer between November 2011 and November 2023. Patients were identified using current procedural terminology codes, with exclusions for children, incarcerated individuals, patients who were pregnant at the time of injury, and those lacking suitable radiographs or presenting with excluded injuries (eg, Type III fractures). Picture archiving and communication system medical imaging software measured parameters on injury and surgery dates, while operative details were extracted from records.

Medical students underwent training in medical techniques to ensure consistency for intra-rater and inter-rater reliability analyses. Measurements were compared to standard values, and a paired t-test assessed differences in radiographic measurements.

Results: Comparison of EFCR and non-EFCR groups (n=593) revealed no significant preoperative differences in radial incline (P = 0.39), radial height (P = 0.60), or volar tilt (P = 0.67). Postoperative surgical intervention analysis showed a statistically significant improvement in volar tilt in the EFCR group (P = 0.01), with a mean increase to 8.69° (SD = 8.11). In contrast, the non-EFCR group showed an increase of 6.35° (SD = 8.67).

Conclusion: These results demonstrate the efficacy of the EFCR approach in addressing volar tilt postoperatively, suggesting potential superiority over conventional methods in optimizing radiographic outcomes for patients with DRF.

Keywords: Distal Radius Fracture; Forearm; Trauma

INTRODUCTION

Humans are vulnerable to various injuries and fractures in daily activities, with distal radial fractures (DRF) being particularly prevalent. Regardless of the cause—trauma, accidents, or other circumstances—prompt treatment is crucial. Traditionally, immobilization is the primary orthopaedic intervention before further treatment.[1]

Research traces distal radius fractures back 5,000 years to ancient Egypt, documented in the "Edwin Smith Papyrus."[2] Studies suggest that the shift to ambulation without assistance has increased the risk of DRF, particularly in the older population, which has an elevated susceptibility to falls and injuries in athletics. Surgical approaches have significantly altered the landscape, challenging the traditional use of splinting for fractures.[3]

In the past few decades, operative techniques have become pivotal in treating DRF injuries. In the 1970s, Kapandji introduced percutaneous pinning with intrafocal pinning, eliminating the need for surgical incisions.[4] In the 1980s, external fixators and internal fixation emerged, marking a historical shift in steel types from stainless steel to lighter titanium alloys.[5-8] It is well established that while external fixators are commonly used for temporary fixation, internal fixators are generally preferred for long-term treatment.

Rapid advancements in treatment have raised questions about the best approach for DRF injuries. Some advocate for nonoperative treatment, including reduction and cast immobilization, due to complication rates as high as 27.0%.[9] Research suggests that DRF may lead to a loss of volar tilt, with a normal tilt ranging from 7° to 15°. A tilt of 20° or more indicates unstable fractures, while a tilt of 25° or more is associated with dorsal intercalated segment instability (DISI).[10]

Unfortunately, few studies explore surgeons' skill sets, reflecting the rapid progression in this field. Thus, this article examines advancements in volar-locking plates, which are commonly used for open reduction and internal fixation of DRF. One notable advancement is the use of the extended flexor carpi radialis (EFCR) approach in treating DRF. A 2023 study by Orbay et al[11] presented compelling evidence that the EFCR approach not only facilitates effective management of DRF injuries, but also enhances surgical access for reduction and implant application.[12]

To highlight experts in this rapidly developing field, the authors introduce Dr. Deana Mercer, a distinguished orthopaedic surgeon specializing in shoulder, elbow, and hand microvascular surgery. With over a decade of experience, Dr. Deana Mercer is notable among women orthopaedic surgeons and is certified as an expert in orthopaedic surgery. Her impressive track record includes over 10,000 surgical hours, with more than 800 cases involving the treatment of DRF in adults.

Through a retrospective analysis of radiographs depicting DRF injuries in patients operated on by Dr. Mercer, the authors aim to highlight the potential impact of an expert surgeon's work. Additionally, the authors intend to align her findings with existing literature, emphasizing that surgical treatment of DRF using the EFCR approach may ultimately reduce the incidence of complications, ultimately benefitting the at-risk population more effectively.

METHODS

Selection of Radiographs

Institutional Review Board approval was obtained (HRP #21-477) to conduct a retrospective chart review. Using current procedural terminology codes, the authors identified patients who underwent open reduction and internal fixation for DRF performed by Dr. Deana Mercer between November 2011 and November 2023. A total of 815 adult patients, aged 18 to 58, were included in the study. Exclusion criteria included children, incarcerated individuals, and patients who were pregnant at the time of injury. Patients were also excluded if they lacked appropriate preoperative or postoperative radiographic films for measurement. Additionally, patients with injuries too severe for accurate measurement, such as complete fractures (commonly referred to as Type III fractures) or moderate-to-severe Type II fractures based on the Mason Classification, were excluded.

Medical records were reviewed to analyze the dates of injury and surgery. Picture archiving and communication system medical imaging software was then used to measure radial inclination, radial height, and palmar/volar tilt on radiographic images from both the date of injury and the date of surgery.[13] Furthermore, information on specific parameters, including patient age, tourniquet time, follow-up duration, operative time, and operative side (left or right), was extracted from the operative reports using the institution's clinical record software, PowerChart.

Observer Training

Ten medical students from The University of New Mexico School of Medicine received training in measuring radiographic parameters, either as their primary or secondary role, and were responsible for conducting all measurements. Consistency was assessed through intra-rater and inter-rater reliability analyses. Measurements obtained by medical students primarily trained by Dr. Deana Mercer were compared with those of students who were secondarily trained during the initial inter-rater agreement assessment.

Following a methodology similar to that described by Watson et al,[14] medical students repeated their measurements, which were then compared against those of both primary and secondary trainers. Any improper measurement techniques identified during this process were addressed through feedback from the principal investigator. If errors were identified during the training period prior to the study, students were required to remeasure and undergo further evaluation to ensure proper technique. This rigorous process aimed to minimize variability in image interpretation caused by both systemic and random factors.

Measurement Guidance

Medical students were responsible for measuring a total of 815 radiographs. After a detailed evaluation of each radiographic film, 593 patient radiographs were deemed suitable for further analysis. Measurements included parameters such as radial inclination (degrees), radial height (millimeters), volar tilt (degrees), and radial shift (millimeters), following the observer training protocol.

Statistics

A paired t-test was used to evaluate the statistical significance of differences between the radiographic measurements obtained in the study and the standard measurements described by O'Malley et al,[15] which represent expected outcomes during the surgical treatment of DRF. Additionally, the means of the data collected before and after the implementation of the EFCR approach were compared to identify any statistically significant differences in achieving the desired radiographic measurements.

Additional Considerations

In every operative report, the type of approach—EFCR versus non-EFCR—was explicitly stated. EFCR cases were labeled as "EFCR approach," while non-EFCR cases were described as "Henry approach, a volar approach; an incision was made over the flexor carpi radialis (FCR) tendon...through the FCR sheath," allowing for consistent classification based solely on operative documentation. In EFCR cases, the Skeletal Dynamics Geminus distal radius volar locking plate with distal locking screws and non-locking shaft screws was used uniformly. In non-EFCR cases, implant selection varied by year: Hand Innovations plates were used in 2011, Acumed plates in 2012, and Geminus plates from 2013 onward. All implants were volar locking plates. Operative time was extracted from the operative reports and reflected total surgical duration from incision to closure. Average operative time for EFCR cases was 77.07 ± 42.04 minutes, and for non-EFCR cases, 74.03 ± 36.60 minutes. A Welch's t-test comparing operative times showed no significant difference between the groups (P = 0.188).

RESULTS

A total of 123 subjects who underwent the non-EFCR approach and 468 subjects who underwent the EFCR approach were identified through chart review. In the non-EFCR group, average age was 48.13 ± 16.26. The average operative time was 74.03 ± 36.60 minutes with average tourniquet time at 250 mmHg being 47.03 ± 21.38 minutes. Average follow-up duration was 3.9 ± 6 months. In the EFCR group, average age was 52.56 ± 17.95. Average operative time was 77.07 ± 42.04 minutes with average tourniquet time at 250 mmHg being 46.07 ± 16.54 minutes. Average follow-up duration was 3.5 ± 3.6 months.

Pre-surgical measurements of the non-EFCR approach showed mean values of radial inclination (17.25 ± 6.90°), radial height (8.89 ± 3.47°), and volar tilt (-4.48 ± 16.28°), while the pre-surgical EFCR approach measurements were 16.56 ± 8.13° for radial inclination, 8.67 ± 4.37° for radial height, and -5.23 ±18.08° for volar tilt (Figure 1). Post-surgical measurements for the non-EFCR approach indicated mean values of 23.18° ± 4.33° for radial inclination, 11.76° ± 2.54° for radial height, and 6.38° ± 8.67° for volar tilt. For the EFCR approach, post-surgical mean values were 23.41° ± 4.66° for radial inclination, 11.84° ± 2.80° for radial height, and 8.69° ± 8.11° for volar tilt (Figure 2).

Statistical analysis was performed using paired t-tests to compare pre-surgical and post-surgical measurements between the EFCR and non-EFCR groups. The pre-surgical comparisons showed no statistically significant differences for radial inclination (P = 0.39), radial height (P = 0.60), or volar tilt (P = 0.67). Post-surgical comparisons revealed no significant differences for radial inclination (P = 0.62) or radial height (P = 0.79), but a significant difference was observed for volar tilt (P = 0.01).

Regarding intra-rater reliability, the intraclass correlation coefficient (ICC) for postoperative radial inclination, radial height, and volar tilt was 0.83, 0.70, and 0.83 respectively (95.0% confidence interval (CI) 0.81 – 0.86, P = 4.2e-156; 95.0% CI 0.66 – 0.74, P = 2.9e-89; 95.0% CI 0.80 – 0.85, P = 2.4e-150, respectively), indicating good to excellent reliability. Ratings of preoperative radial inclination, radial height, and volar tilt demonstrated excellent agreement with ICCs of 0.89, 0.83, and 0.87, respectively (95.0% CI 0.87 – 0.90, P = 1.6e-200; 95.0% CI 0.80 – 0.85, P = 2.4e-150; 95.0% CI 0.85 – 0.89, P = 6.5e-184, respectively).

Regarding inter-rater reliability, the ICC for post-operative radial inclination, radial height, and volar tilt was 0.505, 0.666, and 0.528 respectively (95.0% CI 0.369–0.644, P = 3.69e-23; 95.0% CI 0.562 – 0.768, P = 5.16e-64; 95.0% CI 0.411–0.657, P = 1.76e-42,

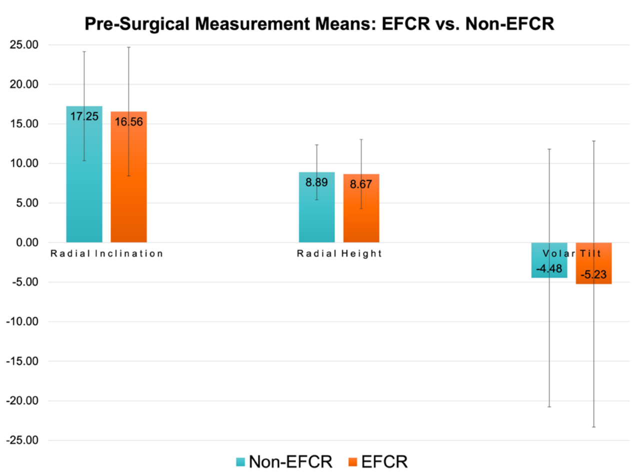

Figure 1. *Pre-surgical measurements for radial inclination, radial height, and volar tilt in the Henry and EFCR groups.*

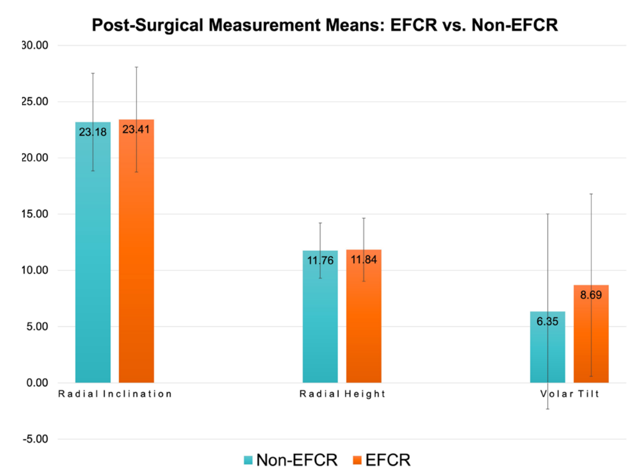

Figure 2. *Post-surgical measurements showing improvements in radial inclination, radial height, and volar tilt for both approaches, with EFCR showing greater improvement in volar tilt.*

respectively), indicating moderate reliability. Raters of preoperative volar tilt also demonstrated moderate agreement (ICC 0.610, 95.0% CI 0.501 – 0.723 P = 8.72e-57). Raters of preoperative radial inclination and radial height demonstrated poor agreement with ICC 0.395 and 0.396, respectively (95.0% CI 0.285 – 0.529 P = 4.62e-28; 95.0% CI 0.286 –0.53 P = 3.62e-28, respectively).

These findings suggest that both intra-rater and inter-rater reliability demonstrated moderate to excellent agreement in values of interest (ie, volar tilt), thus supporting the outcomes of this study. The ICC values were interpreted based on Koo & Li and Shrout & Fleiss, where values below 0.50 indicate poor reliability, 0.50 to 0.75 indicate moderate reliability, 0.75 to 0.90 indicate good reliability, and values above 0.90 indicate excellent reliability.[16,17]

DISCUSSION

This study provides compelling evidence to support the efficacy of the EFCR approach for surgical management of DRF. The results demonstrate a significant improvement in volar tilt in the EFCR group with a mean increase in fixation of 8.69°, compared to 6.35° in the non-EFCR group, which is closer to measurement in what is considered normal anatomy. This suggests that the EFCR approach may be more effective in restoring volar tilt postoperatively, a parameter important for ensuring optimal functional recovery and reducing the risk of long-term complications (ie, DISI). Furthermore, studies have shown that the EFCR approach significantly improves mobility compared to the traditional volar henry approach, while also being safe and effective, backing the authors' findings.[18,19]

The improvements observed in the EFCR group align with the growing body of literature suggesting that this technique offers advantages over traditional approaches.[20,21] Previous studies have shown that the EFCR approach provides better surgical access, particularly when performing carpal tunnel release, which is crucial for accurate implant placement and precise fracture reduction, especially in the absence of an assistant for manual retraction.[22] Additionally, enhanced visualization and control during the procurement may reduce risk of complications such as malunion or fixation failure, which are more common with other advanced surgical techniques.[23]

On the topic of visualization, a study by Ilyas found that volar-extensile approaches allow for carpal tunnel release and provide direct visualization and fracture reduction of the volar-ulnar corner of the distal radius, the radioulnar joint, and other areas of the joint.[24] A Brazilian study also indicated that functional assessments using the Disability Arm, Shoulder, and Hand questionnaire showed better results for radial styloid access compared to the Henry approach for daily function, although the difference was not statistically significant.[25] The literature on other metrics used to assess visualization in the EFCR approach remains sparse, which should be considered in future studies on this topic.

This study reiterates the need for further exploration of the comparative effectiveness of different surgical approaches for DRF. While the EFCR approach showed promise in this cohort, future studies with larger sample sizes, more diverse patient populations, and longer follow-up periods are critical to confirm the long-term benefits of this technique and to determine whether the radiographic improvements lead to functional changes for patients.

Finally, the high clarity in operative report language allowed for confident case classification without ambiguity, reducing misclassification bias in the comparative analysis. Although different implant manufacturers were used in early non-EFCR cases, all were volar locking plates with consistent screw configuration. Additionally, despite EFCR's more extensive exposure, operative times were statistically similar between groups, supporting the procedural efficiency of the EFCR and indicating that the choice of approach does not significantly affect operative duration.

Limitations

Several limitations should be considered when interpreting the results of this study. First, the retrospective nature of the chart review inherently limits the ability to control potentially confounding variables, such as patient demographics, fracture severity, and comorbidities, all of which may influence surgical outcomes. Although exclusion criteria were applied to remove extreme cases, unaccounted factors may still have affected the radiographic measurements. Additionally, the involvement of ten student data collectors introduced variability, particularly in the measurement of volar tilt, which is the most challenging parameter to assess using Picture Archiving and Communication Systems, especially for amateur measures at the medical student level.

Second, reliance on radiographic film interpretation introduces the potential for measurement errors, despite comprehensive observer training and reliability analyses. While intra-rater and inter-rater reliability were evaluated, human error in the measuring parameters such as radial inclination, radial height, and volar tilt, remains a possibility. Variability in measurement outcomes among data collectors further emphasizes the need for additional analysis using agreement statistics. To address this, each data collector measured each radiograph twice, with at least 25 hours between measurements to assess intra-rater reliability. Then, inter-rater reliability was evaluated by having the data collectors measure the same 60 subjects again, with the results compared to those of an orthopaedic expert to ensure that the novelty of the experience did not interfere with the data quality. These analyses will be completed in the coming months to finalize the results.

Third, this study focused on a cohort of patients treated by a single surgeon, Dr. Deana Mercer. As a result, generalizability of these findings to other surgeons or institutions may be limited. Variations in surgical techniques, experience levels, and patient populations could lead to different outcomes. This study also did not assess long-term follow-up to evaluate the clinical significance of the improvements in volar tilt, radial height, and radial inclination achieved post-operatively. Future studies should explore whether these radiographic improvements with the EFCR approach translate into functional benefits or reduced complication rates.

Fourth, there was variability in implant manufacturer used in non-EFCR cases prior to 2013. However, all implants were volar locking plates with consistent screw types, which limits the impact of this variability on outcomes. Another limitation is the broad range of operative times, which likely reflects variation in fracture severity. While average times were similar between groups, this heterogeneity may mask subtle differences in operative complexity.

Lastly, the sample size for the Henry approach (n = 123) was smaller compared to the EFCR approach group (n = 468), which may limit the statistical power to detect differences between the two groups. Larger, multicenter studies are needed to draw more robust conclusions regarding the comparative effectiveness of these surgical approaches.

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Fluoroscopy-Guided Versus 3D Navigated Percutaneous Sacroiliac Screw Fixation: A Comparison of Radiation Exposure and Surgical Duration

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ABSTRACT

Background: Pelvic ring injuries are complex surgical challenges requiring significant radiation exposure for safe placement of sacroiliac (SI) screw fixation. Traditionally, SI fixation has been performed with conventional C-arm fluoroscopy to guide screw placement. 3D navigated imaging is a technique that uses fluoroscopic scans and a navigation tracker to guide screws in space. The purpose of this study is to characterize a single institution's experience with navigated SI fixation and the resulting radiation exposure to patient and staff.

Methods: Records of 60 patients who underwent SI fixation using either conventional fluoroscopy (43) or 3D navigation (17) were reviewed. Exposure data (radiation time, radiation dose, and surgical duration) were compared. The data were evaluated for correlations between the primary outcomes and patient factors (age and body mass index (BMI)).

Results: Radiation time per screw was significantly less in the 3D navigation group (19.5 seconds vs 39.2 seconds, *P* <0.001). However, there was no difference in radiation dose or surgical duration between the two groups. There was a positive correlation between radiation dose per screw and BMI. The primary outcomes were not affected by the exclusion of patients with a BMI greater than 40.

Conclusion: The results of this single-institution study demonstrate a significant decrease in radiation time when performing SI fixation using a 3D navigated technique compared to conventional fluoroscopy. However, this reduction did not translate to a decreased radiation dose or a shorter surgical duration. These findings suggest noninferiority of the navigated technique when compared to conventional fluoroscopy, with the added benefit of reduced radiation exposure to operating room staff when their physical positioning during imaging is considered.

Keywords: Acute Care Surgery; Radiation Exposure; Sacroiliac Joint; Surgical Navigation Systems

INTRODUCTION

Pelvic ring disruptions are severe bony and ligamentous injuries, most commonly caused by blunt trauma such as motor vehicle accidents or falls from a height.[1] These injuries are generally severe and are associated with major hemorrhage, craniocerebral injury, abdominal injury, and death. They typically occur after high-energy mechanisms of injury in patients between 18 years of age and 35 years of age.[2] However, there is a bimodal age distribution, with a similar peak of prevalence in women over 70 years of age, often resulting from low-energy injury mechanisms in the setting of poor bone quality.

Sacroiliac (SI) disruptions, in particular, present complex surgical challenges that require safe screw fixation to facilitate mobilization. When compared to non-operative management, surgical fixation of these injuries leads to earlier weight bearing and mobilization, shorter hospital stays, and improved functional outcomes.[3,4] The goals of operative intervention are to restore the biomechanical axis and stability of the pelvic ring, allowing the patient to progress with weight bearing, facilitate mobilization, and ultimately heal with normal anatomical alignment. Early surgical intervention is therefore critical in reducing the risks associated with immobility, such as pneumonia, thromboembolic events, pressure ulcers, and psychological complications.[5]

Historically, pelvic ring injuries were treated non-operatively or with large open approaches and fixation.

Fortunately, with advances in intraoperative imaging technologies, surgical stabilization is now typically performed using a percutaneous, minimally invasive approach. Compared to open treatment, percutaneous fixation requires less operative time, results in less bleeding, and is associated with lower morbidity.[6] Percutaneous SI screw fixation is typically performed using conventional C-arm intraoperative fluoroscopy to guide safe screw placement with osseous corridors visualized on x-ray. However, this technique requires obtaining multiple intraoperative fluoroscopic images, exposing both the patient and the healthcare team to harmful radiation.

Alternatively, computer-assisted navigation is a technique that uses an intraoperative 3D fluoroscopy scan along with a navigation tracker placed on a fixed bony landmark. This technique reduces the amount of intraoperative fluoroscopy required for implant positioning and fixation.[7] There has been previous research describing the differences between conventional fluoroscopy and 3D navigated techniques – the majority of which demonstrates benefits of 3D techniques in respect to screw placement, operative time, and radiation exposure.[1,5,8-11]

The purpose of this study is to add to the existing body of literature by characterizing this institution's experience with 3D navigated SI fixation and its impact on radiation exposure to both the patient and surgical staff. The authors hypothesize that SI screw fixation using 3D navigated imaging will result in less radiation exposure (measured as radiation time and dose) and a shorter surgical duration compared to similar cases using traditional fluoroscopic imaging techniques.

METHODS

All surgical cases of SI screw fixation were retrospectively reviewed at The University of New Mexico from September 2022 to May 2024. Institutional Review Board approval was obtained (#23-087), and patient consent was waived due to the observational nature of the study.

All patients undergoing either conventional or navigated SI screw fixation for pelvic ring injuries during the study period were considered. The selection criteria were based on the type of surgical procedure, which included percutaneous posterior pelvic ring screw fixation. Both SI screw fixation and trans-sacral screw fixation were included. Exclusion criteria included incomplete patient records, missing surgical or imaging data, any anterior pelvic ring fixation, and patients undergoing other surgical procedures during the same anesthesia event, typically in the setting of polytrauma.

The primary outcomes assessed were:

1. Radiation Time: Defined as the total duration of radiation exposure during the procedure, measured in minutes, as recorded by the fluoroscopy system used (Ziehm Vision RFD 3D, Orlando FL). This was then divided by the number of screws placed.

2. Radiation Dose: Measured as the total dose of radiation received by the patient, reported in milliGray (mGy), as recorded by the fluoroscopy system used during surgery (Ziehm Vision RFD 3D, Orlando FL). This similarly was then divided by the number of screws placed.

3. Surgical Duration: Defined as the time from the initial incision to the closure of the surgical wound, measured in minutes, as recorded in the operating room (OR) anesthesia record.

Patient demographic information, including age, sex, and body mass index (BMI), was extracted from the electronic medical record to control for potential confounders. Outcome data were also obtained directly from the procedural logs maintained by the surgical and radiology teams. All data were anonymized prior to analysis.

The primary comparison was between radiation time, radiation dose, and surgical duration for the two surgical techniques. Descriptive statistics were used to summarize the outcomes for each technique. A Mann-Whitney U test was used to compare means between groups, given the non-normally distributed data. Median values were primarily compared, rather than the mean values, to limit the effect of outliers. The data were then evaluated for correlations between the primary outcomes and patient factors, such as age and BMI. These correlations informed further sub-group analysis. Statistical significance was set at a standard P-value of < 0.05. All statistical analyses were performed using *R* statistical software. Charts were reviewed and analyzed by two independent researchers to ensure accuracy and consistency.

RESULTS

A total of 60 patient charts met inclusion and exclusion criteria, with 43 patients in the conventional group and 17 patients in the navigated group. The study included 26 women and 34 men. The age of patients in the study group ranged from 12 years of age to 82 years of age, with an expected bimodal distribution (Figure 1). BMI values ranged from 15 to 49. There was no significant difference in the number of screws placed per patient between the two groups ($P = 0.85$).

Radiation Time

There was a statistically significant difference in total radiation time between the two techniques. The conventional fluoroscopy group demonstrated higher average and median total radiation time compared to the 3D navigated fluoroscopy technique ($P < 0.001$). This difference persisted when evaluating radiation time per number of screws placed, with the conventional group showing higher median radiation time per screw (39.2 seconds) compared to the 3D navigated group (19.5 seconds) ($P < 0.001$).

Radiation Dose

No significant difference in total radiation dose was observed between the conventional (88.52 mGy) and 3D navigated (78.2 mGy) fluoroscopy groups ($P = 0.40$). There remained no difference when comparing radiation dose per screw between the conventional (42.23 mGy) and navigated (38.49 mGy) groups ($P = 0.62$).

Surgical Duration

The surgical duration did not differ significantly between the conventional fluoroscopy and 3D navigated techniques ($P = 0.24$). No difference was observed when comparing surgical duration per screw between the two groups, with the conventional group demonstrating a median of 35.25 minutes per screw and the 3D navigated group demonstrating a median of 39.25 minutes per screw ($P = 0.62$).

Correlation with Patient Factors

Further analysis of the data revealed a strong positive correlation between radiation dose and BMI ($R = 0.68$, $P < 0.001$) (Figure 2). This correlation was observed in both the conventional ($P < 0.001$) and navigated ($P < 0.001$) groups. However, no significant correlation was found between BMI and either radiation time per screw ($P = 0.50$) or surgical duration per screw ($P = 0.95$) (Figure 3).

There was a slight negative correlation between radiation time per screw and age ($P = 0.011$) (Figure 4). This correlation was observed in both the conventional ($P = 0.11$) and navigated ($P = 0.12$) groups. However, no significant correlation was found between surgical duration per screw and age ($P = 0.16$).

Given the demonstrated relationship between radiation dose and BMI, the authors performed a sub-analysis excluding patients with a BMI greater than 40 to limit the effect of this potential confounder. This excluded a

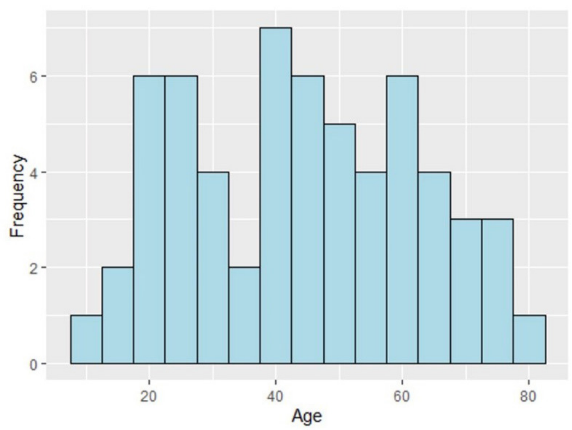

Figure 1. Demographic data showing the expected bimodal age distribution of pelvic ring injuries requiring surgical fixation.

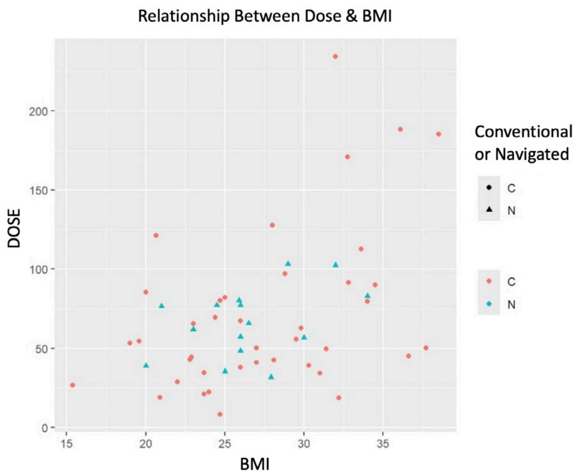

Figure 2. Positive correlation between radiation dose and BMI shown in both the conventional and navigated groups.

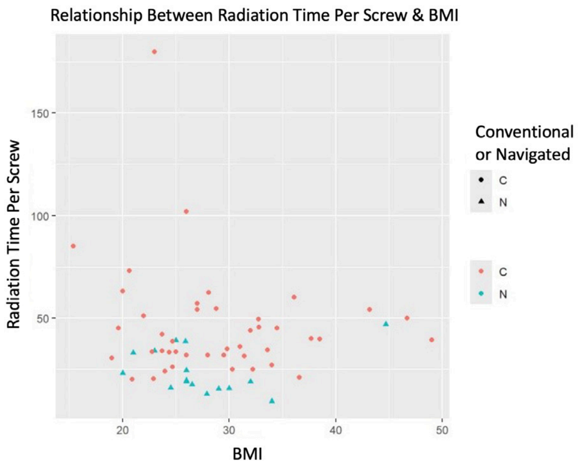

Figure 3. Radiation time per screw clusters around a lower value for the navigated technique when compared to conventional technique. There is no correlation between radiation time per screw and BMI.

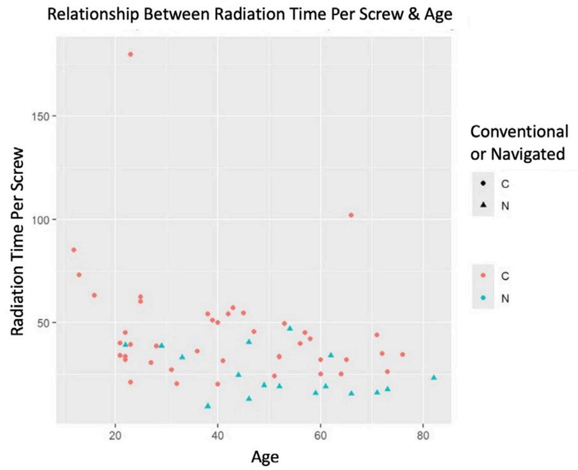

Figure 4. Negative correlation between radiation time per screw and age. The navigated group clusters around a lower radiation time per screw, but both groups demonstrate the slight negative correlation.

total of four patients. The results of the repeat analysis showed no change in the outcome data. The conventional group continued to demonstrate increased radiation time and radiation time per screw compared to the navigated group. However, there remained no significant differences in radiation dose, surgery time, or surgical duration per screw between the two groups. Thus, the exclusion of patients with a BMI greater than 40 did not meaningfully affect the outcomes of this analysis.

Summary of Results

In summary, while conventional fluoroscopy resulted in higher total radiation time compared to 3D navigated fluoroscopy, no significant differences were found between the two techniques in terms of radiation dose or surgical duration per screw. A positive correlation between radiation dose and BMI was observed, but this did not affect the overall comparison between the two fluoroscopic techniques. Excluding patients with a BMI greater than 40 did not alter the findings.

DISCUSSION

To perform safe SI screw fixation, surgeons must understand complex pelvic and sacral anatomy, including distinct variations, and be able to reliably obtain and interpret intraoperative imaging. Anatomical challenges are common, as the upper sacrum has a high degree of variability in shape, rendering image interpretation difficult.[12] Sacral dysmorphism, described as a narrowed or nonexistent trans-sacral corridor through the first sacral segment, is a common variant of sacral morphology with an incidence of 11.0% to 44.0% in the general population.[13] Patients with sacral dysmorphism undergoing SI or trans-sacral screw fixation are at increased risk for cortical penetration and nerve injury.[10,13] These anatomical realities underscore the need for reliable imaging during surgical fixation.

The conventional technique of SI screw fixation is technically complex. It is heavily dependent on both the fluoroscopic technician and the surgeon's ability to interpret the fluoroscopic images, while simultaneously controlling wire placement.[12] Static fluoroscopic images are obtained from the inlet, outlet, and lateral projection views of the pelvis to identify anatomical landmarks and guide the placement of wires or drills.[12] The image intensifier can only visualize one plane at a time.[10] The rate of incorrect SI screw placement using this technique is estimated to range from 2.0% to 15.0%.[1]

In contrast, navigated 3D imaging is a technique that uses an intraoperative 3D fluoroscopic scan. A navigation tracker is placed on a fixed bony landmark near the surgical anatomy of interest, and a computed tomography (CT) scan is performed. The resulting images are transmitted to a navigation workstation, where they are used to register and label surgical instruments in 3D space. After registration, guide wires, drill guides, cannulated drill bits, and screws are placed in the desired corridor under navigated guidance aligned with the intraoperative scan.

Navigation systems were introduced for spine and pelvic surgery to improve precision and accuracy in screw placement.[7] Theoretical benefits include excellent image quality, greater regional view of the pelvis, and reduced metal artifact.[7] Some studies suggest that CT-guided screw placement is more accurate and associated with lower radiation doses.[7,12,14] However, other studies report that navigation may result in equal or even increased radiation exposure.[14] This discrepancy is likely due to variations in study design and the type of navigation system used (eg, preoperative CT, intraoperative CT, O-arm, etc).

In this study, the radiation time required for SI fixation was significantly higher in the conventional group compared to 3D navigated group. However, the authors found no significant difference in total radiation dose or radiation dose per screw. These findings are likely explained by the differences in how images are obtained between the two techniques. The 3D navigated fluoroscopic scan is brief but requires higher radiation doses to penetrate soft tissues, particularly when imaging in the oblique planes needed to complete a "spin." This results in a fluoroscopic study that is shorter in time but similar in overall dose.

While an equivalent radiation dose result supports the noninferiority of the navigated technique, another critical consideration is the physical positioning of the surgical team during radiation exposure. During the preoperative 3D scan in the navigated technique, the medical staff is generally positioned more than six feet away from the scanner, behind additional radiation protective equipment, or even outside the OR entirely. This contrasts with the conventional technique, where surgeons and support staff are positioned directly next to the C-arm during live fluoroscopy. As such, while the overall radiation dose to the patient is equivalent between the two techniques, the radiation exposure to surgical staff is significantly lower in the 3D navigated technique. Radiation exposure to surgical staff is under-studied in the existing literature, and use of the 3D navigated technique could substantially decrease lifetime radiation exposure and associated health risks.[10,15]

Another benefit of the 3D navigated technique is that it does not rely on live imaging, making it less susceptible to real-time issues that impair visualization, such as poor bone quality, transitional anatomy, increased bowel gas, or inconsistent C-arm positioning. Once the scan images are obtained, surgeons or trainees can work in fixed horizontal and vertical planes, as opposed to working orthogonally to the variable inlet and outlet angles of the conventional C-arm. However, this lack of reliance on live imaging also creates a static environment, which can limit flexibility, especially during fracture reduction. If bony fragments are displaced during reduction, a repeat fluoroscopic scan is required to re-register the new bony positions before implants can be safely adjusted.

The authors also hypothesized that surgical duration would be shorter in the navigated technique compared to the conventional technique. However, the literature on this topic is conflicting, with evidence showing no difference, as well as both longer and shorter durations when navigation is applied.[14] The novelty and experience of surgeons using navigated techniques may contribute to this lack of consensus. This study demonstrated no statistical significance in surgical duration or surgical duration per screw between the two techniques. These results support the noninferiority of the navigated technique in terms of surgical timing and efficiency when performed by experienced surgeons. The study also reaffirmed the clear correlation between radiation dose and BMI, a well-recognized phenomenon in pelvic surgery. This correlation persisted when analyzing the data for the conventional and navigated groups separately, suggesting no advantage for either technique in patients with a high BMI.

Limitations of this study include its observational nature and relatively small sample size. A difference may have been detected if more navigated cases had been performed. The study is also limited by the lack of outcomes related to screw and patient clinical outcomes – two factors that are more likely to inform clinical decision between the two techniques.

In summary, when comparing conventional versus 3D navigated SI screw fixation, the conventional fluoroscopy technique required more radiation time with a similar overall dose. The 3D navigated technique did not increase surgical duration and offered a clear benefit in terms of radiation exposure to OR staff given their positioning during imaging. The authors reaffirmed a positive correlation between radiation dose and BMI. Ultimately, there are benefits to both conventional and 3D navigated techniques, and this study supports noninferiority on most measures. It is likely best practice for surgeons to be proficient in both techniques, enabling them to choose the most appropriate one based on clinical scenarios. Further research on screw positioning and patient outcomes is needed to more definitively determine if one technique is truly superior.

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Fibula Strut Allograft with Proximal Tibia Autograft for Treatment of Humerus Nonunion: A Case Report and Review of Oligotrophic Nonunion Management

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ABSTRACT

Due to their high incidence and frequent need for reoperation, nonunions of the humerus present a significant challenge in orthopaedics. Using fibular struts to treat nonunions have demonstrated excellent results. While fibular autografts provide both biologic and structural benefit, high donor site morbidity must be considered. Although their application in midshaft humeral nonunions remains limited, fibular allografts avoid donor site morbidity. Enhancing fibular strut allografts with biological components offers a promising strategy for treating fractures that have failed prior revisions. This case study presents a 36-year-old woman with an aseptic oligotrophic midshaft humeral nonunion who had an unsuccessful revision surgery. Definitive treatment with a fibular strut allograft and a tibial autograft led to improvements in both clinical symptoms and radiographic healing. This case underscores the benefits of combining fibular strut allografts with tibial autografts for successful outcomes, emphasizing the need for further research in this area.

Keywords: Allograft; Bone Transplantation; Fracture Healing; Humeral Fractures; Reoperation

INTRODUCTION

Fractures of the humerus account for 5.0% of all fractures in orthopaedics, with approximately 15.0% progressing to nonunion.[1,2] Adding to the challenge, 33.0% of nonunions are associated with repair-related complications.[3,4] Nonunions occur most often in the proximal humerus, with a smaller percentage affecting the midshaft. Treatment options for humeral nonunions include external fixation, open reduction internal fixation (ORIF) with plating, and intramedullary nailing.[5] These are often augmented with autograft, allograft, stem cells, platelet-rich plasma, demineralized bone matrix, and bone morphogenetic proteins. Current literature lacks a consensus on a standard treatment approach, emphasizing the importance of patient-specific factors for each repair.

Fibular strut allografts have shown promise in the treatment of humerus fracture nonunion.[6,7] While there is strong evidence supporting their use in proximal humerus fractures, research on their application to midshaft nonunions, particularly for oligotrophic ones and in combination with tibial autograft, are limited. The authors present a case of a 36-year-old patient with an aseptic oligotrophic humeral midshaft nonunion that was ultimately treated with a fibular strut allograft with tibia autograft augmentation.

CASE REPORT

Following ejection from an all-terrain vehicle, a 36-year-old woman sustained multiple pelvic fractures with labial hematoma, right distal radius fracture, and a right minimally displaced humeral shaft fracture. Two days after the injury, she underwent ORIF of the humerus. She remained hospitalized for six weeks to treat a labial abscess complicated by sepsis, which required multiple debridements. Two months postoperatively, the humerus showed interval callus formation without evidence of hardware loosening (Figure 1). Four months after surgery, the patient showed callus formation over the lateral cortex of the humerus, but a visible fracture line remained along the medial cortex. At 11 months, the humerus had developed a nonunion, leading to further evaluation (Figure 2).

The patient demonstrated elevated inflammatory labs, including erythrocyte sedimentation rate and C-reactive protein. However, the interventional radiology bone biopsy showed no bacterial growth, and revision ORIF was subsequently performed. Intraoperatively, prior

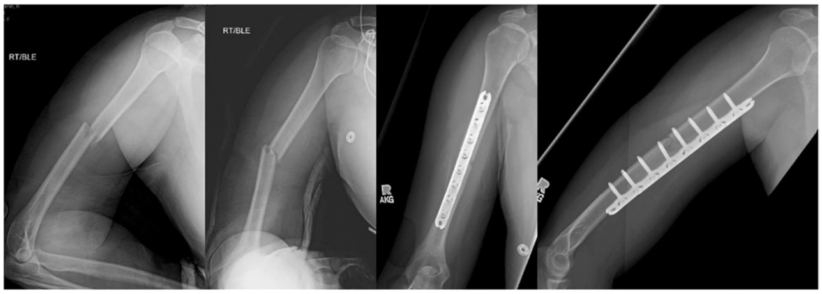

Figure 1. *X-ray of initial fracture and two-month follow-up after primary open reduction and internal fixation.*

Figure 2. *X-rays of initial open reduction and internal fixation 11 months postoperatively.*

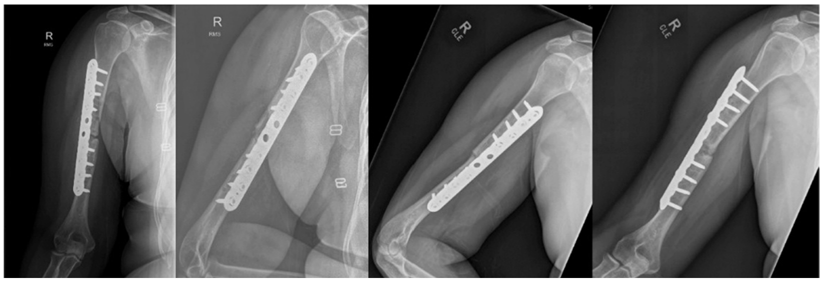

Figure 3. *X-ray of revision open reduction and internal fixation postoperatively and one-year follow-up.*

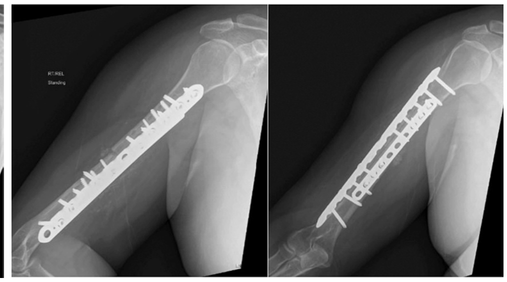

Figure 4. *Two-week post definitive operation.*

implants were removed, the fracture site was debrided to healthy bleeding bone, and there were no signs of infection. A 10-hole compression plate was placed with demineralized bone matrix surrounding the fracture site. Despite the revision ORIF, the patient did not achieve bony healing and showed signs of hardware loosening 12 months later (Figure 3). Infection was once again ruled out with a negative bone biopsy. At this time, the patient began experiencing shoulder pain and weakness attributed to a possible rotator cuff injury that magnetic resonance imaging was unable to discern, due to metal artifact. Therefore, the decision was made to perform another revision ORIF, using a fibula allograft strut and proximal tibia autograft.

In the operating room, a tourniquet was applied to the right lower extremity, and a 2-centimeter vertical incision was made over the anteromedial proximal tibia metaphyseal flare under fluoroscopy. Blunt dissection was then performed to expose the cortical bone. The Zimmer-Biomet Avitus Pilot Hole was used to enter the metaphysis, and a harvesting curette extracted 10 milliliters to 15 milliliters of bone graft.

Attention was then turned to the humerus. An anterolateral approach was used through the patient's prior incision. All implants were removed, and the fracture was debrided to healthy bleeding bone. Next, the humeral canal was proximally and distally reamed to size 11. Irrigation was preformed, and the fibular bone allograft was shaped, inserted into the canal, and filled with a mixture of the harvested tibia autograft and cancellous bone allograft. A 12-hole compression plate was then positioned across the fracture site, ensuring that the screws did not engage with the fibula allograph to allow for proper compression. An additional 10-hole plate was placed anteriorly. Finally, the remainder of the bone graft mixture was placed over the fracture site. The wound was closed in standard fashion. Postoperatively, the patient was instructed to remain non-weight bearing on both the right upper and lower extremities, while maintaining full range of motion at the elbow. She received 24 hours of cefazolin and was prescribed 100 milligrams of doxycycline two times per day for seven days.

The patient demonstrated no postoperative complications at her two-week and two-month postoperative visits (Figure 4). She reported minimal pain in her right humerus and noted a significant improvement in her symptoms, along with improved strength on rotator cuff examination. Her radiographs showed progress in healing, with callus formation, and no signs of implant failure or malalignment.

DISCUSSION

Due to high rates of complications and revisions, humerus nonunions pose significant challenges. Surgical decision-making relies on several factors, including the patient's biological healing environment, biomechanics, and overall health. An important early distinction in nonunion management is septic versus aseptic nonunion. In this case, both the biopsy and intraoperative samples were culture-negative, indicating an aseptic nonunion. Another important factor in nonunion management is assessing the degree of bone formation, as hypertrophic, oligotrophic, and atrophic nonunions require different treatments.[8] This patient exhibited oligotrophic nonunion, characterized by limited callus formation and incomplete fracture consolidation.

Managing oligotrophic nonunions is challenging due to their overlapping characteristics with both hypertrophic and atrophic nonunions. A literature review conducted from 2014 to 2024 using PubMed and Embase databases identified four case reports and five case series outlining treatment approaches for oligotrophic humeral non-unions (Table 1). Common findings across these studies suggest a trend toward combining mechanical support with biological augmentation, resulting in union rates exceeding 90.0%.

Structural support can be accomplished through plating, intramedullary nails, or external fixation. For fractures that have failed previous intervention with change in the biological environment, intramedullary nailing has shown promise in promoting successful healing.[9–12] Gessmann et al[13] and Singh et al[14] enhanced this approach by combining intramedullary nails with locking compression plating in their case reports on oligotrophic nonunions, achieving successful union. However, due to the rotator cuff injury, which is a relative contraindication to intramedullary nailing, this approach was avoided in this patient.

Regarding biological augmentation, iliac crest autograft—either cancellous or tricortical—was the most commonly used adjunct, used in seven out of the nine studies reviewed. Other biological strategies include recombinant human bone morphogenetic protein-2 (rhBMP-2) combined with autogenous bone grafting, as described by Choi et al,[15], who reported 100.0% union across 24 long-bone fractures (including one humerus). Nei et al[16] chose to use platelet-rich plasma (PRP) and demineralized bone matrix for biological augmentation, successfully achieving union in an average of 15 months.

Fibula allograft struts have been previously used in long-bone nonunions for their ability to provide adequate fracture fixation without periosteal disruption. While they have been employed in osteoporotic and atrophic humeral nonunions, their use in oligotrophic nonunions remains uncertain.[17] In their series of long-bone nonunions, Yadav found that autologous fibular struts effectively provide bony stability and osteogenic factors, although a seperate study from Vail highlighted the significant donor site morbidity in fibular autografts.[18,19]

Table 1. *Recent Approaches to Management of Oligotrophic Humerus Nonunions*

	Number of Patients	Time to Union (from definitive surgery)	Fixation Type	Biological Augmentation	Union Rate	Complications
Patient in this study (2024)	1	3 months	Fibular strut allograft, dual LCP	Tibial cancellous autograft	1.0	None
Unal et al[20] (2023)	10	N/A	5 Single LCP 5 Dual LCP	Autograft, Allograft, or combined (unspecified)	N/A	None
Polat et al[10] (2021)	8	5 months	InSafeLOCK® humeral nail	Tricortical iliac crest autograft	1.0	Not Reported
Ziveri Et al[21] (2020)	1	6 months	LCP	Tricortical iliac crest autograft	1.0	None
Feng et al[22] (2020)	1	8 months	Dual LCP	Tricortical iliac crest autograft	1.0	None
Arikan et al[23] (2018)	18	4.4 months	LCP	Tricortical iliac crest autograft	0.95	None
Singh et al[14] (2017)	1	6 months	IMN + LCP	Iliac crest cancellous autograft	1.0	None
Gessmann et al[13] (2016)	34 (atrophic & oligotro-phic)	3 months	IMN & anterior compression plate	Iliac crest cancellous autograft	1.0	1x Radial nerve palsy
Nie et al[16] (2021)	2 (humeral)	15 months	Plate	Demineralized bone matrix, autologous PRP	0.94 (total)	None
Choi et al[15] (2015)	1 (atrophic)	6 months	Plate or nail (not specified)	BMP-2 com-bined with autogenous bone	0.95	None

Similar to this case, Fink et al[5] reported a case series of humerus nonunion with fibular allograft intramedullary fixation, where the majority (77.0%) of patients achieved bony union postoperatively.

As a strategy to promote healing after significant bone loss due to tumor resection, fibular strut allografts have previously been combined with tibial bone autograft in the reconstruction of large osseous defects in orthopaedic oncology.[24,25] Priano et al[26] demonstrated success in applying a similar approach for nonunion repair, using a fibular strut allograft combined with autograft growth factors in a pediatric radius nonunion. In this case, the combination of a fibular strut allograft and tibia autograft was selected to provide both structural and biologic support to promote bone growth. To the authors' knowledge, this is the only report of using fibular allograft combined with tibial cancellous autograft bone augmentation for nonunion repair.

The proximal tibia has become a popular harvest site due to its larger harvest volume and lower complication rates, ranging from 1.0% to 4.0%.[27-29] Candidates for proximal tibia bone harvest have a lower functional baseline, due to the potential risks of harvest site fractures, as documented in a previous case report.[30] This patient's activity level was limited to daily living activities; however, the authors would reconsider this harvest site for individuals who are highly active or have baseline osteoporosis.

At her most recent follow-up, the patient demonstrated significant clinical improvement and radiographic evidence of callus formation, indicating successful bony union. This case and review emphasize the challenges in treating oligotrophic humerus nonunions and highlight recent trends in management. The combination of fibular strut allograft and tibial autograft provides a promising balance of mechanical stability and biological support, while avoiding the morbidity associated with iliac crest harvest. Continued research and clinical reporting are essential to refine these techniques.

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Rare Case of Fungal Osteomyelitis Affecting an Intramedullary Lag Screw

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Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Osteomyelitis is an infection of the bone that is most commonly of bacterial origin. Cases of fungal osteomyelitis are rare, and treatment often requires a prolonged course of antimicrobials. The authors report a case of a 72-year-old man with fungal osteomyelitis affecting an intracortical lag screw, which was discovered during fixation of the left femoral shaft following an injury that occurred 68 years after placement of the affected lag screw. Chronic osteomyelitis can be indolent and subclinical, with the patient experiencing no signs or symptoms of the disease despite having bone infection for decades. This condition may become clinically apparent when a later injury necessitates operative treatment and potentially adversely affects the recovery from that injury.

Keywords: Intramedullary Fracture Fixation; Invasive Fungal Infections; Osteomyelitis

INTRODUCTION

Osteomyelitis is an acute or chronic infection of the bone that is often of bacterial origin and characterized by inflammation and progressive destruction of bone tissue.[1] While bacteria are the most implicated pathogens in osteomyelitis, fungal pathogens are uncommon causes of osteomyelitis.[2] Osteomyelitis is classified as acute or chronic based on histopathological findings and the temporality of disease.[3] Chronic osteomyelitis is classically characterized by the presence of separated pieces of necrotic bone, also known as necrotic bone sequestra.[4,5] When left untreated, osteomyelitis can progress to infection into other regions of bone and surrounding tissues.[6] Even with appropriate treatment, osteomyelitis can lead to adverse outcomes.[6,7]

Chronic osteomyelitis may remain indolent and subclinical, only becoming apparent when there is an injury that the infection predisposes the patient to. Additionally, in the case of operative repair of a fracture at or near the site of infection, a subclinical infection may become apparent when the recovery process is adversely affected.[8] In the orthopaedic trauma setting, recognizing chronic or indolent osteomyelitis is an important factor for consideration as it can affect the treatment course and recovery of the patient's injury. Even without recent symptoms or signs of issue, history or clinical evidence of remote skeletal injury or infection should alert the surgeon to possible chronic indolent and subclinical infection. Treatment of the new injury may be complicated by the possible pre-existing osteomyelitis.[9] Furthermore, the organism may be quite unusual or hard to treat, such as fungus.

This report describes a case of chronic fungal osteomyelitis, involving a previously placed femoral lag screw, that was diagnosed during surgical fixation of the same femur.

CASE REPORT

History: A 72-year-old man presented to the emergency department with complaint of left lower-extremity pain following a fall while attempting to dismount a motorcycle. The kickstand malfunctioned and, as the motorcycle fell to the left, he braced himself with his left leg and struck the ground at a 45° angle, feeling an immediate onset of severe pain.

Physical Exam: The left thigh was grossly deformed, shortened, and externally rotated with no appreciable abrasions, lacerations, or ecchymosis. A 13-centimeter scar was noted on the lateral proximal thigh.

Radiographic Exam: Initial radiograph of the left femur demonstrated an oblique fracture at the junction of the proximal to mid diaphysis of the left femur with displacement and rotational malalignment. An intra-cortical screw was noted to be approximately 6 centimeter proximal to the fracture. In addition, there was sclerosis and cyst-like irregularities of the bone adjacent to the fracture and to the intracortical screw with scalloping of the endosteum and stippling of the proximal diaphysis (Figures 1, 2). A computed tomography (CT) scan was consequently indicated showing irregular, sclerosed bone (Figure 3). Irregularities in bone quality generated a differential diagnosis of neoplastic versus chronic osteomyelitis, prompting biopsy of the bone.

Figure 1. *Initial AP radiograph demonstrates an oblique fracture at the junction of the proximal to mid diaphysis of the left femur with displacement and rotational malalignment.*

Figure 2. *Initial lateral radiograph demonstrates an oblique fracture at the junction of the proximal to mid diaphysis of the left femur with displacement and rotational malalignment.*

Figure 3. *CT image revealing a displaced acute femoral mid diaphyseal fracture with a metallic screw shown to be embedded in the proximal femoral shaft lateral cortex.*

Related History: The patient in this study reported a history of left femur fracture in 1955, when he was five years old. He reports having fallen from an 8 ft height, landing on his left thigh, causing a closed transverse fracture of his left femur. He underwent open reduction internal fixation and placement of a single intracortical screw and was placed in a spica cast for three months. The patient was not given antimicrobials as the fracture was closed and demonstrated no signs of infection. No subsequent operations were performed. He reported no pain near the site of injury until 20 years to 30 years ago when he began experiencing dull pain around his incision site while participating in sports. This pain was relieved by rest and anti-inflammatory medications and was non-debilitating.

Laboratory Results: The patient had unremarkable lab values and inflammatory markers were not elevated (ESR 7, CRP < 0.3, WBC 7.09).

Treatment Course: He was placed in skeletal traction and underwent open reduction internal fixation with placement of an intramedullary nail. The authors biopsied reamings of the intramedullary canal and samples of bone taken with a pituitary rongeur. The surgical pathology report showed necrotic bone with numerous fungal organisms present. The patient was diagnosed with indolent fungal osteomyelitis. The patient completed a 12-month course of Voriconazole prescribed by an infectious disease physician. There were no postoperative complications or clinical signs of exacerbation of chronic indolent infection at the patient's one-year follow-up appointment. Radiographs demonstrated a healed fracture with an intramedullary nail and retained intracortical screw (Figures 4, 5).

Figure 4. *AP radiograph at one-year post-fixation demonstrated a healed fracture with an intramedullary nail and retained intracortical screw.*

Figure 5. *Oblique view radiograph at one-year post-fixation demonstrated a healed fracture with an intramedullary nail and retained intracortical screw.*

DISCUSSION

The authors believe this infection was initially contracted via direct inoculation at the time of the patient's initial injury. Although less likely, a hematogenous secondary seeding of the fracture site could have occurred. The patient healed his original fracture 67 years ago and the femur appeared grossly normal. However, there were focal changes within the femur, which may have caused weakening of the bone.[10] The presence of chronic indolent osteomyelitis of the femur shaft may have contributed to the second fracture.

The treatment team in this study elected not to remove the screw that was thought to be infected at the time of the initial surgery. This is due to the unknown infection status of the patient at the time of surgery, the fact that the screw did not interfere with the planned operative fixation, and the removal requiring additional approach through the thigh to retrieve the screw. If the screw were intramedullary, it could have potentially prevented passage of the implant through the canal. The authors chose not to remove the screw for the reasons noted above, but recognize that screw removal as an adjunct to fracture treatment and anti-fungal medication would be reasonable in this situation. Theoretically, an infected retained foreign body cannot be sterilized by antibiotics alone and retention of the infected foreign body likely increases the probability of persistence of the infection.

Infectious disease physicians and orthopaedic surgeons weighed the potential benefits against costs for three separate treatments: 1) repeat surgery; 2) antifungal therapy; and 3) a combination treatment method to remove the screw and eliminate the infection once confirmed. The benefits of a repeat operation include removal of the foreign body thought to be the source of infection and debridement of infected bone, which is otherwise prone to cause persistence of fungal infection.[11,12] An additional operation may avoid the side effects of prolonged treatment, and may be less expensive than one year of antifungal therapy.[13,14] Bone debridement is an important treatment for acute osteomyelitis, but the role of debridement in chronic indolent infection is more controversial. It is generally impossible to identify the full extent of infected bone in chronic indolent osteomyelitis. The bone is usually functional and extensive removal may create a bone defect that causes more functional problems than retention of bone affected by indolent infection. Treatment should be considered on an individual patient basis and be specific to the extent of their disease.

In conclusion, the authors report a rare case of fungal osteomyelitis affecting an intramedullary lag screw that was treated with long-term antifungal therapy. Early intervention in this condition is recommended to avoid complications, such as impaired wound healing leading to possible subsequent bone injury.

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Closed Treatment of Displaced Radial Neck Fracture in an Adult

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

ABSTRACT
Making up 1.5% to 4.0% of all fractures, radial head and neck fractures are typically treated based on the severity of angulation at the radial neck or if range of motion (ROM) is blocked. In this study, we present a case of a 43-year-old woman with a Mason Type 2 radial neck fracture, successfully treated with closed reduction and one week of immobilization, resulting in near anatomic radial neck angulation without the need for operative intervention. The patient returned to work within two weeks and regained full ROM by six months, maintaining near anatomic reduction throughout.

Keywords: Elbow Injury; Radial Neck Fracture; Radius Fracture

INTRODUCTION
Radial head and neck fractures are relatively common, accounting for approximately 33.0% of elbow fractures and 1.5% to 4.0% of all fractures.[1] The radial head was once thought to be expendable and fractures were often treated with excision. The radial head has since been recognized for its key role in the biomechanics and stability of the elbow and forearm. The radial head is a critical secondary valgus stabilizer of the elbow, particularly in the setting of a medial collateral ligament injury.[2] Furthermore, Rabinowitz et al[3] found that the radial head is a primary forearm stabilizer by demonstrating up to 7 millimeters of proximal radial migration after radial head resection in cadaveric models. Unrecognized forearm instability resulting from radial head and neck fractures often results in limited range of motion (ROM), wrist deformity, and chronic pain.[4] An intact and appropriately angulated radius is paramount to wrist, forearm, and elbow stability and function.

An improved understanding of the functional anatomy and kinematics of the elbow has demonstrated that ideal treatment of radial head and neck fractures is vital. In general, non-operative management is recommended for Mason Type 1 fractures, which are nondisplaced or minimally displaced (<2 millimeters). In contrast, operative management is often used for Mason Type 2 fractures, which are displaced (>2 millimeters), and for Mason Type 3 comminuted fractures.[5]

Appropriate treatment of Mason Type 2 radial neck fractures remains controversial as these fracture patterns may be associated with either stable or unstable fracture fragments and may or may not have an associated mechanical block to motion.[6] Although closed reduction is well described for pediatric radial neck fractures, there are no reports of closed reduction without internal fixation for Mason Type 2 radial neck fractures in adult patients.[7] We present the case of an otherwise healthy 43-year-old woman with a Mason Type 2 radial neck fracture, successfully treated nonoperatively with a near-anatomic reduction in the emergency department.

CASE REPORT
A 43-year-old right-handed, athletic woman presented to the emergency department with an acute left radial neck fracture, sustained in a mountain biking accident when she fell onto her outstretched arm. She had no significant past medical history. The left upper extremity was neurovascularly intact and the fracture was closed. She was exquisitely tender over the radial head. Elbow ROM was slightly limited when compared to the contralateral extremity, with approximately 5° of limitation in both pronation and supination. The patient had no other significant injuries and denied any prior injuries to the left elbow.

Initial radiographs of the elbow and forearm revealed a radial neck fracture with approximately 20° of apex ulnar angulation and a compromise in the congruency of the radiocapitellar joint line (Figure 1). We informed the patient that the fracture angulation could be addressed through closed reduction, with the aim of preventing further displacement and potentially avoiding the need for operative fixation. She opted to proceed with closed reduction, and Ketamine was used avoiding the need for operative fixation. She opted to proceed with closed reduction, and Ketamine was used for pain management. We reduced the radial head using the Israeli/Kaufman maneuver in which the forearm was supinated and pronated while the elbow was held at 90° of flexion with direct pressure over the radial head.[8]

Improved alignment was demonstrated on miniature C-arm fluoroscopy and the patient was placed in a well-padded sugar tong splint with the elbow positioned at 90°. A mold was applied over the radial head to maintain the reduction. She tolerated the procedure well. Formal radiographs and a computed tomography scan were obtained to further evaluate the elbow injury, which demonstrated that the radial neck was now in near anatomic alignment (Figures 2-4).

The patient was seen one day later in the hand-specialty clinic. Due to her near anatomical fracture alignment, we decided to proceed with conservative management in the splint for an additional week. After one week, the splint was removed and the patient transitioned to a sling to begin light ROM exercises to prevent stiffness. Three weeks later, the patient was seen in clinic, and new three-view elbow radiographs showed that the alignment of the radial neck fracture was maintained (Figure 5). Her elbow ROM was limited to 30° to 100°. She lacked approximately 10° of supination and 20° to 30° of pronation. She was otherwise neurovascularly intact. The patient returned to work but was limiting herself to desk work. At this point, we recommend she discontinue the sling and slowly progress to all activities as tolerated. Six months post-injury, she had full ROM equal to the contralateral side without pain or tenderness.

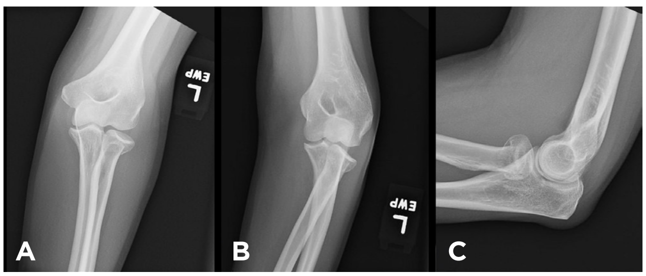

Figure 1. *A) Anteroposterior; B) oblique; C) lateral left elbow injury radiographs showing an angulated left radial neck fracture with radiocapitellar joint line incongruency notable on all three views.*

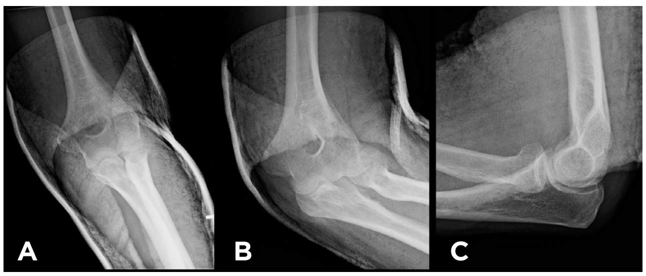

Figure 2. *A) AP; B) oblique; C) lateral left elbow post-reduction radiographs showing improved alignment of the radial neck fracture and radiocapitellar joint line congruence.*

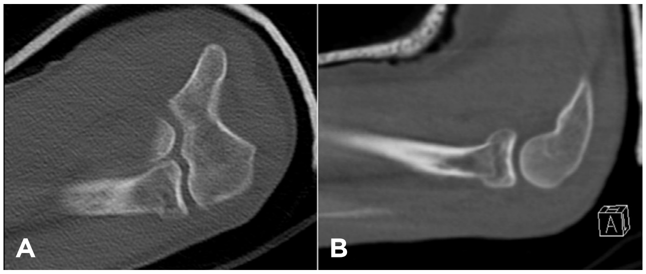

Figure 3. *A) Coronal and B) sagittal computed tomography scan slices of the left elbow, post-reduction, showing improved alignment of the radial neck fracture and elbow joint line congruence.*

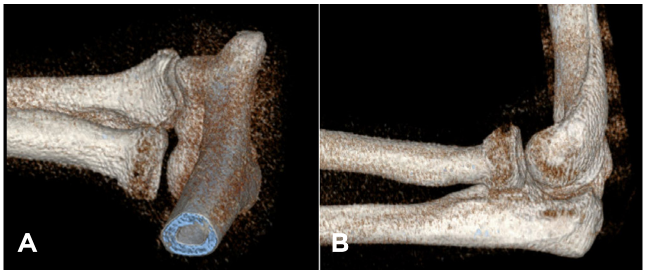

Figure 4. *A) Coronal and B) sagittal views of a 3D reconstruction of the left elbow, post-reduction, showing improved alignment of the radial neck fracture and elbow joint line congruence.*

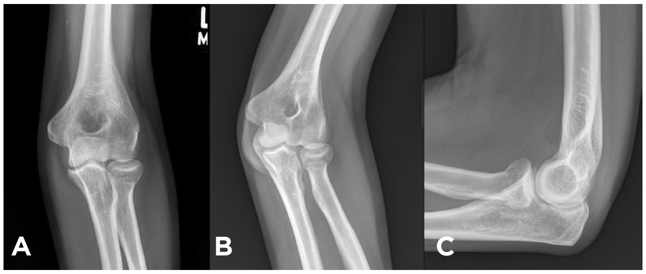

Figure 5. *A) AP; B) oblique; C) lateral left elbow radiographs, three weeks after injury, showing a healing left radial neck fracture with maintained radiocapitellar joint line congruence.*

DISCUSSION

The complex articulation of the radial head in both the radiocapitellar and proximal radioulnar joints highlights the importance of proper management of radial head and neck injuries to preserve optimal function. These radial neck fractures are often classified using the Mason classification system in which Type 1 fractures are non-displaced or minimally displaced (<2 millimeters), Type 2 fractures are displaced (>2 millimeters), and Type 3 fractures are highly comminuted.[5] Mason fracture Types 1 and 2 may be treated conservatively with exercise alone, yielding good to excellent outcomes in the majority of patients.[5,9-11]

In a prospective study of 237 patients, Duckworth et al[10] followed 156 radial head and 81 radial neck fractures, finding that 93.0% of patients achieved excellent or good Mayo Elbow Scores. Specifically, Mason Type 1 and 2 fractures had mean scores classified as "excellent."[10] In comparison, Herbersson et al[11] demonstrated that, among 100 radial head and neck fractures, injured elbows exhibited mean flexion and extension deficits of 2° and 4°, respectively, compared to uninjured elbows, with a mean follow-up of 19 years. Although outcomes of nonoperatively managed radial head and neck fractures are generally well tolerated, patients may experience deficits in their elbow ROM compared to both their contralateral extremity and their pre-injury state.

Radial neck fracture reductions are frequently performed in the pediatric population. While these reductions are not frequently performed in adults, minimally displaced pediatric radial neck fractures tend to result in excellent outcomes if they remain adequately reduced. For this reason, the general recommendation is to attempt closed reduction for isolated, closed pediatric radial neck fractures. Operative intervention is then considered if this reduction is inadequate or not maintained in the following weeks.[7]

Although the patient's radial neck injury in this study was mild and could be treated conservatively without reduction, we recommended closed reduction due to her high-demand occupation, in an effort to maximize the recovery of her elbow ROM. We used the Israeli/Kaufman maneuver, which is frequently used to reduce pediatric radial neck fractures. The maneuver involves supination and pronation of the forearm while the elbow is held in 90° of flexion and direct pressure is held over the radial head.[8]

One week after reduction, the patient in this case was able to transition out of her splint and return to work. At six-month follow-up, she had regained full ROM equivalent to her contralateral extremity. While conservative management (without reduction) may result in acceptable elbow function for Mason Type 1 and 2 radial neck fractures, closed reduction to improve radial head angulation to more anatomic parameters may be considered in high-function patients, with the goal of maximizing recovery of elbow ROM, and ultimately, function.

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Two-Stage Total Knee Arthroplasty (TKA) for a Rigid and Infected Knee: A Rare Case Report of *Aspergillosis*

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Conflict of Interest The authors report no conflicts of interest.

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

ABSTRACT

Knee infection caused by *Aspergillus* is a rare condition that presents a diagnostic challenge for orthopaedic surgeons and musculoskeletal specialists. This case report aims to describe the treatment of a patient with active articular *Aspergillus* infection and knee arthrofibrosis through a two-stage total knee arthroplasty (TKA). A 37-year-old woman presented with knee arthrofibrosis, which was complicated by an *Aspergillus* infection. The treatment involved a two-stage procedure: 1) bone cuts for TKA and systemic antibiotic therapy; and 2) TKA with the use of specific antibiotic-loaded cement. The patient has been followed for 30 months, showing no signs of failure.

Keywords: Aspergillus; Arthroplasties, Knee Replacement; Treatment

INTRODUCTION

Knee infection caused by *Aspergillus* is a rare condition that can pose a diagnostic challenge for orthopaedic surgeons and musculoskeletal specialists. It is more commonly reported in the ribs, spine, and sternum, particularly in patients with an identified primary infection site.[1,2]

The typical clinical history is marked by slow progression and multiple incorrect treatments, which contribute to disease spread and significant joint compromise. Consequently, in advanced cases involving extensive articular surface destruction, complete fungal eradication may not result in a favorable clinical outcome, as symptoms are attributed to articular surface destruction.[3]

CASE REPORT

A 37-year-old woman presented with chronic, progressive knee pain attributed to knee synovitis. She reported no comorbidities or history of medication or drug use. Bone scintigraphy revealed isolated involvement of the left knee. Based on magnetic resonance imaging (MRI) findings, the presumptive diagnosis was lipoma arborescens, prompting a synovial biopsy that confirmed chronic, non-specific synovitis. At that time, no specimens were sent for culture (Figure 1).

Despite initial treatment, symptoms persisted and the patient underwent two additional arthroscopic total synovectomies within one year. However, these surgical interventions failed to provide pain relief, and the patient's joint range of motion (ROM) progressively worsened. Clinical evaluation revealed a swollen left knee with a limited ROM of 10° to 30° and a limping gait, supported by crutches. A subsequent MRI indicated recurrent synovitis and an increase in both the size and number of bone erosions. Given the mirrored joint involvement, bone changes, slow progression, and mild systemic symptoms, an atypical or low-virulence intra-articular infection was considered the leading hypothesis (Figure 2).

The physicians in this case discussed treatment options with the patient, which included: 1) knee arthrodesis with an external fixator; 2) above-knee amputation; and 3) a two-stage total knee arthroplasty (TKA). The patient chose the two-stage TKA, despite being informed of the potential risk of recurrence and failure. During the initial stage of the procedure, all cuts for the TKA were made, and samples were sent for bacterial, fungal, and tuberculosis cultures. Broad-spectrum antibiotic therapy with vancomycin and meropenem was started, and an antibiotic-loaded static spacer (vancomycin and gentamicin) was placed in the joint.

Thirty days postoperatively, synovial tissue culture identified *Aspergillus* species, leading to the initiation

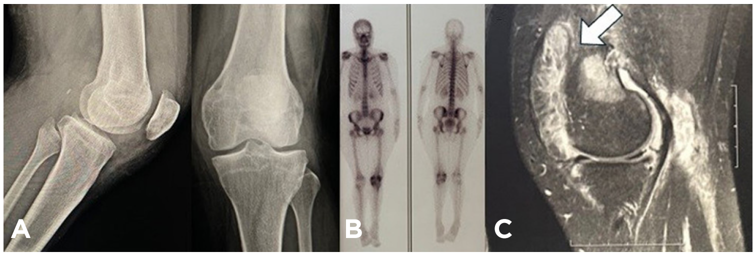

Figure 1. *Initial image investigation. A) X-rays without gross abnormalities; B) Bone scintigraphy revealing isolated left knee compromise; C) Initial MRI scan. Arrow points to synovial thickening that was misdiagnosed as an arborescent lipoma.*

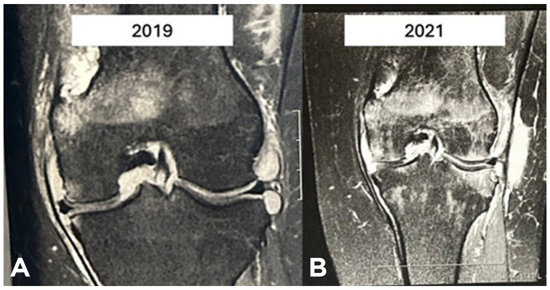

Figure 2. *Changes on MRI images from 2019 to 2021. Advancement of bone compromise, including extension to the proximal tibia and distal femur.*

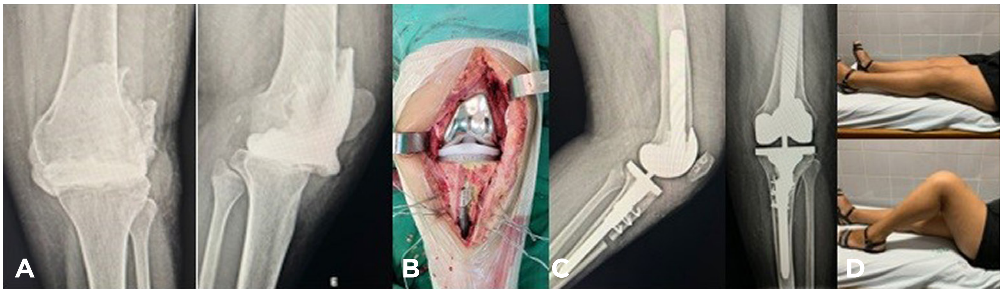

Figure 3. *Stepwise approach to suspected unknown joint infection. A) TKA bone cuts and static spacer manufacture; B) Intraoperative image illustrating tibial tuberosity osteotomy to address the rigid knee situation; C) and D) 30-month follow-up visit x-ray and clinical aspect.*

of 200 milligrams of voriconazole twice daily. After six weeks of antifungal treatment, the prosthesis implantation was performed. The bone cement was loaded with 750 milligrams of amphotericin B, 4 milligrams of vancomycin, and 500 milligrams of gentamicin. Non-cemented stems enhanced prosthesis fixation and oral voriconazole was prescribed for six months.

At the 30-month follow-up visit (2024), there were no signs of clinical or radiological failure. The patient was able to walk without assistive devices, had 90° ROM, complete extension, and was pain free (Figure 3).

DISCUSSION

Aspergillus sp infection is a rare condition that has few reports in the literature. Most cases are associated with underlying immunosuppressive conditions or previous joint surgical intervention. Tiwari et al[4] have reported the occurrence of articular Aspergillosis in an immunocompetent patient and highlighted the importance of considering that diagnosis in patients without known risk factors. This case report presents notable aspects, including lack of risk factors indicating immunosuppression or previous knee intervention. The low virulence intra-articular infection emerged as a hypothesis based on insidious joint destruction without clear clinical manifestations of infection, such as fistulae and redness. The patient presented with synovitis (swollen knee) without accompanying local warmth. In situations such as these, it is important for physicians to be informed on atypical infections and specific culture protocols ordered.[1]

Systemic and local antibiotic therapy are key to addressing bone and joint fungal infections. Although adequate pharmacologic therapy was guided by culture results in this case, additional local empiric therapy was offered through the cement. Anagnostakos and colleagues have demonstrated the importance of addressing the specific causative organism and widening the coverage for agents that were not identified through culture.[5]

The majority of studies describing approaches to knee fungal infection include surgical debridement and systemic antifungal therapy. Due to the fact that the patient in this case presented with advanced cartilage compromise and knee arthrofibrosis, the physicians adopted the two-stage TKA, aiming to treat infection, pain, and ROM issues.[6]

Koutserimpas et al[7] summarized the treatment of articular *Aspergillus* infections by evaluating 29 patients with this condition. The authors described several surgical strategies, including arthrocentesis, arthroscopic techniques, and open synovectomy. However, they did not find any references to the use of TKA in such cases. A two-stage TKA may present a viable option in establishing an infection-free environment, allowing prosthesis implantation, and maintaining a functional ROM.[7]

TKA should be considered a viable option for patients with *Aspergillus* knee infections. The two-stage approach aids in diagnosis confirmation and allows for the planning of appropriate systemic and local antibiotic therapy, thereby improving the safety of the procedure.

This report presents a successful case that underscores the need for further investigation into this challenging scenario. Currently, patients should be made aware of the limited data regarding the outcomes of TKA in treating native knee fungal infection treatments, with treatment decisions based on an individualized case assessment.

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Proximal Tibia Biplanar Anterior and Lateral Closing Wedge Osteotomy with Concomitant Revision Anterior Cruciate Ligament Reconstruction: A Case Report

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

ABSTRACT

This report documents a unique, successful strategy to manage a failed anterior cruciate ligament reconstruction (ACLR) in the setting of coronal and sagittal plane malalignment. The patient is a 38-year-old man with a history of a failed ACLR who presented with recurrent knee instability. Imaging revealed a posterior tibial slope (PTS) of 17° complicated by a varus malalignment of 10°. A single-stage anterior and lateral closing wedge tibial osteotomy (biplanar) with simultaneous revision anterior cruciate ligament reconstruction was performed. Final radiographic evaluation revealed that the tibial osteotomy healed with correction of coronal alignment to a physiologic 3° varus and a PTS of 7°. The patient returned to an active lifestyle without limitations.

Keywords: Anterior Cruciate Ligament; Orthopaedics; Osteotomy

INTRODUCTION

The combination of clinically significant varus and posterior tibial slope (PTS) malalignment presents a difficult scenario in the presence of a failed anterior cruciate ligament (ACL) graft and recurrent knee instability. Excessive PTS and varus malalignment have both been shown to increase the forces placed on the ACL, thereby increasing the potential for graft failure, which makes surgical correction and graft protection necessary in properly indicated patients.[1,2]

Biplanar tibial osteotomies and their impact on posterior tibial slope and varus alignment of the knee have been previously researched and documented.[3,4] However, correction in both planes, along with a simultaneous or staged ACL reconstruction, is a newer treatment option. A literature search identified only a handful of articles published within the past three years, none of which used the same technique used for this patient.[5-8]

Additional considerations in the setting of a revision ACL reconstruction (rACLR) include the evaluation of non-bony structures to mitigate factors that may contribute to postoperative knee instability. Medial and lateral meniscus tears, improper tunnel placement and size, and other soft-tissue deficiencies are among the many factors that can affect the success of a rACLR.[9-11]

This case report discusses the authors' experience with a patient who returned to their pre-injury level of athletics following a biplanar anterior and lateral closing wedge high tibial osteotomy (Bi-PlanarClosingWedge HTO or bpcwHTO) for slope and varus correction, along with a simultaneous rACLR using autograft quadriceps tendon.

The patient was informed that information about this case would be submitted for publication and they provided consent.

CASE REPORT

The patient is a 38-year-old man with a history of a left knee ACL tear and reconstruction with medial meniscectomy seven years prior. Three years before presentation, he reinjured the knee while playing tennis, resulting in a rupture of the left ACL graft. Preoperative physical examination revealed a positive Lachman with soft endpoint, positive pivot shift with clunk, negative posterior drawer, and negative varus and valgus stress testing at both 0° and 30°. The patient rated his pain at a 7 out of 10 on the Numeric Pain Rating Scale (NPRS). Imaging confirmed a 17° PTS, 10° varus deformity, 6.66 millimeters of anterior tibial subluxation, complete ACL graft rupture, and progression of medial compartment arthritis compared to imaging performed seven years prior (Figures 1A-1D).

A paper template developed by the surgical team, including senior authors LN and RCS, illustrated an asymmetrical osteotomy wedge needed for concomitant varus and slope correction (Figures 2A & 2B). The Fujisawa Point was identified and used for coronal alignment correction due to its documented use for patients with medial compartment degeneration and ligamentous instability.[12,13]

The lateral bpcwHTO was performed using two infra-tubercular tibial cuts to reduce the risk of fibular nerve palsy. An asymmetrical biplanar tibial osteotomy was performed and required for correction in two planes, along with a fibular osteotomy to allow for reduction (Figures 3A & 3B). Final fixation of the tibial osteotomy was achieved with a TOMOFIX® (Synthes, USA) plate (Figure 4). An ipsilateral quadricep tendon autograft with bone plug soaked in vancomycin was selected as the graft choice, given the prior bone tendon bone autograft harvest.[14,15] Graft placement used the previously drilled graft tunnels, which were in an acceptable position.

Postoperative instructions included weight bearing as tolerated immediately following the surgery. At two months postoperative, radiographs demonstrated secure fixation with PTS corrected to 7° and varus neutralized to 3° (Figures 6A & 6B). The patient

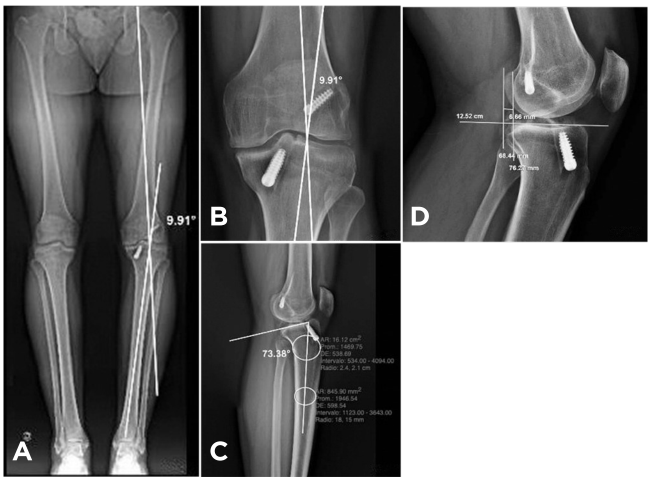

Figure 1. *A) Preoperative weight bearing full-length radiograph demonstrates varus deformity of nearly 10° with hardware from the primary ACLR; B) Anteroposterior radiograph of the knee shows varus alignment and mild medial joint space narrowing with intact hardware from prior bone tendon bone autograft ACL reconstruction; C) Preoperative lateral weight bearing radiograph of the left knee displaying a PTS of nearly 17°; D) Preoperative anterior tibial subluxation (ATS) measured 6.66 millimeters on lateral radiographs.*

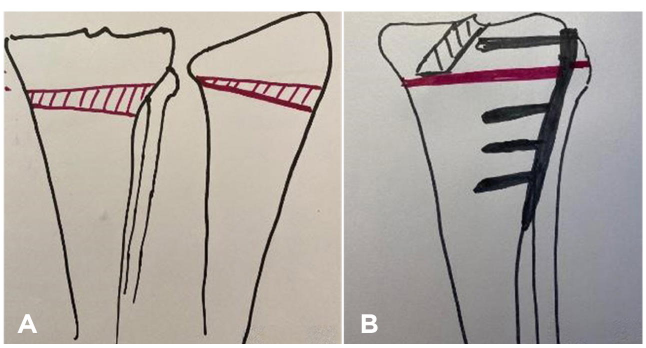

Figure 2. *Preoperative paper template demonstrating the asymmetrical bony cut via a bpcwHTO followed by plate fixation and tunnel positioning for placement of rACLR with quadriceps autograft.*

Figure 3. *Placement of two osteotomes demonstrating the two-cut technique for a bpcwHTO with radiographic imaging confirming placement and subsequent bone wedge removal with remaining flat opposing surfaces.*

Figure 4. *Placement of two osteotomes demonstrating the two-cut technique for a bpcwHTO with radiographic imaging confirming placement and subsequent bone wedge removal with remaining flat opposing surfaces.*

Figure 5. *Lateral radiograph with the knee in extension taken immediately following the procedure demonstrates a correction of the ATS from 6.66 millimeters to 1.59 millimeters.*

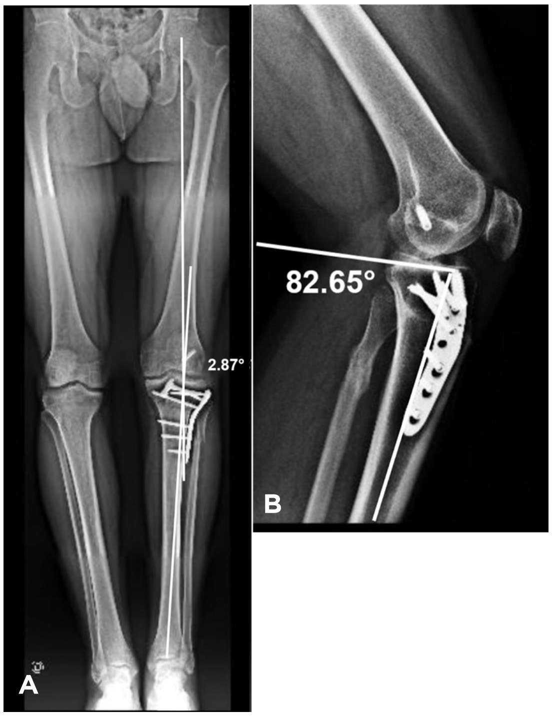

__Figure 6.__ A) Full-length weight bearing radiograph; B) lateral radiograph showing final fixation at two months post operation. Postoperative PTS was corrected from ~ 17° to ~ 7°. Postoperative coronal alignment improved from a varus measurement of ~ 10° to ~ 3°.

completed six months of physical therapy before slowly transitioning back to tennis. At three years postoperative, the patient had a NPRS score of 0, an International Knee Documentation Committee score of 86.2, Lysholm knee score of 94, and returned to brace-free tennis without limitations or instability.

DISCUSSION

This case illustrates the successful use of a biplanar anterior and lateral closing wedge osteotomy to reduce PTS and correct varus deformity with a simultaneous rACLR. There are limited surgical technique descriptions in the literature to guide biplanar osteotomies in the setting of ACL rupture.[3,6,12] Indications for osteotomies after failed ACLR include both varus and posterior slope corrections when there is more than 10° of varus deformity with simultaneous medial degeneration and 12° of posterior slope.[1,16,17] Large varus deformities greater than or equal to 10° substantially increase forces across the ACL, and when this deformity is isolated in the setting of a failed ACLR, coronal correction is indicated.[18] Similarly, current literature indicates that a PTS greater than 12° increases the risk of graft failure in a reconstructed ACL.[19-23] The authors considered additional surgical techniques and focused on identifying the properly indicated patient, as both factors contribute to a positive outcome.

Müller et al[3] highlight a different approach to address the same pathology in the form of a biplanar medial opening wedge high tibial osteotomy (mowHTO). The described technique corrected varus deformity and PTS in patients with symptomatic medial osteoarthritis and biplanar deformity. When rACLR was indicated, it was recommended to wait six months following the osteotomy and perform the procedure in a staged fashion to allow for bone consolidation. Müller et al[3] concluded that while a biplanar mowHTO is useful for addressing complex anatomy, as presented in this case, further research is needed to evaluate the long-term efficacy of this procedure. In the authors' experience, mowHTO is a useful procedure, but due to the potential complication of increasing the already large PTS of 17° seen in this patient, the bpcwHTO used in this case was a better fit for the patient's pathology.

Price et al[5] discussed a similar biplanar mowHTO approach for the correction of coronal and sagittal plane malalignment. The patient was a 38-year-old woman with a history of polytrauma who presented with an ACL rupture, varus deformity, and increased PTS. The biplanar osteotomy was performed first to correct the slope and varus malalignment, followed by staged ACLR 23 months later.[5] In the bpcwHTO approach used in this case, the authors avoided increasing the PTS with an opening wedge osteotomy and avoided potential non-union complications, allowing for immediate weight bearing and, most importantly, avoiding the need for a staged approach and the associated social pressures.

In a biomechanical cadaver study, Imhoff et al[1] indicated that the goal of achieving a perpendicular tibial plateau in the setting of an ACLR led to the greatest reduction in stress on the ACL (33.0% reduction in graft force at 200N and 58.0% at 400N) and a significant reduction in anterior tibial translation compared to native alignment. This research supports biplanar correction in the setting of a previous ACL graft failure, as seen in this case.

Biplanar high tibial osteotomy procedures have been shown to be effective in correcting PTS and varus malalignment. Literature searches demonstrate that although proximal tibial biplanar corrections are a newer technique, they show promise at effectively decreasing stress on native and reconstructed ACLs. This case documents a novel approach to correcting both varus and PTS in the setting of a simultaneous rACLR with a three-year follow-up and a good outcome. Further studies are needed to determine the efficacy of different surgical techniques for the treatment of coronal and sagittal plane malalignment during simultaneous rACLR. However, in the presence of ACL failure and significant varus and PTS, this appears to be a useful approach for patient care.

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Recurrent Baker's Cyst in a Pediatric Athlete: A Case Report

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Informed Consent Informed consent was obtained from parent for use of de-identified images and case information for the purposes of medical education.

ABSTRACT

Also known as popliteal cysts, Baker's cysts are fluid-filled lesions found in the popliteal fossa, typically originating from the gastrocnemius-semimembranosus bursa. While these cysts are relatively common in adults, with a prevalence ranging from 5.0% to 41.0%, they are extremely rare in children, showing an incidence of just 2.4%. In most cases, Baker's cysts result from intra-articular knee pathologies that lead to an increased production and sequestration of synovial fluid. The authors present the case of an athletic 16-year-old adolescent boy with a recurrent left-knee Baker's cyst with magnetic resonance imaging showing no intra-articular pathology. Despite conservative treatment, including non-steroidal anti-inflammatory drugs, and several cyst aspirations, knee instability and pain persisted. Subsequent arthroscopy revealed a longitudinal tear of the posterior horn on the left medial meniscus, which was repaired. Following surgery, Baker's cyst was resolved. Two months postoperatively, the patient regained 88.0% of his pre-injury strength and successfully returned to sports.

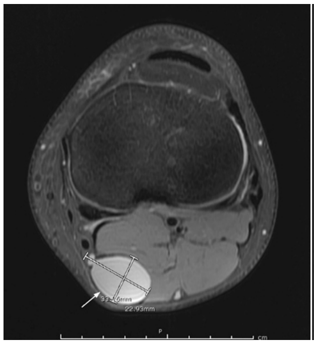
Keywords: Arthroscopy; Baker's Cyst, Meniscus; Knee; Pediatrics

INTRODUCTION

Also known as popliteal cysts, Baker's cysts are fluid-filled lesions that develop in the popliteal fossa, typically originating from the gastrocnemius-semimembranosus bursa. While common in adults, accounting for 5.0% to 41.0% of the population and often associated with degenerative joint conditions (eg, osteoarthritis, rheumatoid arthritis, meniscus tears, ligament injuries), these cysts are relatively rare in children, with an incidence of only 2.4%.[1-3] Unlike in adults, Baker's cysts in children are frequently a primary condition, arising from a herniated posterior knee joint capsule rather than being secondary to intra-articular pathologies.[3,4] Interestingly, research indicates that children who participate in sports are more likely to develop Baker's cysts, with one study reporting a prevalence rate of 60.7%.[2] This suggests that the repetitive stress placed on the knee during athletic activities may play a role in their formation.[5]

Despite their usual benign nature, Baker's cysts can cause significant discomfort and disability, particularly when they become large or rupture.[3,6] Ruptured Baker's cysts can mimic the clinical presentation of deep vein thrombosis.[7] Furthermore, a physical exam may not distinguish a Baker's cyst from other posterior knee masses, such as soft-tissue tumors, hematomas, or lipomas.[8] This potential for misdiagnosis underscores the importance of accurate and timely evaluation.

The treatment approach for Baker's cysts depends on the presence and severity of symptoms, as well as the underlying cause.[9] Conservative management is often the first line of treatment for asymptomatic or mildly symptomatic cysts.[2,3] This typically involves rest, activity modification, non-steroidal anti-inflammatory drugs (NSAIDs), and physical therapy focusing on strengthening the muscles surrounding the knee.[1,2] For patients with persistent pain or functional limitations, aspiration of the cyst fluid followed by corticosteroid injection into the joint or cyst may provide relief.[2,10] However, it is essential to address the underlying cause of Baker's cyst to minimize the risk of recurrence. Surgical intervention is generally reserved for cases refractory to conservative measures with the intent of addressing the underlying condition that caused the effusion leading to the Baker's cyst. Studies have shown favorable outcomes for both non-operative and operative treatments.[1-3,10] For example, intracystic corticosteroid injection with cyst fenestration has been found to be effective in conservative management, while arthroscopic treatment of associated intra-



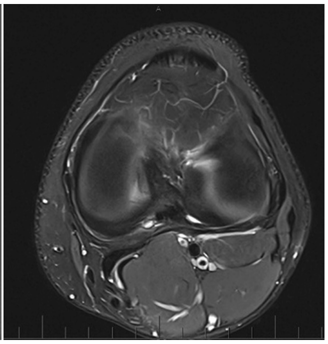


Figure 1. *Initial Baker's cyst observed on T2-weighted axial MRI scan - pre-aspiration.*

Figure 2. *Sagittal MRI images showing cyst and slight signal change in the posterior horn of the medial meniscus, but no discrete tear.*

Figure 3. *T2 coronal image through the posterior horn of the medial meniscus, demonstrating no discrete meniscus tear.*

Figure 4. *T2-weighted axial MRI following second cyst aspiration reveals synovial fold with resolved cyst.*

articular pathologies often leads to reduction or resolution of the cyst.[4,9,11] Despite positive results, it is important to note that recurrence rates can vary depending on the treatment approach and the continued presence of underlying conditions.

CASE REPORT

An athletic 16-year-old adolescent boy presented to the clinic with left knee pain that had been present for approximately one year. He described the pain as pinching and aching, with a pain scale rating of 7 out of 10, which is exacerbated by physical activity and prolonged sitting. The patient noted subjective knee instability with frequent episodes of knee buckling during football practice. His physical restrictions included sports activities, squatting, pivoting, and carrying heavy objects. He did not report any recent injuries or trauma. The patient was previously treated by a primary care provider who provided a steroid injection and naproxen; however, no diagnostic tests or studies were conducted. His medical history was negative for smoking, alcohol, and illicit drug use. On physical examination of the left knee, tenderness was noted along the posteromedial and medial joint lines, accompanied by a palpable, mobile soft-tissue mass in the popliteal fossa. There was no evidence of soft-tissue adhesions, warmth, or erythema. McMurray's test was positive. The patient demonstrated full strength (5/5) on the straight-leg raise. Vascular assessment revealed good circulation with normal capillary refill time.

X-rays revealed no fracture or malalignment. Magnetic resonance imaging (MRI) confirmed the diagnosis of a large Baker's cyst dissecting posteriorly into the soft tissue superficial to the medial gastrocnemius muscle, measuring approximately 3.4 centimeters x 2.3 centimeters x 4.8 centimeters, with a large effusion in the knee (Figure 1). Of note, there was no evident underlying meniscus tear, ligamentous injury, cartilage lesion, or other specific cause of the knee effusion (Figures 2 & 3).

A stepwise approach was taken, which included non-operative care such as physical therapy, a home exercise program, over-the-counter NSAIDs, ultrasound-guided aspiration, and a steroid injection. The Baker's cyst initially resolved following aspiration and steroid injection; however, it reappeared within two weeks in the posterior knee, accompanied by pain, instability, and intermittent swelling. The cyst was re-aspirated to provide symptomatic relief and subsequently resolved (Figure 4). Despite this, the patient developed another Baker's Cyst with more severe pain in the posterior knee, indicating the need for surgical intervention to rule out any intra-articular pathology. Arthroscopic evaluation revealed a longitudinal tear of the posterior horn of the medial meniscus (Figure 5). An all-inside meniscus repair was performed with microfracture of the notch to augment healing (Figure 6).

Two months postoperatively, the patient was able to perform physical activities with minimal limitations and regained 88.0% of the left knee strength and endurance compared to the contralateral knee. Six months postoperatively, he showed significant improvement in knee function and pain. Single assessment numeric evaluation score increased from 40/100 to 90/100, visual analog scale score decreased from 75/100 to 30/100, and knee injury and osteoarthritis outcome score for joint replacement indicated reduced stiffness

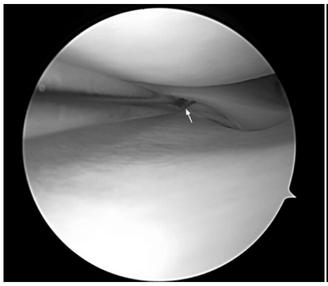


Figure 5. *Intraoperative arthroscopy revealing medial meniscus tear.*

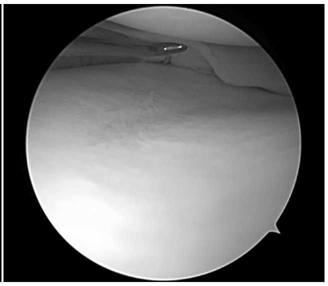


Figure 6. *Intraoperative image of arthroscopic meniscal repair.*

and symptom severity. Patient-reported outcome measures pediatric scores reflected stable mental health and improved quality of life. These findings suggest a successful recovery with better joint function, pain relief, and overall well-being.

DISCUSSION

This case highlights the challenges of diagnosing and managing recurrent pediatric Baker's cysts, particularly when initial imaging is unclear. Unlike adults, where cysts often result from degenerative issues, pediatric cases are often idiopathic.[3,4,12] While the exact mechanism remains unclear, it is possible that repetitive microtrauma from sports could lead to increased synovial fluid production, promoting cyst formation in children.[5] Furthermore, sports-related injuries, such as meniscal tears, can contribute to the development of Baker's cyst, as the increased fluid production associated with these injuries may lead to cyst formation.[12,13] This case emphasizes the importance of conducting a comprehensive evaluation for intra-articular pathology when initial imaging studies are inconclusive and symptoms persist despite conservative measures.

The patient's MRI did not reveal any overt meniscal tear, prompting an initial conservative management approach.[2] While MRI is a valuable diagnostic tool, its sensitivity in detecting subtle or small intra-articular pathologies, such as meniscal tears, can be limited.[1] This limitation highlights the need for clinical vigilance, a high index of suspicion, and consideration of further diagnostic modalities, such as arthroscopy, when symptoms persist despite normal imaging results.[14,15] The arthroscopic procedure ultimately identified a medial meniscus tear that had been missed on MRI, underscoring the importance of direct visualization in cases of diagnostic ambiguity.[14]

The presence of the meniscal tear likely led to chronic joint inflammation and increased synovial fluid production, which contributed to the formation and recurrence of the cyst.[3] Repairing the meniscal tear addressed the underlying cause of joint irritation, effectively halting the cycle of fluid accumulation and cyst formation.[3,12] Ultimately, early and targeted intervention can significantly improve outcomes and quality of life for pediatric patients with recurrent Baker's cysts, especially when conservative treatments fail and imaging findings are inconclusive.

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Treatment of Congenital Cruciate Ligament Absence in a Teenager Knee-Ding Stability

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ABSTRACT

The congenital absence of the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) is an extremely rare condition, with an estimated prevalence of 0.017 per 1,000 live births for ACL agenesis. The authors present the case of a 15-year-old adolescent girl with autosomal dominant multiple synostosis, who developed progressive bilateral knee pain and functional limitations. Bilateral knee x-rays revealed trochlear dysplasia and an absent tibial eminence, suggesting a congenital ligamentous abnormality. Magnetic resonance imaging confirmed the bilateral absence of both the ACL and PCL. Surgical reconstruction of both ligaments was performed, with the first procedure taking place in October 2024. Postoperatively, the patient followed a rehabilitation protocol in physical therapy. This case underscores the rarity of bilateral ACL and PCL agenesis and the importance of timely surgical intervention to alleviate symptoms and improve function.

Keywords: Anterior Cruciate Ligament; Congenital Abnormalities; Joint Instability; Posterior Cruciate Ligament

INTRODUCTION

Anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) agenesis are exceedingly rare congenital conditions characterized by the complete or partial absence of these essential stabilizing ligaments within the knee joint.[1] Congenital absence of the ACL, referred to as ACL agenesia, has an estimated prevalence of 0.017 per 1,000 live births.[2,3] The incidence of isolated PCL agenesis is poorly documented due to its rarity, but both congenital and traumatic PCL injuries occur at a rate of 1.8 per 100,000 individuals, often alongside ACL agenesis.[1,2,4]

Several genetic conditions have been linked with combined ACL and PCL agenesis, such as autosomal dominant multiple synostosis, Larsen Syndrome, Fibular Hemimelia, and Nail-Patella Syndrome.[5,6] Previous research has also indicated a genetically inherited autosomal dominant pattern that may account for agenesis of both the ACL and PCL, potentially linked to a copy number variation deletion in the CEP57L1 gene, which is expressed in ligament tissue.[7,8]

These ligaments, alongside the medial (MCL) and lateral (LCL) collateral ligaments, are integral to maintaining knee stability, proprioception, and proper biomechanics during dynamic activities.[8-10] Consequently, the congenital absence of the ACL can lead to substantial knee instability, joint malalignment, and an increased susceptibility to degenerative changes over time.[2,9,11] While some individuals can achieve high function despite PCL deficiency, biomechanical studies demonstrate that the PCL plays a critical role in knee stability, particularly in limiting posterior tibial translation and rotational laxity.[1,10] In cases of complete absence of both ligaments, the knee's ability to withstand rotational and anterior-posterior forces is substantially compromised, resulting in pronounced joint laxity, altered gait mechanics, and an increased risk of early osteoarthritic changes.[1,6,9,10] Although agenesis of these ligaments is typically an isolated defect, they may present with other congenital abnormalities affecting the knee, lower extremities, hips, and spine.[7] Diagnosis of ACL agenesis is typically confirmed via magnetic resonance imaging (MRI), which may also identify associated anomalies such as hypoplasia of the lateral femoral condyle, irregularities of the tibial intercondylar spines, absent or abnormal menisci, and patellar dislocation.[6,10-12]

CASE REPORT

A 15-year-old right-handed adolescent girl with a medical history of autosomal dominant multiple synostosis, anemia, anxiety, and migraines presented with bilateral knee pain. She reported a several-year history of discomfort that worsened with increased physical activity, describing the pain as a dull, continuous ache rated 7 out of 10 in severity. Accompanying symptoms included a sense of knee instability on uneven terrain. Pain was aggravated by physical activity, knee flexion and extension, cold temperatures, and prolonged sitting or standing. The patient experienced significant functional impairments, including difficulties with squatting, kneeling, pivoting, running, jumping, and cutting, but denied any episodes of patellar dislocation, instability, or prior knee trauma.

The patient exhibited tenderness along the medial and lateral joint lines of both knees, a posterior sag sign, and Lachman and posterior drawer tests showing grade III instability. Other tests, including the patellofemoral grind, patellar apprehension, McMurray's, and varus and valgus stress tests, were negative. She walked with a heel-to-toe gait and showed neutral knee alignment, with no knee effusion. Leg strength was 5/5, sensory examination was normal, skin was intact, and both legs had good perfusion and capillary refill.

Bilateral knee x-rays were performed, which revealed the presence of trochlear dysplasia, absence of a femoral notch, and absent tibial eminences, suggesting complete agenesis of the ACL and PCL (Figures 1A-1C). An MRI of both knees confirmed the diagnosis, demonstrating the complete absence of bilateral ACL and PCL, in addition to macerated medial meniscus (Figure 2A).

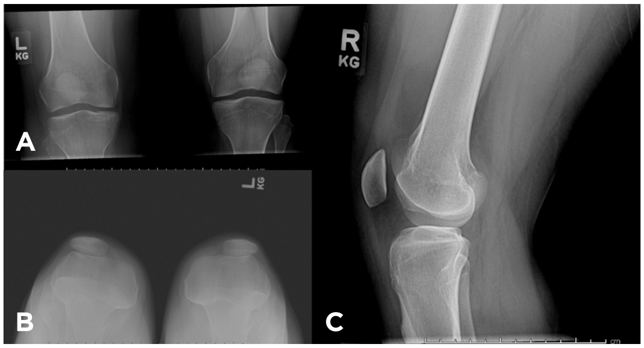

Figure 1. *A) Anteroposterior x-ray of bilateral knees; B) merchant x-ray of right knee; C) lateral x-ray of bilateral knees.*

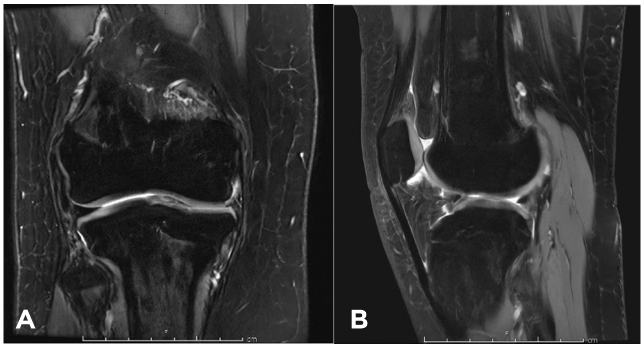

Figure 2. *A) T2-weighted Coronal MRI of right knee, demonstrating absence of ACL and PCL; B) T2-weighted Sagittal MRI of right knee, demonstrating absence of ACL and PCL.*

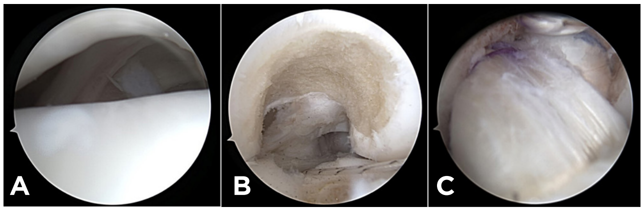

Figure 3. *A) Arthroscopic image demonstrating no intercondylar notch, no ACL, no PCL; B) arthroscopic image following notchplasty, meniscofemoral ligament visualized within the posterior notch; C) arthroscopic image demonstrating reconstructed ACL and PCL.*

The patient was diagnosed with congenital absence of the bilateral ACL and PCL. Due to the failure of conservative measures—including 12 physical therapy visits on two separate occasions over multiple years—and the severity of clinical symptoms and significant functional limitations, surgical reconstruction of the ACL and PCL was deemed necessary. The reconstruction procedure began with the right knee, as the first surgery was performed in October 2024 due to more pronounced symptoms and pain in that knee. The surgery consisted of arthroscopic exam notable for a macerated medial meniscus, preserved cartilage, complete absence of an intercondylar notch with hypoplastic tibial eminences, and complete absence of an ACL and PCL (Figure 2B). A notchplasty was performed to recreate an intercondylar notch, using the intact meniscofemoral ligament as a guide to determine the desired notch width (Figures 3A & 3B). ACL reconstruction was performed using an anterior tibialis allograft, and an all-inside PCL reconstruction was performed using a quadrupled hamstring allograft. The ACL and PCL were fixated on the femur and tibia with suspensory fixation (Figure 3C).

Postoperatively, the patient was advised to use crutches with 50.0% weight bearing and to gradually increase activities while wearing a knee brace. She began physical therapy afterward, with follow-up appointments at two weeks, six weeks, and three months. At her six-week appointment, the patient was walking with minimal assistance, reported major improvements in stability and knee pain, exhibited a range of motion from 0° to 80°, and showed stable results on the Lachman and posterior drawer tests.

DISCUSSION

Although isolated congenital absence of the ACL is more common, PCL absence typically occurs alongside ACL agenesis, underscoring the rarity of this condition.[2] Most cases of congenital absence of the cruciate ligaments also involve other knee abnormalities, such as hypoplasia of the lateral femoral condyle, tibial intercondylar spines, trochlear dysplasia, and either abnormal or absent menisci.[13-15] Additionally, these defects increase mechanical stress on the knee ligaments and are commonly found in skeletallyimmature patients, which raises the likelihood of ligamentous abnormalities.[1,16-18]

Treatment for this condition ranges from conservative treatment to surgical intervention.[14,19,20] Based on the literature review, there are only a few dozen reports of ACL agenesis worldwide, limiting research regarding the efficacy of surgical treatment of congenital absence of the ACL and PCL.[15,16,21] The few case reports found in the literature address the treatment of ACL agenesis, but not PCL.[1] The congenital absence of the cruciate ligaments is usually asymptomatic and is often managed conservatively, as the joint surface may adapt to compensate for the missing ligaments, allowing for an even distribution of forces.[22,23] However, after failure of conservative measures, including extensive physical therapy, surgical intervention is recommended to reconstruct ligaments and restore knee stability.[2,6] Despite treatment, most of these patients will likely progress to knee replacement later in life, secondary to resulting knee arthritis.[6,24] Manner et al[16] created a three-tier classification system for cruciate ligament dysplasia, which aids in diagnosing patients with cruciate agenesis.[2,3,13,15] In this case, the patient presents with a Type III classification. However, the classification system does not offer specific treatment guidelines for this level of dysplasia, highlighting the need for further research.[15]

CONCLUSION

This case of congenital ACL and PCL absence in an adolescent girl highlights the need for early diagnosis and intervention of rare ligament abnormalities. Although this condition affects knee stability, timely surgical reconstruction may provide better outcomes. Clinicians should consider ligament agenesis in cases of unexplained knee instability, particularly with congenital anomalies. Further research is needed to examine genetic factors and improve treatment and long-term outcomes.

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Scar Tissue Adhesions, Neuromuscular Guarding, and Functional Recovery: A Case Report of Physical Therapy Post-Cholecystectomy

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ABSTRACT

Scar tissue from abdominal surgeries, such as cholecystectomy, can lead to long-term issues such as restricted movement, painful spasms, and impaired function. Laparoscopic adhesiolysis is a common surgical treatment for pathological scar tissue impairments. Conservative care, such as physical therapy, is a commonly used approach for managing pathological scar tissue. In this case, manual therapy techniques and targeted exercises successfully reduced the intensity and frequency of abdominal spasms, improved core strength and endurance, and enhanced overall functional mobility. These improvements were reflected in enhanced scores on the Lower Extremity Functional Scale and the Vancouver Scar Scale in a 59-year-old woman who was referred to physical therapy following a cholecystectomy five years prior. This case demonstrates the effectiveness of a combined manual and exercise-based physical therapy approach in treating chronic scar tissue adhesions, muscle spasms, and functional limitations post-cholecystectomy, highlighting the importance of a comprehensive treatment plan for managing patients with similar conditions.

Keywords: Cholecystectomy; Manual Therapy; Muscular Spasms; Physical Therapy

INTRODUCTION

Adverse consequences of scar-tissue formation, including malformation and pathological adhesions, are risks associated with any surgical intervention and can result in long-term impairments that negatively impact quality of life.[1,2,3] This is particularly problematic after abdominal surgeries due to limited tissue extensibility around vital organs, leading to movement impairments and muscle spasms.[1] While scar tissue complications from abdominal surgeries are not commonly treated in outpatient physical therapy, manual therapy has been shown to significantly improve scar tissue mobility and increase the abdominal pain pressure threshold, making it a viable conservative treatment option.[2,4,5]

Abdominal surgeries, such as cholecystectomy,

may involve the removal of organ components (eg, gallbladder in cholecystectomy), leading to inflammation and subsequent scar tissue formation. Scar tissue formation is a physiological process that involves complex interactions between various cell types, growth factors, and extracellular matrix components. Excessive collagen deposition during this process can lead to the formation of dense, fibrous tissue that lacks the elasticity and functionality of normal tissue.[2] As scar tissue matures, it contracts due to myofibroblast activity and becomes denser through collagen remodeling. Its final structure is influenced by mechanical stress, with collagen fibers aligning along lines of tension, which can impact tissue flexibility and function.[3,6] Reduced tissue mobility may result in a constant state of protective guarding due to increased reactivity of the neuromuscular system, leading to more frequent spasms from quick-stretch contractions in non-contractile tissue.[7] Failure to adequately address these impairments can limit a patient's functional mobility, potentially affect organ function, and lead to chronic pain syndromes, all of which negatively impact quality of life.[3,8-11]

Therefore, incorporating manual therapy alongside targeted exercises is crucial for effective functional scar remodeling. While adhesiolysis, the surgical removal of scar adhesions, is often used to reduce scar complications, it carries the risk of recurrence and additional scar formation, with reported success rates as low as 46.0%.[3,5,12] Physical therapy offers a conservative option to address tissue mobility, musculoskeletal function, and proper collagen remodeling. Soft tissue mobilization (STM), including Instrument-Assisted Soft Tissue Mobilization (IASTM) and cupping, has been shown to effectively improve mobility and reduce symptoms associated with excessive scar tissue.[13-16] Additionally, movement-based treatments enhance tissue mobility, strength, and functional movement patterns, further supporting long-term healing and function.[17]

CASE REPORT

A 59-year-old woman presented to physical therapy five years after a cholecystectomy with persistent abdominal discomfort, painful spasms, and a significant decline in physical activity due to excessive scar tissue tension. She experienced spasms during movements involving the abdominal cavity, such as laughing, coughing, and sneezing, which limited her ability to participate in hobbies like gardening, kayaking, and walking her dogs. Her primary goals included exercising without pain or spasms and returning to kayaking, which had previously been a significant part of her recreational activities.

Examination revealed an observable and palpable adhesion around her 7-inch right-sided post-cholecystectomy scar. The Vancouver Scar Scale was utilized for a clinical scar assessment.[18] Abdominal musculature was palpably hypotonic in the affected region compared to the contralateral side (Table 1). The physical therapy assessment identified scar tissue adhesions and abdominal weaknesses as the primary factors limiting the patient's core stability and functional capacity.

Treatment addressed primary impairments including scar tissue adhesions, soft-tissue restrictions, and core weakness. Manual therapy treatment included IASTM, STM, and cupping for scar tissue mobilization to increase tissue extensibility, remodel adhesions, and improve mobility.[5,12-15] These techniques have been shown to decrease scar tissue and myofascial adhesions, stimulate connective tissue remodeling through fibroblast recruitment and collagen repair, and improve scar mobility by lifting and separating fascial layers.[16,19] Therapeutic exercises were used to enhance core strength, mobility, and functional capacity while supporting proper soft tissue alignment for effective scar tissue remodeling (Appendix 1).[15,17]

Patient education played a significant role in the treatment process. The patient was instructed to use coordinated and synchronized breathing techniques during functional movements. Additionally, she received instructions for home exercises and soft tissue mobilization, and actively engaged in self-management strategies to maintain progress beyond therapy sessions.

At discharge, the patient achieved all goals, with notable improvements both subjectively and objectively. She experienced spasms only rarely during quick movements, and they were minimal in intensity compared to her initial presentation. Previously difficult daily activities became more comfortable. While the patient had not yet attempted kayaking, she expressed confidence that she would be able to resume this activity without difficulty. At discharge, she felt equipped with the tools and strategies needed to maintain her gains at home and continue progressing with her home exercise program (HEP). She mentioned that she was confident in her ability to return to all of her desired physical activities.

The patient's scar tissue showed considerable improvement, with diminished pain during palpation and pressure. This was supported by the observable improvement in her functional mobility. While she did not meet the minimal clinically important difference (MCID) for the Lower Extremity Functional Scale (LEFS), a self-reported questionnaire used to assess

Table 1. *Objective Findings Before and After Treatment*

Objective Measure	Initial Evaluation	Discharge
Lumbar lateral flexion ROM	R: 16cm*; L: 14cm*	R: 21cm; L: 21cm
Hip extension MMT	R: 4-; L: 4+	R: 4+; L: 4+
Hip abduction MMT	R: 4+; L: 4-	R: 4+; L: 4
Hip internal rotation MMT	R: 4+; L: 4-	R: 4+; L: 4+
Hip external rotation MMT	R: 4+; L: 4-	R: 4+; L: 4+
DLLT hold at 15° flexion	28 seconds	34 seconds
LEFS	70	74
Single-leg stance time	R: 4 seconds; L: 4 seconds	R: 30 seconds; L: 30 seconds
Vancouver Scar Scale	4	1

*R = Right; L = Left; ROM = Range of Motion; * = Symptom Provocation; MMT = Manual Muscle Test; DLLT = Double Leg Lowering Test; LEFS = Lower Extremity Functional Scale* functional ability in performing everyday tasks related to the lower extremities, there was a notable positive change in this measure.[20] Her progress in functional goals, along with subjective reports, indicates meaningful improvement achieved through physical therapy treatment. The limited objective improvement in LEFS score is due to the patient reporting a lack of intention to run or hop, activities accounting for 20.0% of the total LEFS score.[20]

The patient made considerable progress toward her goals and is expected to continue improving with ongoing adherence to her HEP. She was also encouraged to gradually reintroduce functional activities, such as kayaking, once she feels ready, while monitoring for any recurrence of spasms. At discharge, the patient expressed satisfaction with her progress and felt well-prepared to independently manage her condition moving forward.

DISCUSSION

This case highlights the effectiveness of a combined manual and exercise-based physical therapy approach in addressing chronic scar tissue adhesions, muscle spasms, and functional limitations in a patient following a cholecystectomy. Physical therapy interventions targeting scar tissue mobilization and core stabilization were effective in improving her functional capacity and reducing symptoms. By integrating manual therapy for scar tissue mobilization with core stabilization and functional exercises, the patient experienced considerable improvements in mobility, strength, and function, leading to improvement in her overall quality of life. The positive outcomes emphasize the importance of a comprehensive, patient-centered approach to post-surgical rehabilitation and highlight the value of physical therapy as a non-invasive, effective intervention for managing complications associated with scar tissue dysfunction.

The interventions work synergistically to enhance flexibility, restore normal movement patterns, and promote collagen remodeling, all while decreasing the protective reactivity of the neuromuscular system, a vital component of overall functional improvement.[8,21] Compared to surgical intervention, conservative care is a viable, non-invasive, and cost-effective option with fewer potential adverse consequences.

The patient's adherence to a HEP, coupled with family support in performing scar tissue mobilization at home, played a crucial role in her progress and confidence in continuing maintenance after discharge from physical therapy. This highlights the importance of patient education and self-management strategies in achieving sustained success in rehabilitation.[22] The positive outcomes in this case emphasize the value of physical therapy as a non-invasive, effective intervention for managing complications associated with scar tissue dysfunction. However, it is important to note that the treatment approach may need to be tailored for different surgical sites or patient populations. Future research could explore the efficacy of this combined manual and exercise therapy approach in a larger cohort of patients with various post-surgical scar tissue complications. Additionally, while this case demonstrated success in treating long-standing scar tissue issues, earlier intervention may potentially lead to even better outcomes. Future studies should investigate the optimal timing for initiating physical therapy interventions after surgery to prevent or minimize scar tissue complications.

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Appendix 1. *Therapeutic Interventions*

Visit Number	Treatment
Visit 1 (Initial Evaluation)	• Patient (Pt) education/discussion of current condition and anatomy, course of treatment and plan of care; HEP discussion* • Scar tissue mobilization (using myofascial induction therapy) with Pt education of mechanism, treatment, techniques, and post-treatment expectations • Transverus Abdominus (TrA) education and execution with demo-back • Partial oblique curl-up with TrA, 2 x 15 each side • Static resistance band resisted core twist and return, with neutral spine and deep core-stabilization, resistance band stabilized at door and held out by arms at xiphoid process height, TrA 2 x 15 each side
Visit 2	• Warm up: Elliptical Level (L) 1 x 10 minutes • Open books 10 reps x 10 seconds, each side • Thread the needle 10 reps x 10 seconds, each side • Scar tissue mobilization/myofascial release, cupping ("moving cupping")
Visit 3	• Warm up: Elliptical L1 x 10 minutes • Open books 10 reps x 10 seconds, each side • Thread the needle 10 reps x 10 seconds, each side • Scar tissue mobilization/IASTM scraping.
Visit 4	• Warm up: Elliptical L2 x 10 minutes • IASTM and STM at abdominal to thoracic scarring • Open books 10 x 10 seconds, each side • Seated lateral trunk stretch 10 x 10 seconds, each side
Visit 5	• Warm up: Elliptical L3-4 x 10 minutes • STM and scar tissue mobilization to R lower abdominal quadrant and into R lower rib (some mobilization under R lower rib for access to diaphragm and scar tissue surrounding gallbladder area), including lumbar musculature • Sacral lateral rocking for improved mobility with limited mobility findings during joint play testing. • Thread the needle 10 x 10 seconds, each side • Open books 10 x 10 seconds, each side • Oblique curl up 2 x 15, each side. • Core twist with RTB 2 x 15, each side
Visit 6	• Warm up: Elliptical L4 x 10 minutes • Bilateral sacral rocking grade III - IV; STM at anterior scar tissue utilizing myofascial induction therapy • Seated hamstring stretch, 10 x 10 second holds each.
Visit 7	• Warm up: Treadmill (TM) L3 incline and 3.4 speed x 10 minutes; focus on core engagement and long stride length • STM x 4 minutes each area of scar tissue (x 12 minutes total); cupping x 5 minutes using "moving cupping technique" to R abdominal quadrants for scar tissue adhesions and relief • Standing Lat stretch 5 reps x 10 second holds • D1/D2 flexion and extension motions using core anti-rotation 2 x 10, each side
Visit 8	• Warm up: TM L3 incline and 3.4 speed x 13 minutes; focus on core engagement and long stride length • STM x 4 minutes each area of scar tissue (x 12 minutes total); cupping x 5 minutes to R abdominal quadrants for scar tissue adhesions and relief • D1/D2 flexion and extension motions using core rotation 2 x10, each side • RTB resisted arm extension in standing for improved core control 1 x 10
Visit 9	• Warm up: Elliptical L3 x 13 minutes; focus on core engagement and long stride length • IASTM followed by cupping (using a suction then glide over skin technique) to R abdominal quadrants for scar tissue adhesions, soft tissue restrictions, and soft tissue remodeling • Prone press up 5 reps x 10 second holds, each • LTR's x 2 minutes • Open books 2 x 10, each side • Front plank 3 x 30 second holds
Visit 10	• Warm up: TM 3.5 mph, incline 3 for 14 min • Prone press-up 5-10 reps x 10 second holds, each • Pulley system pushes and pulls of 10 lb. x 10, each • Single-arm rows with black TheraBand resistance, x 10, each • Discharge measurements taken

**All exercises performed were continued as HEP, to be performed daily, except on treatment days.*

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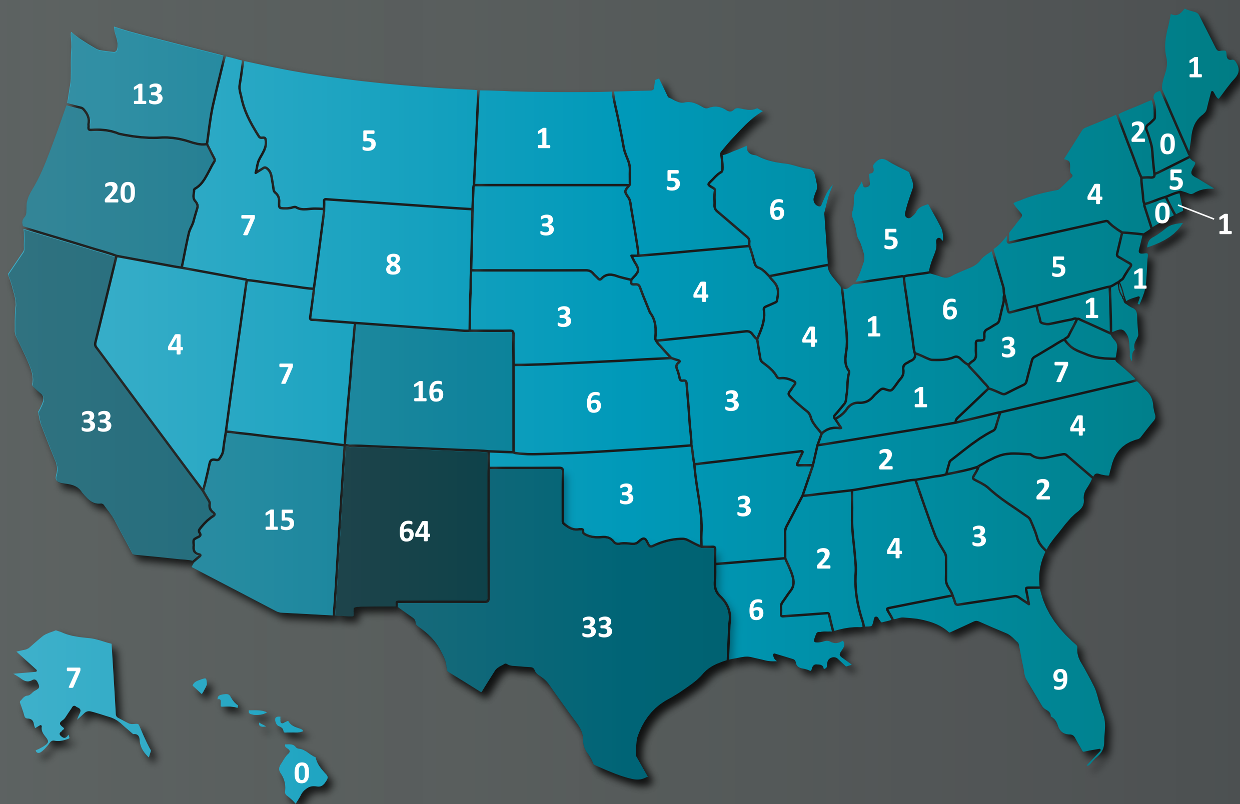

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*Deceased