Temple University
Journal of Orthopaedic Surgery & Sports Medicine

Michael Clancy, MD

Volume 12 Spring 2017

A John Lachman Society Publication

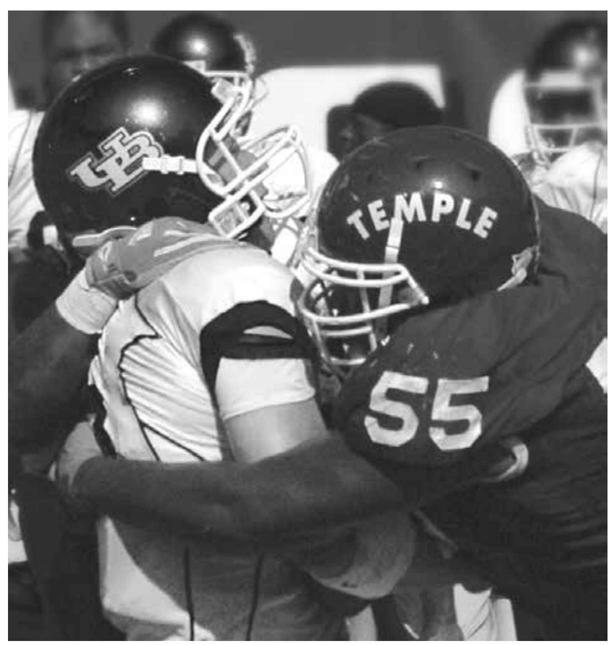

GET 'EM BACK IN THE GAME.
TORNIER
SIMPLICITI™
Shoulder Arthroplasty for Young, Active Patients
» Canal-sparing design preserves bone
» Early intervention opportunity
» Reduces blood loss, OR time and exposure to anesthesia[1]
Learn more at tornieror.com or vumedi.com
888 494 7950
1. Alexander Berth, Géza Pap (2012) Stemless shoulder prosthesis versus conventional anatomic shoulder prosthesis in patients with osteoarthritis. J Orthopaed Traumatol 14:31-37
WRIGHT
FOCUSED EXCELLENCE
Tornier Upper Extremities

The Temple University Concussion and Athletic Neurotrauma Program

Cerebral concussion, traumatic brain injury, transient spinal cord paralysis and brachial plexus injuries are potentially serious insults to the nervous system that are associated with contact athletic injuries. In accord with the principle that the management and return-to-play decisions should only be made by a qualified professional, Temple University has established its **Concussion and Athletic Neurotrauma Program.**

Temple's experienced, multidisciplinary faculty is well-suited to evaluate and manage athletic-induced neurotrauma, utilizing the latest imaging capabilities, neurocognitive **ImPACT™** testing and clinically established **return-to-play** protocols.

Utilizing the facilities of Temple University Hospital, Temple Orthopaedics & Sports Medicine satellite offices, Temple Medical School faculty and in concert with the Shriners Hospitals for Children in Philadelphia, this program is designed to provide the necessary experience to meet the needs of team and family physicians, athletic trainers, athletic administrators, coaches, parents and, most importantly — the athletes.



Proper tackling technique protects both head and cervical spine.

Research Goals

Current understanding of cerebral concussion and athletic-induced traumatic brain injury is limited to a variety of descriptive classifications and epidemiologic patterns. Lacking is an application of the known underlying pathophysiology to clinical management practice with particular regard to injury prevention. Clearly, much is not known and there are many questions to be answered regarding athletically-induced neurotrauma. The goal of this program is to bring this issue to the same meaningful conclusion that Temple physicians achieved with paralytic spinal cord injuries 35 years ago.

Temple University Hospital

Clinical Program

Athletes sustaining impact injuries and experiencing any of the following signs or symptoms should be evaluated and, if indicated, managed by a physician experienced with athletic injuries to the head, spine and brachial plexus:

Central Nervous System

- Loss of consciousness
- Confusion
- Dazed appearance
- Forgetfulness
- Unsteady movements
- Slow cognition
- Personality changes
- Retrograde/antegrade amnesia
- Headache
- Dizziness
- Nausea or vomiting
- Altered sense of well-being

Spinal Cord

- Four extremity paresthesias (numbness)
- Four extremity weakness
- Four extremity transient paralysis

Brachial Plexus

- "Stinger" lasting more than 20 minutes
- "Stinger" with persistent weakness
- Recurrent "stingers"

The neurotrauma team consists of orthopaedic sports medicine specialists, neurologists, neurosurgeons, neurophysiologists, physiatrists and biostatisticians.

ATHLETES REQUIRING EVALUATION AND/OR MANAGEMENT CAN BE SEEN AT FOUR OF TEMPLE'S CLINICAL SITES:

Temple University Hospital

3509 N. Broad Street
5th Floor Boyer Pavilion
Philadelphia, PA 19140
215-707-2111

Cory J. Keller, DO
Michelle A. Noreski, DO

Temple Orthopaedics & Sports Medicine Satellite Offices

515 Pennsylvania Avenue
Fort Washington, PA 19034
215-641-0700

11000 Roosevelt Blvd.
Philadelphia, PA 19116
215-698-5400

450 Corporate Ctr.
Oaks, PA 19456
610-650-5155

E-mail us at: concussion@tuhs.temple.edu
Website: www.templeconcussion.com

Temple Orthopaedics & Sports Medicine

Table of Contents

Temple University Journal of Orthopaedic Surgery & Sports Medicine

How to Reach Us

Temple University Hospital
Department of Orthopaedics, 6th Floor Outpatient Building
Philadelphia, PA 19140
Telephone: (215) 707-3411
Fax: (215) 707-7976

Letter from the Chairman

"To improve is to change; to be perfect is to change often." — Winston Churchill

2016–17 marks a year of great change. As we swear in new leadership in Washington, it seems that changes in healthcare could be profound and rapid. How exactly these changes will be operationalized and what it will mean for our patients has not yet been defined.

At Temple Orthopaedics and Sports Medicine (TOSM) we watch closely as these changes will undoubtedly impact the lives of our patients and how we deliver healthcare. 2017 marks the 125th anniversary of the establishment of Temple University Hospital. On January 18, 1892, a three-story home at 3403 North Broad Street was purchased and re-named Samaritan Hospital. Dr. Russell Conwell was named president of the 20-bed hospital, which was designed to provide free care for those unable to afford payment, regardless of race, nationality or creed. Over the past 125 years, TUH has grown into a 722-bed teaching hospital that supports 17 residency and 17 fellowship programs.

Our department has grown along a similar timeframe to meet the needs of our community. TOSM provides orthopaedic care for an increasingly diverse spectrum of Philadelphians from all walks of life and socioeconomic status. We continue to move forward with our mission and objectives of providing the highest-quality care for all of our patients and educating the next generation of orthopaedic surgeons.

To meet these objectives, we continue to grow and diversify our department. In the fall of 2016, we completed the largest single one-year recruitment in the history of our program. Five highly-talented physicians joined our team: Dr. Hesham Abdelfattah (hand and upper extremity), Dr. Eric Gokcen (foot and ankle surgery), Dr. Min Lu (joint reconstruction), Dr. Zeeshan Sardar (spine surgery) and Dr. Ryan Schreiter (primary care sports medicine). Coupled with steady expansion the year prior, the Department of Orthopaedic Surgery and Sports Medicine has now grown to 20 providers (14 surgeons, four non-surgical providers, and two physician assistants) representing all specialties. With size comes opportunity and flexibility. We are a more nimble department capable of developing partnerships outside of Temple University Hospital to expand the reach of our clinical programs and provide patient experiences similar to and ideally superior to our peers in the city. We have secured our position as the sole orthopaedic providers at Chestnut Hill Hospital providing an environment for positive patient experiences in both outpatient and inpatient elective surgery. The Temple Sports Medicine presence at the Navy Yard is steadily growing. At the same time, we are seeing more and more patients every day at our stronghold locations — Temple Hospital, Northeast Philadelphia and Fort Washington. At each of these locations, we now have complete teams so that patients cannot only be seen closer to home, they can see the right and best specialist for their condition close to home. The growth is not just geographic. Expanded service lines have developed through the dedication of our physicians and teams in key areas such as shoulder arthroplasty, hip and knee arthroplasty options for young active patients, and comprehensive (surgical and non-surgical) sports medicine.

As our clinical enterprise expands, so do the opportunities for our learners. 2016–17 was a time transition and I must give the credit and thanks to our physician educators and residents alike for their willingness to adapt to constant change. It took creativity to ensure that all of our residents had comparable educational experiences as the physician teams changed so rapidly. I believe we are now headed into a "steady state" and our residents will have the opportunity to flourish in any field they should choose to pursue for fellowship training.

Our faculty and residents have had a year of great accomplishment. All should be commended for their efforts but I would like to highlight a few in particular. First, F. Todd Wetzel, MD (Professor and Vice Chair, Department of Orthopaedic Surgery) is currently serving as the president of the North American Spine Society. NASS is a global multidisciplinary medical society of 9,000+ members that utilizes education, research and advocacy to foster the highest quality, ethical, value- and evidence-based spine care. Joseph Thoder, MD (Professor and Chief of Hand Surgery) will be honored in May 2017 for his long-term dedication to education with a portrait ceremony and the first inaugural Joseph Thoder hand lecture. It is only fitting that the first lecturer in this yearly series will be recent alumnus, John Fowler, MD (Assistant Professor, University of Pittsburgh). This event and portrait ceremony were commissioned through the efforts of the Temple Orthopaedic Alumni Foundation. Saqib Rehman, MD was also named medical director of the recently established physician assistant program at TUSOM.

Happenings at TOSM have attracted regional and national attention. We capitalized on this attention by inviting several renowned speakers in the 2016–17. Most notably was a visit from the internationally-respected Freddie H. Fu who shared his decades of experience and thoughts on “Individualized ACL Surgery.” Bradford Parsons (Associate Professor, Shoulder and Elbow Surgery) visited from Mount Sinai to discuss “Operative Options for Proximal Humerus Fractures.” The academic year will wrap up with a visit from Robin V. West, MD, Director of Sports Medicine at Inova Health. Dr. West is the only female head team physician for either a MLB or NFL team, holding the position for both the Washington Nationals and Redskins.

As always, this journal could not be made possible without the efforts of many. Arianna Trionfo (PGY5) has outdone herself in term two as editor of the *Journal.* Drs. Joe Torg and Saqib Rehman continue to be the driving force behind this work. We must also acknowledge the tireless efforts of Joanne Donnelly and the Office of Clinical Research.

It is with great pride that we present the academic accomplishments of our department faculty, residents and students. Our residents are active academically. At the AAOS 2017 Annual meeting, we shared two scientific exhibits, three podium presentations and two original posters. The 12th edition of the *Temple University Journal of Orthopaedic Surgery & Sports Medicine* highlights these and other works from our department. I hope that you enjoy reading through this journal with the same sense of pride and accomplishment for Temple Orthopaedics and Sports Medicine.

Eric J. Kropf, MD
Associate Professor and Chair
Temple Orthopaedics and Sports Medicine

Letter from the Editor-in-Chief

I am proud to present the *Temple University Journal of Orthopaedic Surgery & Sports Medicine,* Volume 12! In keeping with the Temple tradition, this year's Journal represents the tireless efforts and burgeoning achievements of our medical students, residents, faculty, and alumni.

The Department has seen numerous changes over the past year, many of which are chronicled in this edition of the Journal. We continue to include articles published by our medical students, residents and faculty that encompass a broad spectrum of orthopaedic-related topics. Our Distinguished Alumni section highlights some of the early work of Dr. F. Todd Wetzel, President of the North American Spine Society, which helped change the face of orthopaedic spine surgery. Our Special Events section gives our readers a basic overview of the major events that have taken place this year. One new addition: we have incorporated Division Reports to highlight some of the significant changes and accomplishments of our department's subspecialties.

"If I have seen further, it is by standing on the shoulders of giants." While change is inevitable, one thing remains constant: The Temple tradition of clinical and academic excellence that was instilled by our predecessors. In particular, this volume of the Journal is dedicated to one of those people — Dr. Michael Clancy, whose leadership and unwavering dedication to the field of Orthopaedics has left an indelible impression. Though I never met Dr. Clancy, the overwhelming volume of praise and stories that his friends and colleagues continue to share make me feel like I knew him, too. His life and work benefitted not only his patients but everyone he touched. This volume of the Journal proudly honors this great man.

I would like to thank my associate editors, Will Smith, Justin Kistler, and Dayna Phillips, our faculty advisors, Joe Torg and Saqib Rehman, and our research coordinator, Joanne Donnelly — your support and guidance have been invaluable.

Arianna Trionfo, MD
Editor-in-Chief
Class of 2017

Letter from the Residency Director

This past year has been a busy one for the Orthopaedic residency at Temple. We have continued our growth in the faculty, which has provided a good increase in the variety and quality of the educational experience for the residents. On the clinical side, as it has been over the last several years, the residents cover Hand, Joint Reconstruction, Sports Medicine, Spine, Foot and Ankle, and Trauma at Temple University Hospital. They also treat children at St. Christopher's Hospital for Children and Shriners Hospital for Children. Jeanes Hospital and Abington Memorial Hospital remain popular community hospital experiences. The residents' case volume remains high at each of these institutions. Educational activities remain anchored by the daily morning conference and reading schedule as well as regular subspecialty conferences.

Orthopaedic Surgery continues to be a popular and very competitive residency choice among graduating medical students. Last year, we had over 850 applicants for the four residency slots at Temple, with the average USMLE score well above 240. We invited 120 candidates from across the country to interview in January. We continue to have the good fortune to match strong, well-rounded, diverse residency classes from this impressive pool. When they finish, Temple residents have consistently gone to some of the most competitive fellowships in the country. Our 2017 graduates will go on to do fellowships in Pediatric Orthopaedics at Children's Hospital of Philadelphia and Texas Scottish Rite Hospital, Hand Surgery at NYU, and Foot and Ankle Surgery at Duke, all continuing our proud tradition of producing clinically excellent and technically-skilled surgeons.

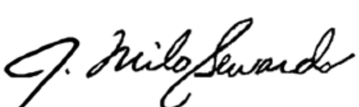
Dustin Greenhill will be leaving North Broad Street for Dallas, where he will continue his streak of obstacle course races, trying to convince his colleagues at the Texas Scottish Rite Hospital to join him in crushing the Tough Mudder, Spartan Race, Battlefrog, etc. They will quickly see that he enjoys using the races to relive his Army days and show off his gymnastic skills as he does a pommel horse routine on the top of each obstacle.

Jim Lachman heads to Tobacco Road, where he will be angling to get out on the Duke golf course between cases while turning up his nose at the craft beers of the Research Triangle. He will happily accept charitable contributions of Duke-UNC tickets, for either basketball or football.

Anastassia Newbury is heading up the New Jersey Turnpike to New York to set up shop at NYU. This move represents the completion of her transition from being a midwestern Nebraska girl, through Philadelphia, to the bright lights and big city life in Manhattan. We all look forward to pictures of Charlie going for walks through Central Park.

Finally, Arianna Trionfo decided that she wasn't going anywhere. She has been completely enamored with Philadelphia since coming off the farm in South Jersey. She will be spending next year at CHOP contemplating the pediatric hip. Apparently, she has offered to continue as editor of this journal since she has put in such strong work doing so over the last few years.

On a personal note, this class represents my own tenure at Temple, as Dustin and Jim were first-year Temple medical students when I returned from my time in the Navy. While each class has its own unique character that I miss once they graduate, this class holds a special place for me. I wish them all well, and assure the readers of this journal that the state of the Temple University Orthopaedic Surgery Residency is indeed very strong.



J. Milo Sewards, MD

Message from the John Lachman Society

The John Lachman Society was founded in 2001 to honor Dr. Lachman and propagate his principles of integrity, teaching, and excellent patient care. The Society also provides discretionary funds for the Chairman to promote and support the academic mission of the Department including student and resident research. The mechanism to accomplish these goals is through the Society's support of the John Lachman Orthopaedic Research Fund (JLORF), incorporated in Pennsylvania as a non-profit corporation. The Internal Revenue Service has determined that the John Lachman Orthopaedic Research Fund is exempt from federal income tax under 501 (C) (3) of the Internal Revenue Code and that contributions to the fund are tax deductible.

It appears appropriate to identify those other potential exogenous sources of support for Temple medical student and Temple hospital orthopaedic resident educational support. These can be divided into two groups: 1) dormant and active academic funds and 2) those supporting primarily non-academic activities. The first group, best described as "dormant," consists of the orthopaedic-endowed chairs in the L.I.F.T. program, which are not funded and exist in name only, i.e., the Steel chair and the Lachman chair. This program was initiated by the Temple-Shriners' alumni group and is predicated on life insurance policies of the contributing members but is controlled by Temple University. It is my understanding that a "new" insurance company that services the policies has submitted bills to keep them active and that the University is considering "cashing" them in.

Funds in the "active" group are: the Medical Orthopaedic Attending Research and Education Fund, the Orthopaedic Residents' Education Fund and the Abraham M. Rechtman Endowed Orthopaedic Research Fund. To my knowledge, these three funds have contributed to, or are currently contributing to, medical student and/or resident research projects or educational programs.

The second group, consisting of the Temple-Shriners' Alumni and the Thoder Portrait and lecture activity, are beyond my determination re tax exempt status. However, I would suggest that contributions for dinners, golf outings, paintings and poorly-attended country club "scientific meetings" are questionable regarding tax exempt status. I would emphasize, however, such activities are important and should be supported, but I would further suggest that their tax exempt status be clarified. It is the John Lachman Orthopaedic Research Fund of the John Lachman Society that since its founding in 2001 has represented a dedicated 501 (C) (3) tax exempt organization actively supporting both Temple medical student and Temple University Hospital orthopaedic resident education and research. These activities include the following:

1) Seed monies for resident research projects.
2) Funds resident expenses for paper/poster presentations at accredited meetings.
3) Funds resident attendance at accredited scientific meetings.
4) Funds award $$$ at annual residents' research day presentations.
5) Funds the *Temple University Journal of Orthopaedic Surgery & Sports Medicine.*
6) Funds the medical student summer research program.
7) Supplements the alumni society commitment shortfall to send residents to board review course.
8) The JLORF paid $3,700.00 for a resident to travel to Berlin to attend a meeting presenting a Shriners' paper because they didn't have the funds.

Those interested in membership in the John Lachman Society should contact the Chairman of the Membership Committee, Milo Sewards, MD, c/o The John Lachman Society, P.O. Box 7283, Wayne, PA 19087.

JOHN LACHMAN SOCIETY MEMBERSHIP — JANUARY 1, 2017

Irfan Ahmed, MD
Philip Alburger, MD
Mohammed-Tarek Al-Fahl, MD
Henry Backe, Jr., MD
Stephen Bair, ATC
Easwaran Balasubramanian, MD
Johnny C. Benjamin, Jr., MD
Donald L. Bishop, MD
Richard Boal, MD
Barry Boden, MD
Christopher Born, MD
Mark Brigham, MD
Jim Bumgardner, MD
Thomas Burke, Jr., MD
Patrick Carey, MD
John Casey, Jr., MD
Steven Casey, MD
Michael Cavanaugh, MD
Eugene Chiavacci, MD
Michael Clancy, MD*
David Clements, MD
Charles Cole, Jr., MD
Andrew Collier, Jr., MD
William Cox, MD
Katharine Criner, MD
Leonard D'Addesi, MD
Ellen DeGroof, MD
Steven Dellose, MD
William DeLong, MD
Alexandra B. deMoura, MD
Douglas Ditmars, MD
Ian C. Duncan, MD
Jorge Fabregas, MD
Kevin Flynn, MS
Kristine Fortuna, MD
Brian George, MD
John Gottlieb, MD
Stephen Heacox, MD
Victor Wei Teh Hsu, MD
James Hurley, MD
Asif Ilyas, MD
David Junkin, MD
David M. Junkin, Jr., MD
Michael Kalson, MD
Robert Kaufman, MD
John Kelly, IV, MD
Andrew Kim, MD
John Kim, MD
Matthew Kleiner, MD
E. James Kohl, MD*
John Kolmer, Jr.
Kevin Kolmer
Moody Kwok, MD
Mathew Landfried, MD
Michael Larkin, MD
Eric B. Lebby, MD
John Lehman, MD
Frederic Liss, MD
Glenn S. Lieberman, MD
Stephen Longenecker, MD
Robert Lykens, MD
Christopher Lyons, MD
Robert Lyons, MD
John Magill, III, MD
Christopher Mancuso, MD
John Manta, MD
Robert Maurer, MD
Owen McIvor, MD
James McLamb, MD
Pekka Mooar, MD
Carlos Moreyra, MD
Ray Moyer, MD
John Murphy, MD
Stephen Orlevitch, MD
Charles Parsons, MD*
Manish Patel, MD
Kenneth Peacock, MD
John Pell, MD
Glenn Perry, MD
Mary Quedenfeld
Chandra Reddy, MD
W. Gale Reish, MD
Edward Resnick, MD*
Robert Richards, Jr., MD
John Richmond, MD
Jack Rocco, MD
James Rogers, ATC
Michael Romash, MD
Jeff Ryan, ATC
Anthony Saker, MD
Anthony Salem, MD
Richard Sandrow, MD
Samuel Santengelo, MD*
Richard Savino, MD
H. William Schaff, MD
Joseph Scornavacchi, MD
J. Milo Sewards, MD
Patrick Sewards, MD
James Shacklett
Gene Shaffer, MD
K. Donald Shelburne, MD
Abraham Shurland, MD
Michael Sitler, PhD
Gary Smith, MD
Gbolabo Sokunbi, MD
Charles Springer, MD
John Stelmach, MD
Edward J. Stolarski, MD
Zigmund Strzelecki, MD
Robert Sutherland, MD
Jay Talsania, MD
Allen Tham, MD
Joseph Thoder, MD
Joseph Torg, MD
Joseph Trubia, MD
Warren T. Vance, MD
Bruce Vanett, MD
John Van Orden, MD
John B. Webber, MD
Paul Weidner, MD
Albert Weiss, MD
F. Todd Wetzel, MD
Gerald Williams, MD
John Wolf, MD
Steven Wolf, MD
Thomas Yucha, MD

*Deceased

Respectively Submitted,
Joe Torg, MD

Letter from the Office of Clinical Trials

The Office of Clinical Trials and Research Support has been going strong since 2004 when it was established under the direction of Pekka A. Mooar, MD and Joseph S. Torg, MD and supported by the School of Medicine's Office of Clinical Research Administration, with Ms. Joanne Donnelly as the full-time research and program coordinator.

The program is now in its 13th year and continues to fulfill the vision of providing the Department of Orthopaedics and Sports Medicine with industry-sponsored clinical trials, resident-initiated research and the eight-week summer research program geared toward those Temple medical students with an interest in orthopaedics. Funding for the program is provided through the federal work-study program and supplemented by the department. The summer research program will host 17 Temple medical students in 2017. The eight-week program involves teaching the students the fundamentals of clinical research via a research topic selected by our orthopaedic surgeons and culminates in generating a finished manuscript. There is an orientation by Dr. Susan Fisher, Department of Clinical Sciences Professor and Chair on the "Nuts and Bolts of Statistics for Clinical Research." Lauri Fennell, Temple Reference and Emerging Technologies Librarian, provides the students with basic and advanced research searching options through PubMed and Ovid and other search engines, as well as RefWorks for managing citations. Chad Pettengill, from the Temple Institutional Review Board, will speak to the students regarding the guidelines pertaining to clinical research. I am looking forward to another exciting and fruitful year with the students.

Current Industry-Sponsored Clinical Trials Drug or Device

Department of Defense
Assessment of Severe Extremity Wound Bioburden at the Time of Definitive Wound Closure or Coverage: Correlation with Subsequent Post-Closure Wound Infection (Bioburden Study)
Saqib Rehman, MD, Principal Investigator; Christopher Haydel, MD, Sub-Investigator.
Prospective cohort observational study. Closed to enrollment, in data collection phase — 4 subjects enrolled.

AESCULAP
A Phase 3, Prospective, Randomized, Partially Blinded Multi-Center Study to Measure the Safety and Efficacy of Novocart® 3D, Compared to Microfracture in the Treatment of Articular Cartilage Defects
J. Milo Sewards, MD, Principal Investigator; Pekka A. Mooar, Sub-Investigator;
Eric Kropf, MD, Sub-Investigator. Open to enrollment — 6 subjects enrolled.

Department of Defense
Local Antibiotic Therapy to Reduce Infection After Operative Treatment of Fractures at High Risk of Infection: A Multi-Center, Randomized, Controlled Trial — VANCO Study
Saqib Rehman, MD, Principal Investigator; Christopher Haydel, MD, Sub-Investigator.
Open to enrollment — 3 subjects enrolled.

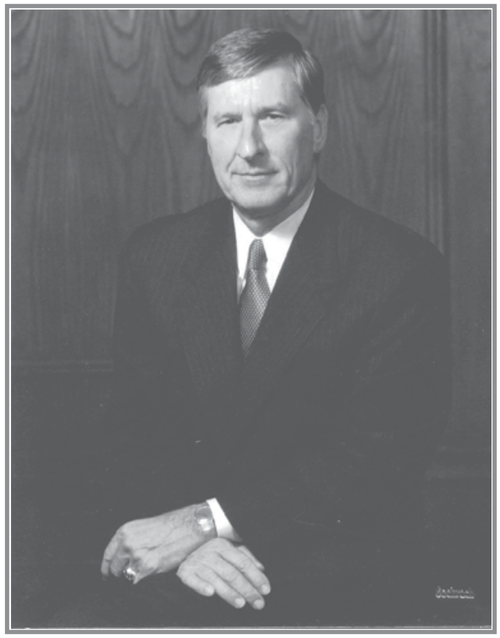
REGAIN
Regional vs General Anesthesia for Promoting Independence After Hip Fracture Surgery (Large Multi-Center Study)
Meera Gonzalez, MD, Principal Investigator, Anesthesia; Christopher Haydel, MD, Sub-Investigator, Orthopaedics. Open to enrollment — 11 subjects enrolled to date.

Joanne M. Donnelly

Dedication

Michael Clancy, MD

Johnny Benjamin, MD



Dr. Moyer trained and practiced with Dr. Clancy. Lou Sutherland was his junior resident. They both have perspectives of the man that I never knew. Dr. Clancy was someone much different to me.

He's the boss.

He's the Chief.

I still find it almost impossible to speak of him in the past tense because for the last 25 years, he has been such a constant presence in my life. I made no major decision, personal or professional, without seeking his guidance.

We've all heard the famous quote, "Give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime." As I stand here before you, I face the tremendous task of *adequately* and *properly* honoring the man who gave me the opportunity and resources that changed my life. He made it possible for me to acquire the skill set to provide not only for myself but, more importantly, for my immediate and extended family. Simply stated: everything I have and everything I provide for my family and community is directly related to the incredible, life-changing opportunity Chief gave me.

Do you remember how you felt when you first put on YOUR Temple white coat — the one with YOUR name on it alongside of those magical words "Department of Orthopedic Surgery?" I still remember and I will never forget. I would bet that every member of our Temple Ortho family, especially those chosen by Dr. Clancy, knows exactly what I mean. I cannot even begin to imagine how different life would be if Chief would have put another name on that piece of paper on match day.

I believe I am the sum of my experiences — we all have a journey which has brought us to where we are now. I'll do something uncharacteristic and uncomfortable for me . . . I'll share a bit of mine.

I am a very private person. I do not seek out new friendships. I do not trust others easily. I don't bare my soul to strangers. Experience taught me to become comfortable being my own island. Following the crowd and trying to fit in was *never* going to work for me. Very early on, the crowd made me painfully aware, in no uncertain terms, that I was *not* one of them, nor would I ever be accepted as one of the "boys." Some of you may share some of these experiences and many of you do not. Therefore, please allow me to elaborate.

Unlike most of you, I did not grow up in Pennsylvania or New Jersey. I'm from Houston, Texas — a city much larger, but, in many ways, not so different than Philadelphia. When I arrived, I respected north Philly but it didn't scare me. You've never seen third ward Houston.

Before me, there were no doctors in my family. My grandparents were cooks and maids — the kind who wore uniforms and worked in the homes of people who would never allow them to enter through the front door. I was told as a little boy that the only way I would ever safely walk in neighborhoods like those was pushing a lawnmower.

Fast forward to 1991, as I neared match day and graduation from medical school at the University of Texas. I was urged, despite my academic achievements, that I should never overlook pediatrics as a career. In 1991 (not 1951), the *entire* UT system, which at the time consisted of five medical schools, had never granted an orthopedic surgery residency to a black person. My medical school — Southwestern, at the famous Parkland Memorial Hospital in Dallas — is considered the crown jewel of the UT system. As I approached match day, my school had proudly never trained in orthopedics a Black, Latino, Asian or Jew, and most definitely not a woman.

I did a rotation at Temple in 1989 and was greeted by a junior resident — Rob Mills. Chief at the Shrine was V. Hermida and his co-resident was Mindy Siegle. I walked into the Temple ER and Gene Ding was an intern. I couldn't believe it . . . I was in heaven. It was as if I'd walked into the United Nations of orthopedic surgery!! It may not be particularly significant to many in attendance, but Dr. Clancy having the foresight, courage and commitment to educate a diverse group of residents is truly remarkable and upholds one of the valued pillars of Temple's mission.

I understand King David's words: "I am the stone the builders rejected . . ." On match day, I foolishly ranked only one program — Temple University Department of Orthopaedics. God and Dr. Clancy blessed me and my family — everything I have, and I will ever have, is because of Chief.

We are Temple Ortho — we never complain and never explain. I am Temple Ortho because Dr. Clancy had the vision, integrity and love to allow me — just a kid from Houston — an opportunity to have a truly amazing life and give to my community in ways I could never have imagined.

Dedication

Thoughts/Reflections Regarding Michael Clancy, MD — June 4, 2016

Lou Sutherland, MD

We are gathered here this morning to celebrate the Life of Dr. Michael Clancy. Although he was something different to each of us — husband, brother-in-law, uncle, physician colleague, mentor — what he was to ALL of us was a special and loyal **FRIEND.**

His life was one of love and service that he extended unconditionally to his family, his country, the departments he led, the physician colleagues and residents who were part of those departments, his friends, and his patients. I suspect these traits of love and service were acquired and nurtured at an early age in the home of his parents, James and Matilda.

Although most of us know Michael's "story," a review of his timeline and accomplishments may indeed reveal something new to each of us.

He was born on September 29th, 1944, sharing that day with his identical twin brother, Jim.

He grew up in the suburbs of Philadelphia and attended Lincoln High School where he enjoyed both academic and athletic success and would, years later, be inducted into the Lincoln High School Athletic Hall of Fame for his basketball prowess.

Trips to the Jersey shore with his family engendered a life-long love of the beach. He was proud to serve as part of the Wildwood Crest Beach Patrol for a short time in his 20s. After this, his summers were spent volunteering at the Philadelphia Naval Hospital.

He and his brother, Jim, both attended Lehigh University where they both played varsity basketball under Coach Tony Packer. Michael excelled in his studies at Lehigh, graduating *summa cum laude* and Phi Beta Kappa in 1966.

It was then onto Jefferson Medical School where he received his Doctor of Medicine degree in 1970. It was during his General Surgical internship year at Temple University Hospital that Michael definitively realized he wanted to become an Orthopaedic Surgeon. He was introduced to Dr. John Lachman at some point during his intern year at Temple and was offered an Orthopaedic Residency position to begin the following year.

After completing his residency in 1975, Dr. Clancy proudly fulfilled his personal commitment to serve his country in the United States Navy. He attained the rank of Lt. Commander at the time of his honorable discharge in 1977.

Shortly after returning to Temple as a junior staff physician, he married his beloved Jackie in July of 1977. Of Michael's many wise decisions, this would prove to be his best!

With Michael's love of sports, he naturally was attracted to the developing Orthopaedic sub-specialty of Sports Medicine. In addition to his staff duties at Temple University Hospital and Shriners Hospital for Children, Dr. Clancy began serving as team physician for a minor league hockey team, the Philadelphia Firebirds, and for his beloved Philadelphia 76ers from 1978 through 1989. The highlight of that era was obviously the NBA Championship year of 1982–83, coached by Billy Cunningham and led by Julius Erving and Moses Malone. Michael took great pride in wearing the Championship Ring awarded him by the Team.

In 1986, Dr. Clancy succeeded Dr. Howard Steel as Chief of Staff of the Philadelphia Unit of Shriners Hospital. A year later, he was named Professor and Chairman of Orthopaedic Surgery at Temple University Hospital, humbly taking the reins from Dr. Lachman. The Temple Shriners Orthopaedic Alumni Association endowed **The John W. Lachman Professorship and Chair of Orthopedic Surgery** in 1989 and Dr. Clancy was named the inaugural designee, a title he held until his retirement. In addition to simultaneously maintaining these two elite, unique positions, Dr. Clancy supervised the Residency Training Programs at both institutions, until Dr. Joseph Thoder assumed the Residency Program Director position at Temple in 1994.

Dr. Clancy was a master surgeon. He possessed an unparalleled ability to direct and guide a resident through an operation with the combination of short, encouraging words and actions — "Retractor goes here!" — that would make most cases proceed with a level of efficiency and purpose as if Dr. Clancy were performing the case himself. Michael was also masterful in the timely use of "qualifying expressive adjectives." If one felt it necessary to use an adjective to make one's point, Michael believed in using one which was certain to get his point across. When unintended circumstances arose during a case, Dr. Clancy's guiding decisions and actions were decisive and definitive in getting the "ship righted" and once again going along the intended path.

Under Dr. Clancy's direction and leadership, both Shriners' and Temple University's Orthopaedic Departments grew in scope, staff and services. His role in the development and success of Temple University's "out-reach satellite" model was monumental. He was able to infuse his team-player attitude to combine the skills of physicians, physical therapists, and certified trainers in the overall care and recovery of both injured athletes and non-athletes alike.

Dr. Clancy and his good friend, Mr. Jim Shacklet, Chairman of the Philadelphia Shriners Hospital Board, were responsible for securing the Philadelphia branch of Shriners Hospital from the Northeast suburbs to its current location on North Broad Street in 1998. This brought not only state-of-the-art Pediatric Orthopaedic care adjacent to the University Hospital, but also brought Shriners' Pediatric Research Center to the University's Medical Education and Research Center.

Unfortunately, when Dr. Clancy was at the pinnacle of his Orthopaedic career, he was forced into early retirement secondary to a disabling degenerative lower back condition which prevented him fulfilling the physical demands of an Orthopaedic Surgeon.

In 2000, upon his retirement, Michael received the **Diamond Award** awarded by the Temple University Auxiliary for his dedication and support to the department and hospital.

Dr. Clancy's accomplishments and service were also recognized by the Temple Shriners Orthopaedic Alumni Association with the commissioning of his portrait, which was presented to the Medical School in December 2001 and is now proudly displayed with other esteemed Temple University Hospital physicians in the University Hospital.

As with all of us, there was a very human side to Michael. He endured the loss of his valued and trusted friends, Mr. Fitz Dixon, Big Jim Shacklet, Ted Quedenfeld, and most recently, his best friend and twin brother Jim. Michael endured these losses with strength, courage, and dignity befitting their support of him.

Shortly after his retirement, Michael confronted his biggest adversary and demon with his entire being. As Jim Rogers eloquently stated in his eulogy for Michael on May 17th, "Paradoxically, it was through his human limitations and frailty that I observed and grew to love and respect the true humility behind our dear Michael Clancy."

With admittance and commitment, through his own strength and courage, and with the help provided by his beloved Jackie and others, Michael developed a depth of resolution which assured success in overcoming his demons. In a letter to me, Michael stated, "I doubt whether the 'demon' has ever faced a line-up that my friends present, led by the Team Captain, Jackie." He also shared an aphorism which motivated him daily: **"Winners do what they have to do, losers do what they want to do. I've never been a loser in my life and, rest assured, I do not intend to start now."** Paraphrasing a passage from St. Paul's Letter to the Romans: Michael's acknowledgement of his affliction produced endurance. And endurance, proven character. And proven character, hope. And hope did not disappoint. When all was said and done, I can distinctly hear Michael saying: "I finally sent the demon packing!" Very believably there was a "qualifying expressive adjective" between "the" and "demon" when he spoke that victory line.

After attending occasional morning resident conferences between 2001 and 2005, Dr. Clancy's love of teaching and his love of the Residency Program drew him back to regular weekly conferences with the residents several times a week between 2007 and 2011. To prepare for these conferences, he exhaustively reviewed the gamut of the orthopaedic literature, sharing his knowledge and wisdom with the residents and students. These thorough reviews enhanced not only the residents' clinical training, but also more readily prepared them for their yearly in-training exam. Michael joked he knew more Orthopaedics at that time than when he was in clinical practice!

After his retirement, Michael also tirelessly continued to serve as the Executive Director of the Temple Shriners Orthopaedic Alumni Association. Dr. Clancy's uncompromising commitment to this organization is the primary reason the Alumni Association remains committed to enhancing the Temple Orthopaedic residents' educational experience and why this association remains financially sound today.

In recent years, as physical issues continued to take their toll, Dr. Clancy withdrew from his teaching role, but remained committed to Temple Orthopaedics through his association with the Alumni Organization and with regular contact with both past residents and former departmental colleagues. In 2014, Michael was invited by Dr. Larry Kaiser, Dean of the Lewis Katz School of Medicine at Temple University and President and CEO of Temple University Health System, to serve on the search committee charged with choosing a new Chairperson of Orthopaedic Surgery at Temple. Dr. Clancy's opinions and input grew to be both respected and valued by Dr. Kaiser and all involved in that process.

During the last several years, he treasured his "quiet time" with his beloved Jackie, and his family and close friends. Having a comfortable routine allowed him to enjoy the benefits of their homes in Rydal, PA and at the Jersey shore.

In considering Dr. Clancy's many accomplishments, undeniably, there was one which gave him the most pride: Temple Orthopaedics. He had a profound and reverent awareness of both the academic and fraternal legacies created and fostered by his mentor, Dr. Lachman. As the one chosen to carry the torch, Michael maintained a constant respect for the legacy created by his predecessor. At Dr. and Mrs. Clancy's insistence, Latch remained an integral part of the Temple Orthopaedic family and Michael relied heavily on him for consistent counsel and guidance in times of doubt and uncertainty. Michael wrote: "Got a card from Latch — No matter how old we get, it's nice to know he's always behind us and with us. Lucky to have been trained by him — luckier still to have been taught by him and, obviously, not just Orthopedics." In his Eulogy delivered for Dr. Lachman on October 18th, 2007, our friend Dr. Phil Alburger referred to the unique and special gift we, as Temple trained Orthopedists, share when he said: "We are in a sense 'Latched' together . . . So it's time to see if the mentoring worked and we are left the daunting prospect of trying to emulate him so that his principles can endure." In the letter included in my personal signed copy of his portrait, Michael wrote: "During my 13 years as chairman, Jackie and I were cognizant of continuing the tradition and camaraderie of the orthopedic department that was in place. It is with pride that I can state this goal was achieved."

As we bid farewell, we can say with confidence, "Michael, well done, our good and faithful friend, well done!" May he rest in peace.

TEMPLE UNIVERSITY
Lewis Katz School of Medicine

Larry R. Kaiser, M.D., Dean
Senior Executive V.P., Health Affairs
President and CEO,
Temple University Health System

3500 N Broad Street
Medical Education Research Building
Suite 1141
Philadelphia, PA 19140

phone: 215-707-8773
fax: 215-707-8431
E-mail: larry.kaiser@tuhs.temple.edu
web: www.temple.edu/medicine

May 13, 2016

Dear Colleagues:

It is with great sadness that I share the news that Temple University Hospital and the Lewis Katz School of Medicine have lost a beloved mentor to generations of orthopaedic residents – and I have lost a friend. Michael Clancy, MD, has passed away at the age of 71.

Mike arrived at Temple as a surgical intern and orthopaedic resident in 1970, and trained under the luminary John W. Lachman, MD. He joined our faculty in 1977, and remained until his retirement in 2009, serving for many years as Chief of Staff at Shriners Hospital for Children and as Chair of the Department of Orthopaedic Surgery and Sports Medicine at Temple. In fact, it's largely to Mike's credit that Shriners relocated to our campus (and that the Shriners Pediatric Research Center now flourishes in MERB). He was a driving force in negotiating these agreements, now part of his legacy.

It is also his legacy that Temple delivers orthopaedic and sports medicine services of excellence. His diagnostic expertise, therapeutic decisiveness, and impeccable standards demanded it. An eminent surgeon with headmasterly instincts, Mike held everyone to the high standards of his own practice. No doubt it was through his own athletic accomplishments (at Lincoln High School and Lehigh University) that he learned the value of true team work. His trainers, therapists and residents were full members of the team. He taught everyone how to focus on the big picture, namely "safe return to full activity." And Mike possessed a singular and uncanny ability to quickly discern it. Throughout the 1980s, Mike was the team orthopaedist for the Philadelphia '76ers. His notoriety soared (especially after the team's 1983 championship season)—and drew celebrities like Moses Malone, Billy Cunningham and Julius Erving to his busy practice. Student athletes and weekend warriors too.

Even after retirement, Mike remained a steadfast advocate of Temple orthopaedics, regularly convening get-togethers with alumni, serving as president of the John Lachman Society and helping secure financial support for orthopaedics research and resident education. I can personally attest to how deeply Mike cared about Temple. Likewise, legions of residents, faculty, staff and patients deeply cared about him. Beneath that stern demeanor was a heart of gold. As his colleagues have said, he was a true pioneer in athletic medicine. His accomplishments were monumental. So was the man.

Memorial plans will be forthcoming. Our sincere condolences to his wife Jackie, his family and his many, many friends, former students and patients.

Sincerely,

Larry R. Kaiser, MD, FACS
Dean and Professor of Surgery, Lewis Katz School of Medicine at Temple University
Senior Executive Vice President for Health Affairs, Temple University
President and CEO, Temple University Health System

Commentary

The Distinguished Alumni Papers

F. Todd Wetzel, MD

These two papers represent a portion of my work when I was privileged to have been a postdoctoral fellow in the Yale Biomechanics Lab under the direction of Dr. Manohar Panjabi. Dr. Panjabi, along with Dr. Augustus A. White, III, is considered to be one of the founding members of spine biomechanics. He and Dr. White coauthored the seminal text, *Clinical Biomechanics of the Spine.* To have spent a year under his tutelage was an honor.

These papers are noteworthy for two reasons. The first is the application of what was then "cutting edge" technology: two-dimensional digitization to quantify vertebral stability/instability after spinal injuries. While this was rather quickly supplanted by three-dimensional technology involving the implantation of tantalum spheres, it was, at the time, reasonably well received. The ability to actually quantify translation and angular rotation in an accurate and validated model helped to advance the study of spinal instability.

The second area that was novel may not seem so today: this was one of the first studies to look at the biomechanical behavior of injuries over time in an *in vivo* model. As such, the healing of the injuries could be quantified over time. This helped sharpen the characterization of instability by adding a temporal component. The obvious translational benefit of these data (and many others) was to help predict "unstable" outcomes based on initial injury severity.

Distinguished Alumni Paper

Biomechanics of the Rabbit Cervical Spine as a Function of Component Transection

F. Todd Wetzel, Manohar M. Panjabi, Richard R. Pelker

Department of Orthopaedics and Rehabilitation, Yale Medical School, New Haven, CT

Summary

The rabbit cervical spine in the form of the functional spinal unit was tested in a manner analogous to that used to study human functional spinal units. Anatomies and biomechanical similarities and differences with the human were demonstrated. The rabbit cervical spine failed abruptly after a well-defined series of anterior or posterior segmental injuries. However, up to the failure point, the rabbit cervical spine exhibited an increased range of motion after each segmental injury. The results of this study were used to develop an *in vivo* model for the study of spinal injury in subsequent projects.

Key Words: Functional spinal unit — Serial injury *in vitro*.

The biomechanical behavior of human cervical spines has been well characterized.[1–6, 8, 9] However, there is a paucity of information about the changes that the spine undergoes with the passage of time after injury or surgical ablation. An animal model is needed to investigate these problems. Any animal model is limited; however, it is not the purpose of this study to imply that the biomechanical information from the rabbit model used here is directly applicable to the human spine. The major utility of this model lies in its use as a system for comparison of various degrees of injuries within itself.

The precise quantification of the biomechanical behavior of the cervical spine has been aided by studying the functional spinal unit, rather than the entire cervical spine.[6, 8, 9] The functional spinal unit is defined as two adjacent vertebrae and all interposed soft tissues. The purpose of this study is to determine the biomechanical behavior of an animal model — the rabbit — in an *in vitro* study by examining rabbit cervical functional spinal units during the serial sectioning of anterior and posterior structures. The information gained from this experiment will be used to develop an *in vivo* model for the study of spinal injury in subsequent projects.

Reprinted with permission from the *Journal of Orthopaedic Research,* 7:723–727 Raven Press, Ltd., New York. ©1989 Orthopaedic Research Society.

Address correspondence and reprint requests to Dr. M. M. Panjabi at Department of Orthopaedics and Rehabilitation, Yale Medical School, New Haven, CT 06510, USA.

Materials and Methods

The anatomy of the rabbit cervical spine is comparable to that of the human, with five single and two paired spinal ligaments connecting any two adjacent vertebrae. The spinous processes are relatively small compared to vertebral bodies. The facet joints are well developed and oriented in the longitudinal plane at an angle roughly 30° to the coronal plane. We define intertransverse ligaments and all structures anterior to them as *anterior* elements, while all structures posterior to them are *posterior* elements. Grossly, the supra- and interspinous ligaments join adjacent spinous processes. The ligamentum flavum is a thin membrane-like structure running deep to the laminae. The facet capsules are thick, fibrous structures enclosing adjacent superior and inferior facets, while the intertransverse ligaments are broad fibrous bands connecting consecutive transverse processes. Both the posterior and anterior longitudinal ligaments are delicate structures connected to the intervertebral disc. In all rabbit specimens examined, the disc space was composed of dense fibrous bands of annulus circumscribing a small well-defined nucleus pulposus.

Rabbit cervical functional spinal units from either C3-4 or C5-6 were tested biomechanically using a protocol similar to the one used earlier for similar studies of the human cervical spine.[6] In a subsequent *in vivo* study, injuries were made at the level of C4. By studying C3-4 and C5-6, we were able to acquire two functional spinal units from each animal, and thus broaden the comparable *in vitro* data base. A limitation of this selection is the exclusion of more proximal and distal segments from biomechanical testing, thus precluding a more comprehensive, level-by-level, biomechanical description of the rabbit cervical spine.

Functional spinal units from young adult New Zealand white rabbits were used. All rabbits were age 6 to 8 months (normal life span of 3 to 5 years). No degenerative changes were observed on any vertebral bodies or facet joints. Although the precise temporal sequence of disc degeneration in the rabbit has not been characterized, the age of the animals used in this study is taken to preclude the presence of senescent changes in the intervertebral discs.

Drill holes were made in the inferior aspect of the inferior vertebral body, and two large anchoring screws were inserted. The functional spinal unit was placed in a specially constructed jig, and the inferior vertebra was fixed in quick setting epoxy with middisc plane oriented to lie horizontally. This was accomplished in such a manner as to leave posterior elements freely accessible. Two 21 gauge needles were then inserted into the upper vertebra via small drill holes that served as markers for motion measurement. These markers were anchored in the cancellous core of the vertebral body, roughly perpendicular to one another in the sagittal plane. A prolene suture was fixed to the upper vertebral body at its geometric center to apply loads. A functional spinal unit being tested in flexion is shown in Fig. 1.

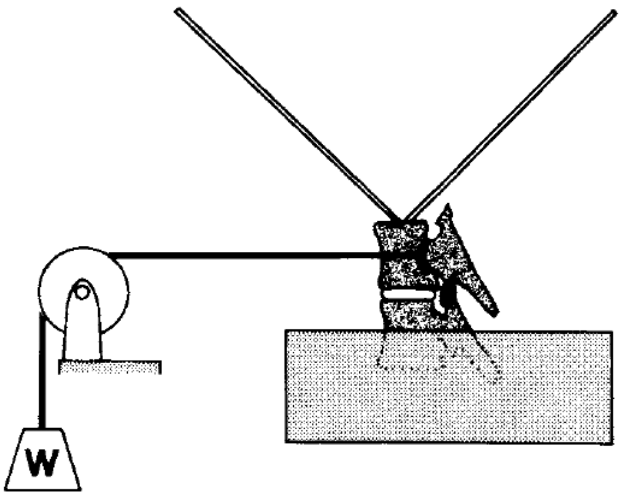


Figure 1. Lateral drawing of a specimen ready for flexion testing. The pin markers are inserted into the body of the upper vertebra to allow measurement of the motion. The prolene suture is fixed to the geometric center of the upper vertebral body to apply loads.

The technique of two-dimensional photogrammetry was employed to analyze vertebral motion in the sagittal plane. The mounted specimen was placed on a table with two fixed markers clearly visible in the background. A radiograph was taken so that the precise positions of the vertebral (needle) markers with respect to the vertebral body were clearly shown. Either an anterior (flexion) or posterior (extension) force of 10 N, approximately 25% of body weight, as used in comparable studies of the human cervical spine[6, 8] was applied. While realizing that a similar force applied to the spine of a quadruped or biped may not produce the same range of motion as in the case of the human, this force magnitude seems reasonable since the mean flexion of human functional spinal units tested from C2 to C7 is 7.9 ± 2.2°[6, 8] and that of the rabbit functional spinal unit tested here is 12.8 ± 3.4°. Three load/unload cycles of 1 min on/1 minute off were used. At the completion of the third "load on" cycle, a lateral photograph of the functional spinal unit and background markers was taken. This was repeated at the end of the third minute of "load off." Ligaments were serially sectioned either from posterior to anterior for the flexion loading or from anterior to posterior for the extension loading, in a manner analogous to that described by Panjabi et al.[6] (Table 1). After each serial section, the experimental procedure of load/unload/photograph was repeated.

All functional spinal units were tested until "failure" occurred. Failure in our case was defined as angular motion of the superior vertebra with respect to the inferior vertebra exceeding 45°, or when the upper and lower vertebrae abruptly separated. This is in contrast to the failure criteria of 90° used earlier.[6, 8] We believe that 45° of angulation is adequate representation of the clinical situation and subsequent *in vivo* study using an animal model.

Roentgenographs and photographs of each specimen were digitized. These data were fed into a specially developed kinematics program that computed angular range of motion and two-dimensional translation after each injury. As a check on digitizing errors, the distance between the tips of the two vertebral markers was computed with each slide. For motion analysis, translations of the anterior inferior vertebral body tip of the upper vertebra and angular range of motion of the upper vertebra with respect to the lower were computed. The accuracy of the motion measurement system was determined by repeatedly digitizing the same set of films ten times and presenting it as standard deviations. This was found to be 0.2 mm for translation and 0.3° for angular range of motion. Since the translational motions found in the experiment were on the same order of magnitude as the errors, only the angular range of motion parameters was analyzed for this study.

Results

Eight functional spinal units, seven from C3-4 and one from C5-6, were tested in flexion. Five functional spinal units, four from C3-4 and one from C5-6, were tested in extension. The tabulation of test data on individual functional spinal units is given in Table 2. In flexion, four of the eight functional spinal units failed following division of all of the structures posterior to and including the intertransverse ligaments (supraspinous and interspinous ligaments, ligamentous flavum, facet capsule ligaments, laminectomy, and facetectomy) (Table 1), while two failed one injury "earlier" (laminectomy/facetectomy) and two failed one injury "later" (posterior longitudinal ligament division). In extension, four of the five specimens failed following division of all of the structures anterior to and including the capsular ligaments (anterior longitudinal ligament, annulus fibrosis, posterior longitudinal ligament, and intertransverse ligaments) (Table 1), while one failed "earlier" after division of the intertransverse ligaments. A representative graph of a functional spinal unit tested in flexion with transection of ligaments from posterior to anterior is shown in Fig. 2. On the horizontal axis is shown the ligament transected, while

TABLE 1. Injuries Producing Failure

Flexion: posterior to anterior sequence of division of structures, for specimen tested in flexion
1. Supraspinous, interspinous ligaments
2. Ligamentum flavum
3. Facet capsular ligaments
4. Laminectomy and bilateral facetectomy
5. Intertransverse ligaments
6. Posterior longitudinal ligament
7. Posterior half of annulus fibrosis
8. Anterior half of annulus fibrosis
9. Anterior longitudinal ligament

Extension: anterior to posterior sequence of division of structures, for specimens tested in extension
1. Anterior longitudinal ligament
2. Anterior half of annulus fibrosis
3. Posterior half of annulus fibrosis
4. Posterior longitudinal ligament
5. Intertransverse ligaments
6. Facet capsular ligaments
7. Laminectomy and bilateral facetectomy
8. Ligamentum flavum
9. Supraspinous, interspinous ligaments

TABLE 2. Test Data on Individual Motion Segments

Specimen Level	Failure Point	Failure Type	Intact Initial ROM (deg)	One Injury Pre-fail ROM (deg)
Flexion: ligament transection from posterior to anterior				
C3-4	Intertran.	0 > 45°	10	31
C3-4	Lam./Fac.	0 > 45°	18	37
C3-4	Post. Long.	0 > 45°	16	41
C3-4	Intertran.	0 > 45°	9	25
C3-4	Intertran.	Dramatic[a]	10	36
C3-4	Lam./Fac.	0 > 45°	19	36
C3-4	Post. Long.	Dramatic[a]	11	36
C5-6	Intertran.	Dramatic[a]	10	36
Extension: ligament transection from anterior to posterior				
C3-4	Capsular	0 > 45°	9	21
C3-4	Capsular	0 > 45°	15	25
C5-6	Capsular	0 > 45°	8	25
C3-4	Capsular	0 > 45°	9	28
C3-4	Intertran.	0 > 45°	18	27

ROM, range of motion.
[a]Abrupt separation of vertebrae.

on the vertical axis is the resulting vertebral angulation due to the application of the load. As a comparison, a similar graph based upon data generated by flexion tests of human cervical functional spinal units[8] is also shown. Unlike the human functional spinal unit, the rabbit functional spinal unit exhibits greater incremental range of motion for each serial injury, but, like its human counterpart, it fails abruptly.

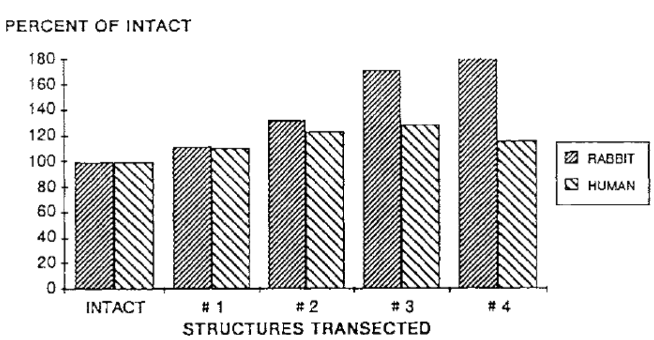


Figure 2. Flexion ranges of motion for the rabbit and human cervical spinal units expressed as percentages of their corresponding intact values vs. posterior structure transected. See Table 1 for explanation of the structures transected.

Discussion

The results of the rabbit *in vitro* tests of ligament transections are similar to those reported in comparable studies involving the cervical and lumbar spine specimens in humans. Similar to the human cervical spine, failure occurs abruptly after a well-defined series of anterior (or posterior) injuries. However, unlike the human cervical spine, which exhibits little change in its range of motion up to the failure point, the rabbit cervical spine exhibits an increasing range of motion after each incremental serial injury. Further, the human cervical functional spinal unit demonstrates a decrease in range of motion after facetectomy. Thus, while biomechanical similarities between quadrupedal and bipedal cervical functional spinal units, in this case between rabbit and human, exist, extrapolation of animal data to human situations must be made with caution.

How applicable to this model are the observations of Panjabi et al.[6] and White et al.[8] requiring that "all anterior elements plus one" and "all posterior elements plus one" be intact to prevent failure? In the flexion test, division of structures up to and including the intertransverse ligaments produced failure in 50% of the specimens tested; two failed one serial injury "earlier," and two failed one serial injury "later." If one then considers the injury to the transverse ligament to be that producing failure, the observations of Panjabi et al.[6] and White et al.[8] are applicable, provided the transverse ligament is included in the "anterior" groups of elements.

Since the transverse processes in the rabbit cervical spine are anterior to the canal, this seems anatomically and functionally plausible. White et al.[7] further stated that the adult cervical spine is on the "brink of instability" when all of the anterior or all of the posterior elements are destroyed. This implies that any serial injury that further destabilizes the spine would result in complete biomechanical failure. Using these guidelines in the rabbit model, injuries producing failure appear to be serial posterior division of the structures up to and including the intertransverse ligaments (flexion), and serial anterior division of the structures up to and including the facet capsular ligaments (extension).

The utility of this study is twofold. First, methodology from human cervical biomechanical tests has been applied to an animal model. Similarities and differences in biomechanical behavior are observed. Second, and most important, is the use of this information to construct an injury system to be employed in the rabbit model for an *in vivo* investigation.[7] Only in this way can data on the applicability of *in vitro* data to *in vivo* situations be acquired. While one can hopefully gain insight into the human situation using such models, again it must be emphasized that caution is required to extrapolate to the human findings from any animal experiment, *in vitro* or *in vivo*.

Acknowledgment

This research was supported by National Institute of Health Grants AR 30361 and AR 34699. Technical help from J. Duranceau, E. Hult, and D. Summers is gratefully acknowledged. This work was presented in part at the 12th Cervical Spine Research Society, New Orleans, LA, 1984.

References

1. Fielding JW. Normal and abnormal motion of the cervical spine from C2 to C7, anirontgenography. *J Bone Joint Surg Am.* 46:1779–1781, 1964.
2. Goel VK, Clark CR, McGowan D, Goyal S. An in vitro study of the kinematics of the normal, injured, and stabilized cervical spine. *J Biomech.* 17:363–376, 1984.
3. Halliday DR, Sullivan CR, Hollingshead WH, Bahn RC. Tom cervical ligaments: neuropsy examination of normal cervical region. *J Trauma.* 4:219, 1964.
4. Lysell E. Motion in the cervical spine. *Acta Orthop Scand Suppl.* 123:000–000, 1969.
5. Panjabi MM, White AA III. Basic biomechanics of the spine. *Neurosurgery.* 7:76–93, 1980.
6. Panjabi MM, White AA III, Johnson RM. Cervical spine mechanics as a function of transection of components. *J Biomech.* 8:327–336, 1975.
7. Wetzel FT, Panjabi MM, Pelker RR. Temporal biomechanics of posterior cervical spine injuries in the rabbit model. *J Ortho Res.* 7:000–000, 1989.
8. White AA III, Johnson RM, Panjabi MM, Southwick WO. Biomechanical analysis of clinical stability in the cervical spine. *Clin Orthop.* 109:85–96, 1975.
9. White AA III, Southwick WO, Panjabi MM. Clinical instability in the lower cervical spine. *Spine.* 1:15–27, 1976.

Temporal Biomechanics of Posterior Cervical Spine Injuries *in vivo* in a Rabbit Model

F. Todd Wetzel, Manohar M. Panjabi, Richard R. Pelker

Department of Orthopaedics and Rehabilitation, Yale University School of Medicine, New Haven, CT

Summary

There are numerous clinical and biomechanical criteria for determination of acute spinal instability. No data, however, exist on the biomechanical behavior of the injured, untreated spine during the healing period. Using a rabbit model, this study was designed to quantify changes in the mechanical properties of the injured spine over time. Sixteen rabbits were assigned to four injury groups: Injury 1 (C4-5 supra/intraspinous ligament transection), Injury 2 (C4 laminectomy), or Injury 3 (C4 laminectomy, plus bilateral facet capsular ligament transection). The fourth injury group was Sham (posterior exposure of C4-5, no spinal injury). Preinjury range of motion was determined by standardized flexion-extension radiographs on all animals. Postinjury flexion-extension radiographs were taken at four, eight, and 12 weeks. At the end of 12 weeks, animals were killed. Mean range of motion at C4-5 for all injury groups *decreased* from preinjury values. The greatest decrease was for the most severe injury. At eight weeks, the range of motion for this injury was less than half of the preinjury level and increased to 62% of the preinjury level at 12 weeks.

Key Words: Cervical spine injuries — Biomechanical changes — Spinal instability.

Knowledge of biomechanics of the cervical spine is crucial for proper management of traumatic injuries, elective surgical ablations, and ongoing destructive disease processes. Alterations in mechanical integrity and neurological status frequently determine the optimal treatment of spinal injury. Intentional removal of spinal structures during surgery may also compromise spinal stability and lead to acute or progressive neurological deficit and deformity. Thus, the acute assessment of "stability" has been the subject of numerous investigations. Munro[8] discussed factors contributing to stability of the cervical spine. Panjabi et al.[10] and White et al.[15] serially removed ligamentous and bony structures from cadaveric cervical spines to correlate injury severity with instability under physiologic flexion/extension produced with 25% body weight loading. The most severe injuries, still physiologically stable, were found to be those in which all of the anterior elements "plus one," or all posterior elements "plus one," were intact. The results were incorporated into a nine point checklist for diagnosing clinical instability in the cervical spine.[15] Similar studies have been conducted in the thoracic and lumbar regions.[9, 11]

All of these studies were temporally "static," i.e., the biomechanical behavior of the spine was studied immediately after injury, with no emphasis upon the ongoing biological processes of healing and biomechanical adaptation. These temporal processes are evident in clinical practice. For example, a type III dens fracture, while acutely unstable, will become stable over time if protected by external means so that healing may occur.[3] Conversely, a multiple level laminectomy is acutely stable, but if unprotected will lead to a chronic, adaptive deformity that will destabilize the spine.[2] Hence, biomechanical criteria valid at the time of initial injury do not permit an accurate prognosis of delayed stability or instability for a given injury.

Biochemical studies on the healing of some spinal injuries, notably of the disc, are present in the literature,[6, 7] as are studies on the healing of various ligaments and tendons of other joints.[1, 4, 5, 12, 13] To our knowledge, however, there are no biomechanical studies concerning the healing and adaptive changes of the injured spine. The present study intends to address this issue by quantifying changes in the biomechanical behavior of the injured spine *in vivo* over time in an animal model.

The rabbit model used here has been described in detail by Frank et al.[4] There are notable similarities and differences between the animal model and the human cervical spine. As with any animal model, caution should be exercised when attempting to extrapolate any conclusions reached here to the human spine.

Materials and Methods

Sixteen adult New Zealand white rabbits were used for this experiment. Food and water were provided ad libitum. All animals were examined daily. Each animal underwent

Reprinted with permission from the *Journal of Orthopaedic Research,* 7:728–731 Raven Press, Ltd., New York. ©1989 Orthopaedic Research Society.

Address correspondence and reprint requests to Dr. M. M. Panjabi at Department of Orthopaedics and Rehabilitation, Yale Medical School, New Haven, CT 06510, USA.

one of four surgical procedures and serial postoperative functional radiographs, thus providing a continuous biomechanical picture of the healing process. Four animals were placed in each injury group.

Surgery was performed under sterile conditions. All animals were premedicated with intramuscular ketamine (Ketaject, Bristol Labs, Syracuse, NY, U.S.A.), 35 mg/kg. This ensured complete muscular relaxation. Induction was performed using nitrous oxide. Anesthesia was maintained by a combination of nitrous oxide and halothane (Halocarbone, Inc., Hackensack, NJ, U.S.A.). All surgery was done via a standard posterior midline approach. Animals were randomly assigned to one of four injury groups. Injury selection was made on the basis of *in vitro* tests,[14] in such a manner as to avoid frank instability and ensure survival during the healing period. Injury #1 consisted of transection of supra- and intraspinous ligaments at C4-5. Injury #2 was C4 laminectomy. Injury #3 consisted of C4 laminectomy plus bilateral facet capsular division. The sham group — Injury #4 — underwent posterior exposure of C4-5 without any spinal column injury. For 24 h preoperatively and 48 h postoperatively, all animals received intramuscular procaine penicillin. Animals were examined daily, and routine postoperative analgesia was provided. No form of postoperative immobilization was used in any group.

Standardized lateral flexion/extension radiographs were taken at the following times: preoperatively, and at four, eight, and 12 weeks postoperatively. Prior to each set of films, the animal was sedated with i.m. ketamine, 35 mg/kg to ensure complete muscle relaxation as described above, and minimize any active muscular contribution to the bending stiffness. It was then placed in a special apparatus to apply flexion and extension loads of 10% body weight with respective moment arms of 5 and 10 cm to the injured area.

These load magnitudes were arrived at in the following manner: In a preceding *in vitro* experiment,[14] a load of 25% body weight was applied to a rabbit cervical functional spinal unit. Since the rabbit vertebra was 1 cm in height, the corresponding applied moment was 0.25 "body weight–centimeters." The moment arms required *in vivo* to produce cervical motion were larger, presumably due to the passive resistance of muscles and other soft tissue restraints. Flexion loads were applied through a moment arm of 5 cm, thus producing a total flexion moment of 0.5 "body weight–centimeters" (which equals 5 cm x 10% body weight). The apparatus in which the animals were tested held them in the prone position; thus, the moment arm required for extension was larger in order to compensate for the weight of the head. The total extension force applied was 1 "body weight–centimeters" (which equals 10% body weight x 10 cm).

The lateral flexion and extension radiographs were digitized and range of motion was calculated utilizing a specially developed automated computer program. By superimposition of the inferior vertebra in flexion and extension views, the relative motion of the superior vertebra was determined. This process was repeated for each level from C3 to C6. Since the injury level was C4-5, only results from this level are reported and discussed. While other kinematic parameters were computed, only measurements of the angular range of motion in the sagittal plane were felt to be reliable indicators of biomechanical behavior.[14] Using the Wilcoxan two-sample rank sum test, statistically significant differences between the preoperative and postoperative biomechanical behavior of different injury groups was determined.

In addition, a single group of randomly selected flexion/extension films were digitized ten times, and range of motion computed at C4-5. Results were analyzed to assess the reliability and reproducibility of our automated superimposition technique.

Results

In the repeatedly digitized films, the standard deviation of the angular range of motion was 0.53°. As such, all data are presented to the nearest whole degree (equal to two standard deviations). The range of motion is tabulated in Table 1 as a function of time and injury group. Graphic representations of mean range of motions at C4-5 as functions of time and injury groups are shown in Fig. 1. Significance with respect to the preinjury range of motion was determined by the Wilcoxan two-sample rank sum test. No statistically significant differences in the range of motion were found between the sham and preinjury groups at any time. The mean range of motion before injury for the groups was 29 ± 5°. The sham injury resulted in a small increase in the range of motion initially to 34 ± 8°. This gradually decreased to 29 ± 8° at eight weeks and 25 ± 5° at 12 weeks. Injury 1 and Injury 2 resulted in an initial decrease in the range of motion (24 ± 9° and 24 ± 6°, respectively) compared to the preinjury levels. This gradually returned towards the preinjury level by 12 weeks (28 ± 5° and 29 ± 3°, respectively).

Injury 3 resulted in a significant ($p < 0.05$) *decrease* in the range of motion compared to the preinjury range of motion at four weeks. This decreased further to 13 ± 6° at eight weeks with a 12-week value of 18 ± 6°. At all these testing periods, the ranges of motion were statistically significantly lower than the preinjury range of motion.

Table 1. C4-5 Angular Range of Motion in Degrees

	Time							
	Preoperative		4 Weeks		8 Weeks		12 Weeks	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sham	29	5	34	8	29	8	25	5
Injury 1	29	5	24	9	21	10	28	5
Injury 2	29	5	24	6	28	5	29	2
Injury 3	29	5	20[a]	6	13[a]	6	18[a]	6

SD = standard deviation.
[a]Significant change ($p < 0.05$) from the preoperative range of motion of 29° using the Wilcoxon two-sample rank sum test.

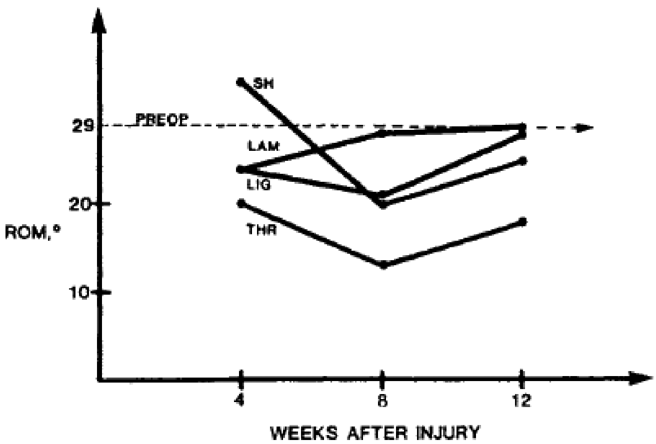


Figure 1. Range of motion in degrees for each injury group as a function of time postinjury. Note that the range of motion of Injury 3 is significantly less than the preinjury range of motion (dashed line) at all time intervals ($p < 0.05$, Wilcoxon two-sample rank sum test).

Discussion

An attempt was made to measure a range of motion in animals immediately postoperatively. In the most extensive injury group — laminectomy and facet capsular transection — this proved incompatible with survival due to uncontrollable hemorrhage provoked by the flexion testing. As such, for the sake of comparison, this testing point was abandoned for all groups. Thus, the possibility of an immediate undetected postoperative increase in range of motion exists. At four weeks, however, all surgical injury groups 1, 2, and 3 demonstrated a decrease in their range of motion from the preoperative levels although not statistically significant. On the basis of *in vitro* studies in the human[9–11] and rabbit[14] spines, one would expect just the opposite, i.e., the range of motion would increase with the transection of spinal elements. A possible explanation for this is that the *in vivo* process of paraspinous soft tissue healing stabilizes the injured spine more than the injury destabilizes it, at least in injuries that, based upon *in vitro* data,[14] are not *acutely* unstable.

At 12 weeks, range of motion of all injury groups including sham shows a tendency to increase from the 4- and 8-week levels and to return to the preoperative level. This in turn implies that the contribution of paraspinous soft tissue healing changes over time and may be diminishing.

The trends noted above tend to substantiate the existence of two "competing" mechanisms: paraspinous soft tissue healing, which stabilizes the spine, and spinal column injury, which destabilizes it. The exact interplay of these mechanisms in this temporal study, however, is far from clear. Between injury groups #1 and #2, there is a suggestion that temporal healing behavior may mimic *in vitro* behavior with the more severe biomechanical injury displaying a relatively greater range of motion and more rapid return to preoperative levels. At a level of accepted statistical significance ($p < 0.05$), postoperative range of motion in injury group #3 is consistently different from the preoperative value; it is *decreased* at all time intervals. Again, on the basis of *in vitro* studies, one would expect just the opposite. With the more extensive injury (laminectomy and facet capsular ligament division), the soft tissue response was vigorous enough to significantly decrease range of motion. Whether or not this quantitative decrease in flexibility would occur with the creation of more severe spinal injuries is unknown. The injury that produced complete biomechanical failure *in vitro,*[14] i.e., laminectomy, facetectomy, and intertransverse ligament division, was, unfortunately, not compatible with animal survival due to uncontrollable hemorrhage produced by facetectomy. This difficulty could be overcome by the use of a larger animal. The quantitative behavior of the injured spine *in vivo* in this critical area of failure, as defined *in vitro,* could then be studied by the methods described above. Subsequent studies await this application.

One variable that has been controlled in the present animal study is the effect of age on the biomechanical behavior of the specimens, a problem frequently encountered in human *in vitro* studies. As noted in the earlier *in vitro* study,[14] all rabbits used were young adults. As such, any biomechanical effects caused by disc degeneration or degenerative changes may be presumed to be absent.

A major problem with static *in vitro* studies concerns their clinical applicability. As such, the reliable transposition of *in vitro* standards to *in vivo* situations is a matter of major importance. As previously noted,[2] injuries that are acutely stable may destabilize over time, with attenuation of the remaining ligamentous restraints. The natural history of these problems is thus of paramount interest. In the current study, in the case of Injury #3, one can conclude, for example, that internal stabilization of the injured animal for the customary 6- to 12-week period used clinically is not required. When, or if, chronic destabilization occurs is not evident in this rabbit model in the setting of a 12-week test. In subsequent studies utilizing a dog model over longer experimental periods, this question will be addressed. Obviously, the timing of appropriate intervention is of paramount importance to the clinician. Studies conducted *in vitro* cannot address this temporal concern. As such, the reliable transposition of in vitro standards to *in vivo* situations is a matter of major importance. This preliminary study has begun to address this problem using the rabbit model.

Acknowledgment

This research was supported by National Institute of Health grants AR 30361 and AR 34699. Technical help from J. Duranceau, E. Hult, and D. Summers is gratefully acknowledged. This work was presented in part at the 13th Cervical Spine Research Society, Cambridge, MA, 1985.

References

1. Balkfors B. The course of knee ligament injuries. *Acta Orthop Scand.* 53(suppl 198):1–54, 1982.
2. Callahan RA, Johnson RM, Margolis RN, Keggi KJ, Albright JA, Southwick WO. Cervical facet fusion for control of instability following laminectomy. *J Bone Joint Surg Am.* 59:991–1002, 1977.
3. Clark CR, White AA III. Fractures of the dens: a multicenter study. *J Bone Joint Surg Am.* 67:1340–1348, 1985.
4. Frank C, Schalhar N, Dittrich D, Shrive N, Dehaas W, Edwards A. Elect range of motionagnetic stimulation of ligament healing in rabbits. *Clin Orthop.* 175:263, 1983.
5. Kappakas GS, Brown TD, Goodman MA, Kikuike A, McMaster JH. Delayed surgical repair of ruptured ligaments: a comparative biomechanical and histological study. *Clin Orthop.* 135:281, 1978.
6. Lewinnek GE, Chen EH, Hayes WL, White AA III. Healing after disruption of intervertebral discs: biomechanical and histological studies. 27th Annual ORS, February 24–26, 1981, p 124.
7. Lipson SS, Muir H. Proteoglycans in experimental intervertebral disc degeneration. *Spine.* 6:194, 1981.
8. Munro D. The factors that govern the stability of the spine. *Paraplegia.* 3:219–228, 1965.
9. Panjabi MM, Hausfeld JN, White AA III. A biomechanical study of the ligamentous stability of the thoracic spine in man. *Acta Orthop Scand.* 52:315–326, 1981.
10. Panjabi MM, White AA III, Johnson RM. Cervical spine mechanics as a function of transection of components. *J Biomech.* 8:327–336, 1975.
11. Posner I, White AA III, Edwards WT, Hayes WC. A biomechanical analysis of the clinical stability of the lumbar and lumbosacral spine. *Spine.* 7:374–389, 1982.
12. Steiner M. Biomechanics of tendon healing. *J Biomech.* 15:951–958, 1982.
13. Vailas AC, Tipton CM, Mathes RD, Gart M. Physical activity and its influence of the repair process of medial collateral ligaments. *Connect Tissue Res.* 9:25, 1981.
14. Wetzel FT, Panjabi MM, Pelker RR. Biomechanics of the rabbit cervical spine as a function of component transection. *J Orthop Res.* 7:723–727, 1989.
15. White AA III, Johnson RM, Panjabi MM, Southwick WO. Biomechanical analysis of clinical stability in the cervical spine. *Clin Orthop.* 109:85–96, 1975.

Original Research

Orthopaedic Surgery Resident Financial Literacy: An Assessment of Knowledge in Debt, Investment, and Retirement Savings

John D. Jennings, MD; Courtney Quinn, MD; Saqib Rehman, MD

Temple University Hospital, Department of Orthopaedics and Sports Medicine, Philadelphia, PA

Abstract

Most orthopedic surgery residents carry significant debt and may enter their practice with little knowledge of business management, minimal retirement savings, and overall poor financial literacy. This study aimed to gauge financial literacy, debt, and retirement planning in U.S. orthopedic surgery residents. Eighty-five allopathic orthopedic surgery residents in the United States completed a 14-question anonymous online survey. The survey assessed demographic data, self-assessed financial knowledge, amount of credit card debt and loans, preparation for retirement, and willingness to participate in formal didactic education on these topics. The majority of respondents were married and aged 30–35. 28% considered themselves to have above average financial literacy, deriving their knowledge primarily from personal research (51%). Despite the majority of respondents reporting over $200,000 in outstanding loans, only 31% of residents surveyed create and stick to a monthly budget. Importantly, 48% are not currently saving any money for retirement. Despite the fact that only 4% of those surveyed report having formal training in investing, personal finance, or retirement savings, the majority (84%) of residents have an interest in learning more about financial planning. In fact, almost 75% of those surveyed consider themselves less prepared for retirement than their peers outside of medical training. This study suggests a role for formal financial education in the orthopedic curriculum to prepare residents for retirement, and help with both investing and debt management.

Introduction

Residents emerge from medical school carrying substantial debt, and are ill-equipped to make many of the important financial decisions needed to carry them into a career and ultimately, retirement. According to the Association of American Medical Colleges, for the class of 2016, the median cost of medical school is $306,171 for private schools and $232,838 for public schools.[1] Residents face this substantial debt with less financial knowledge than their college-educated, non-medical peers and at the cost of significant stress in both their finances and personal relationships.[2, 3]

The Accreditation Council for Graduate Medical Education (ACGME) publishes program requirements for orthopedic surgery in order to ensure that all graduating residents are prepared to enter their practice with at least some minimum level of competency. Interestingly, while practice management, financial literacy, and retirement planning play a crucial role for any orthopedic surgeon leaving residency, there is currently no requirement by the ACGME for any training in this field.

The goal of this study was to evaluate how residents across many orthopedic programs perceived their own level of knowledge with regards to financial literacy, investing, and retirement savings. Furthermore, we sought to determine how interested these residents would be in formal education in this field as a mandatory component of their training.

Methods

A survey was devised in order to assess resident debt, financial knowledge, and willingness to participate in a formal course on these topics. The questions were, in part, derived from those asked in previous studies in other fields.[4–13] Specifically, the questions were:

1. What is your current year in training?
2. What is your current age?
3. What is your current marital status?
4. I would rate my knowledge of finance, investing, and savings as: no knowledge, some knowledge, average, above average, very knowledgeable.
5. My current knowledge about personal finance, investing, and savings is primarily from: previous schooling, personal research, lectures or meetings, I have minimal knowledge on this topic, other.
6. The amount of student loans I have currently outstanding is: no loans (or loans paid off), less than $20,000 ($20k), $20k–$50k, $50k–$100k, $100k–$200k, over $200k.
7. The total amount of credit card debt I carry on average, after monthly payments are made is: none, less than $500, $500–$1k, $1k–$5k, over $5k.
8. With regards to budgeting my income and expenses, I: Do not create a monthly budget, I have a monthly budget but

do not usually stick to it, I have a monthly budget and almost always stick to it.

9. My program offers advice on savings and retirement planning: True, False, Not sure.

10. My institution offers a retirement fund (i.e., 401k, 403b) with matching: True, False, Not sure.

11. The monthly amount I put towards a retirement account is: $0, $1–$150, $150–$300, over $300.

12. The reason that most closely matches why I do not currently invest in a retirement account is: I do invest in a retirement account; I have other expenses (repaying loans, consumer debt, etc.) that do not afford me to save money each month; I don't think I will be at a significant loss if I wait to save until after residency/fellowship is finished and my salary increases; I don't know where to invest my money; I prefer to invest my money in other venues (individual stocks, bonds, primary savings account, etc.) not associated with a retirement account.

13. I would be interested in learning more about personal finance, investing, and retirement savings: True, False.

14. With regards to retirement, I consider myself: more prepared than my colleagues in careers outside of residency/fellowship training, less prepared than my colleagues in careers outside of residency/fellowship training.

Allopathic orthopaedic residency programs across the country were solicited by email and responses were collected anonymously. A total of 20 programs were contacted based on ability to find contact information for the residents. The responses were aggregated for each question and not maintained on an individual basis. No funding was obtained for this study.

Results

A total of 85 residents anonymously completed the surveys in their entirety, with no partial or incomplete survey responses. Demographically, the majority of respondents were age 30 to 35 and married. The most highly represented resident education levels were post-graduate year (PGY)-2 (25.8%), PGY-3 (23.4%), and PGY-4 (20.0%) (Figure 1).

When debt status was examined, the majority (42.0%) of respondents had over $200,000 in outstanding student loans at the time of the survey. Credit card debt was examined separately and most of those surveyed paid their bill off in full each period (65.9%), although nearly a quarter of respondents carried over $1,000 of debt (21.2%). With regards to budgeting, only 30.9% of respondents create and stick to a monthly budget, and the majority (47.6%) do not create any type of budget (Figure 2).

In terms of financial literacy, 71.8% of the residents surveyed rated their own knowledge of finance, investing, and savings as at or below average. When the source of their knowledge on this topic was further explored, the majority (50.6%) gained this information from personal or independent research. In fact, only 4.7% reported that their information in finance, investing, and savings was derived from formal lectures or meetings provided by their residency or medical school. Finally, with regard to retirement savings, 74.1% believe they are less prepared than their colleagues and peers in careers outside of residency or fellowship training (Table 1). Of those surveyed, almost all (83.5%) report they would be interested in implementing formal residency education about person finance, investing, and retirement savings (Figure 3).

When retirement planning was examined, most (48.2%) put no money at all towards retirement. The most commonly cited reason for not investing in retirement was attributed to other expenses that do not allow for saving (34.9%). Only 50.6% had knowledge of whether their institution even offers a retirement account or matching program and 29.4% reported no such account exists through their institution. Program-offered advice on savings and retirement planning was reportedly available to 35.3% of respondents (Figure 4).

Discussion

Orthopaedic surgery residents carry substantial debt owing to multiple sources including car, home, and credit card payments as well as educational loans, similar to findings in other fields of medicine.[7–9, 12, 13] In this study, the majority of those surveyed report over $200,000 of educational debt still owed before factoring in any of the other aforementioned loans and repayments, all in the setting of a disproportionately low income given the years invested in education.[14] The implications of this debt burden are far reaching and influence not only factors such as stress and burnout in the short term, but future decisions regarding savings, loan repayment timing, and retirement planning.

While a substantial portion of this debt is unavoidable, any subsequent mismanagement of finances serves not only to prolong or deepen the amount owed, but can prohibit investment into retirement accounts or future savings. In our study, over 20% of residents surveyed reported more than $1,000 in unpaid monthly credit card debt, which is concerning, considering this is precisely the type of borrowing which needs to be addressed first.[10] Furthermore, relatively few residents create any type of budget, a practice known to be inversely correlated with indebtedness.[5] These early mistakes in debt management serve to protract the fiscal challenges young physicians must manage in their career.[14]

Compared to age-matched peers in non-medical fields, residents of all specialties save substantially less of their income.[5] This discrepancy is likely attributable to the significantly higher level of educational debt and associated loan repayments held by residents, as well as the age at which residents can logistically begin to save. The average college graduate enters the workforce at age 22 with a student loan debt of $28,000 and the opportunity to begin contributions to an employer-offered retirement plan.[15] By comparison, over 42% of surveyed orthopaedic residents in this study carry

Figure 1. Demographic Information

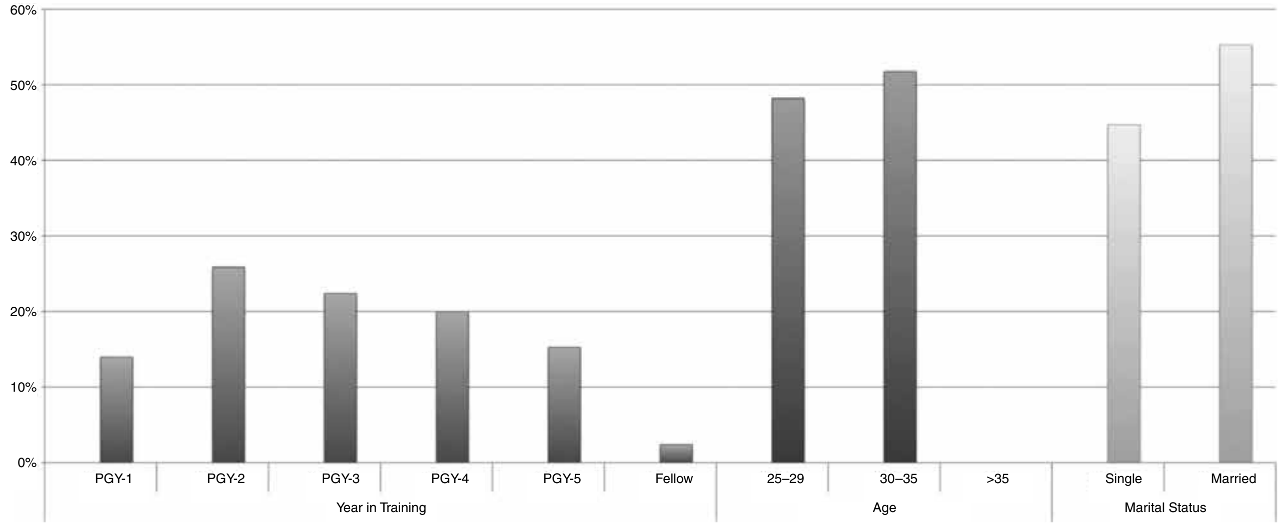


Figure 1 demonstrates demographic information for survey respondents highlighting distributions in year in training, age, and marital status.

Figure 2. Resident Debt

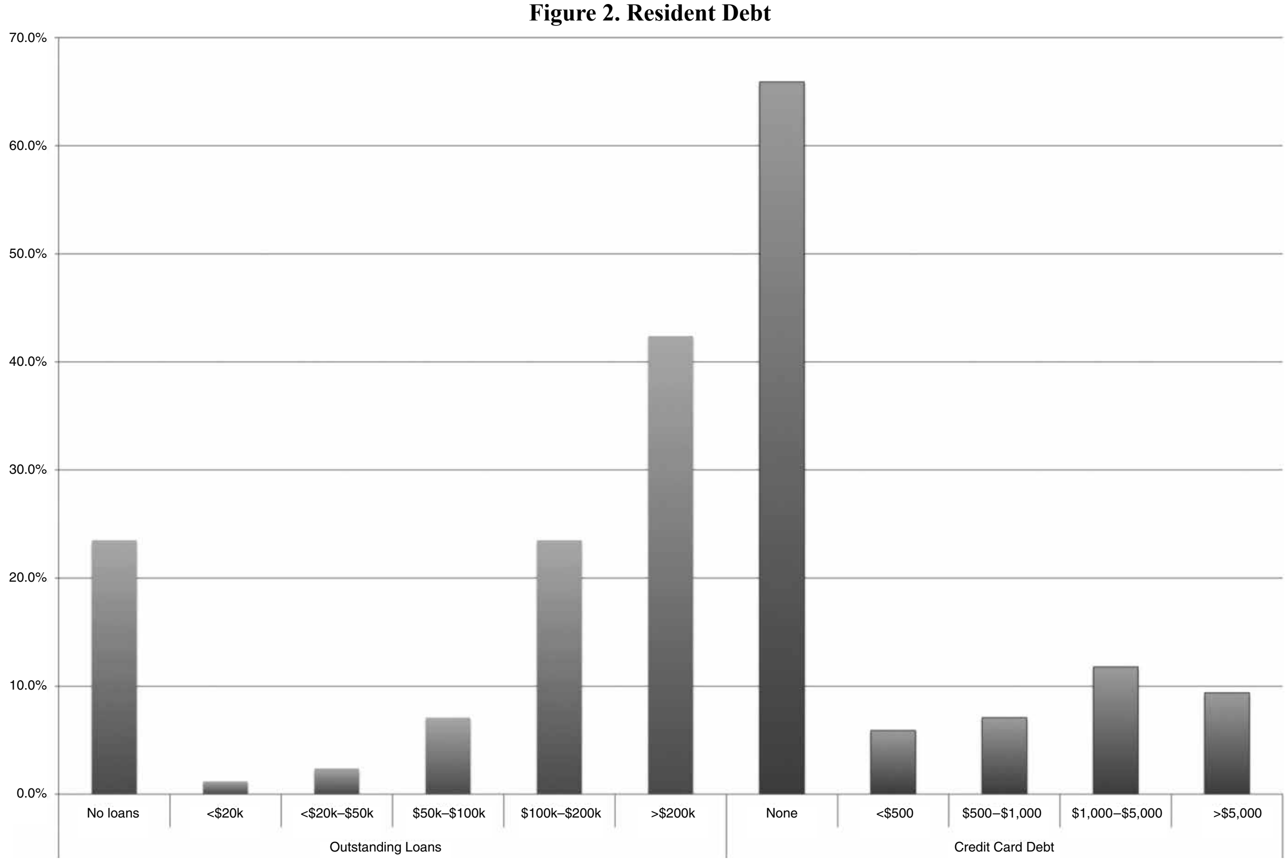


Figure 2 shows the current student loan and credit card debt status of respondents.

roughly seven times more educational debt, possibly explaining why the main reason cited for not investing in a savings or retirement account is lack of liquid assets to do so.

As a result, these residents feel meaningful contributions to life savings is not feasible until substantially later in life, and 74% believe they are thus less prepared for retirement than their peers outside of residency training. Given the principles of compound interest, a nearly 10-year delay in savings may profoundly decrease the amount that is cumulatively amassed. Despite the expected high future earnings for orthopaedic surgeons, this trend towards postponed savings puts the orthopaedic surgery resident at a distinct disadvantage when compared to the general population.

The ramifications of increased financial stressors are numerous and affect many other aspects of residents' life even beyond the management of debt repayment or retirement investing. When orthopaedic surgery residents were surveyed, a large debt burden was associated with increased burnout and depersonalization, decreased quality of life, and increased emotional dysfunction.[16] Similarly, West et al. found a positive correlation between increasing debt and resident burnout, emotional exhaustion, and poor quality of life in internal medicine.[9] As a complicating factor, many residents are actually increasing their work hours in an attempt to combat the financial and social consequences from their building debts. In a study examining finances in emergency medicine residents, Gaspy et al. found that 58% of residents deemed moonlighting a necessity in order to meet their financial needs.[7]

For residents, these worrisome implications in the setting of high debt and low retirement savings are magnified by low financial literacy. The majority of residents in our cohort estimated that their level of financial literacy was below average, which is supported by objective data in other studies to suggest this is likely an accurate assessment.[3, 14] For those residents that have any knowledge about investment, savings, and retirement investing, over 50% cited personal research as their primary source of information. In fact, less than 5% of respondents derive their financial knowledge from medical school or residency lectures or meetings.

Interestingly, in this survey, orthopaedic residents were overwhelmingly interested in building formal financial literacy training into their educational curriculum, with 83% in favor of such a program. Previous studies indicate that personal finance training influences the manner in which residents manage their income, yet there are currently no requirements upheld by the ACGME to implement such education.[3, 14] Providing this basic financial management education to residents could combat the plethora of negative consequences associated with their unique financial situation and would prepare them to enter the next phase of their careers.

Table 1. Survey Responses

Question	Response	Proportion
I would rate my knowledge of finance, investing, and saving as:	No knowledge	7.1%
	Some knowledge	37.6%
	Average	27.1%
	Above average	20.0%
	Very knowledgeable	8.2%
My current knowledge about personal finance, investing, and savings is PRIMARILY from:	Previous schooling (high school or formal college classes)	22.4%
	Personal research	50.6%
	Lectures or meetings provided by my medical school or residency institution	4.7%
	I have minimal knowledge on this topic	15.3%
	Other	7.1%
With regards to retirement savings, I consider myself:	More prepared than my colleagues in careers outside of residency/fellowship training (non-residents)	25.9%
	Less prepared than my colleagues in careers outside of residency/fellowship training	74.1%

Figure 3. Resident Interest

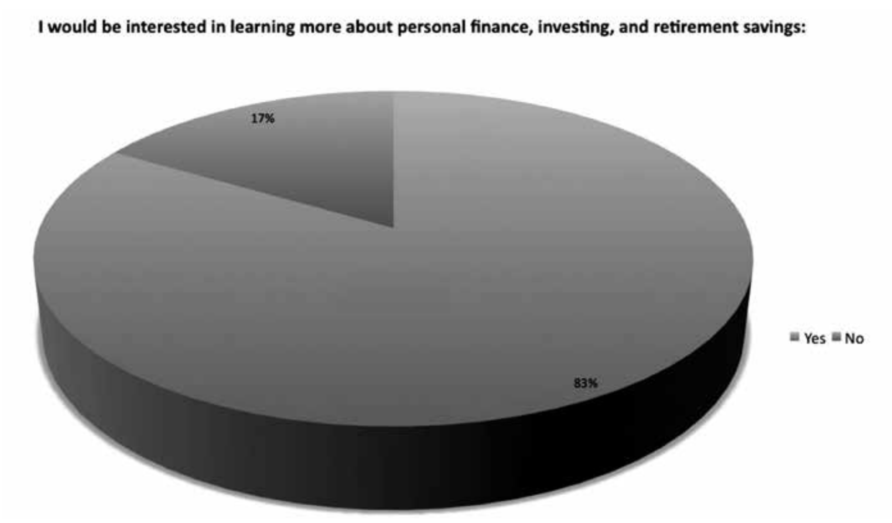


Figure 3 demonstrates the percent of survey respondents who expressed interest in increasing personal financial literacy.

Figure 4. Retirement Investing

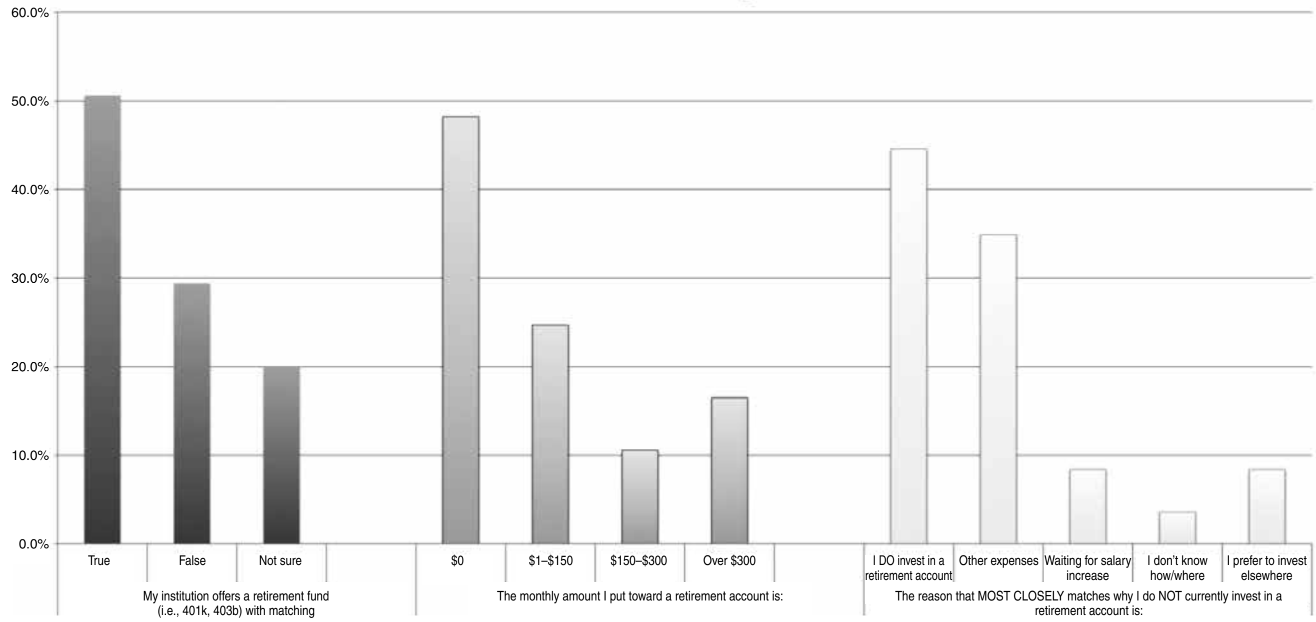


Figure 4 shows the percentage of programs offering retirement funds, amount of money saved for retirement each month by respondents, and the reported reasons that the surveyed residents are not saving for retirement.

References

1. AAMC [Internet]. Medical Student Education: Debt, Costs, and Loan Repayment Fact Card October 2015: https://www.aamc.org/download/447254/data/debtfactcard.pdf. Accessed January 31, 2016.
2. Kibbe MR, Troppmann C, Barnett CC, et al. Effect of educational debt on career and quality of life among academic surgeons. *Ann Surg*. 2009;249(2):342–348.
3. Mizell JS, Berry KS, Kimbrough MK, Bentley FR, Clardy JA, Turnage RH. Money matters: a resident curriculum for financial management. *J Surg Res*. 2014;192(2):348–355.
4. Teichman JM, Tongco W, MacNeily AE, Smart M. Personal finances of urology residents in Canada. *Can J Urol*. 2000;7(6):1149–1155.
5. Teichman JM, Cecconi PP, Bernheim BD, et al. How do residents manage personal finances? *Am J Surg*. 2005;189(2):134–139.
6. Teichman JM, Matsumoto E, Smart M, et al. Personal finances of residents at three Canadian universities. *Can J Surg*. 2005;48(1):27–32.
7. Glaspy JN, Ma OJ, Steele MT, Hall J. Survey of emergency medicine resident debt status and financial planning preparedness. *Acad Emerg Med*. 2005;12(1):52–56.
8. Frintner MP, Mulvey HJ, Pletcher BA, Olson LM. Pediatric resident debt and career intentions. *Pediatrics*. 2013;131(2):312–318.
9. West CP, Shanafelt TD, Kolars JC. Quality of life, burnout, educational debt, and medical knowledge among internal medicine residents. *JAMA*. 2011;306(9):952–960.
10. Lusardi A. Financial literacy: Do people know the ABCs of finance? *Public Underst Sci*. 2015;24(3):260–271.
11. Russell T. Resident debt and the American College of Surgeons. *Surgery*. 2002;132(5):783–784.
12. Finney B, Mattu G. National Family Medicine Resident Survey. Part 1: Learning environment, debt, and practice location. *Can Fam Physician*. 2001;47:117, 120, 126–118.
13. Doherty MJ, Schneider AT, Tirschwell DL. Will neurology residents with large student loan debts become academicians? *Neurology*. 2002;58(3):495–497.
14. Dhaliwal G, Chou CL. A brief educational intervention in personal finance for medical residents. *J Gen Intern Med*. 2007;22(3):374–377.
15. TICAS [Internet]. Student Debt and the Class of 2014. 10th Annual Report. 2014. http://ticas.org/sites/default/files/pub_files/classof2014.pdf. Accessed June 9, 2016.
16. Sargent MC, Sotile W, Sotile MO, Rubash H, Barrack RL. Stress and coping among orthopaedic surgery residents and faculty. *J Bone Joint Surg Am*. 2004;86-A(7):1579–1586.

Original Research

Heterotopic Ossification at External Fixator Pin Sites

COLIN MACELROY VROOME, MD;[1] SAQIB REHMAN, MD;[1] CHRISTOPHER FRAGASSI, BS[2]

[1]*Temple University Hospital, Department of Orthopedic Surgery, Philadelphia, PA;*
[2]*Temple University School of Medicine, Achley, PA*

Abstract

Background: Heterotopic ossification (HO) can occur as a result of muscle injury and its incidence has been noted to be associated with burns and head injury. We have noted that heterotopic bone formation can occur at external fixator pin sites in the thigh and pelvis. Whereas there has been increasing use of temporary external fixation for joint-spanning or damage control purposes, the literature is sparse on the incidence or risk factors for HO development at external fixator pin sites and whether this can affect quadriceps function.

Methods: A retrospective review was conducted for patients treated with external fixators for management of pelvic, femur, and tibia plateau fractures from 2010 to 2015. Follow-up radiographs of the affected site at a minimum of three months following fixator removal was required for inclusion in the study. Radiographs of 53 patients were examined for heterotopic ossification at external fixator pin sites. When present, HO was graded from one to three based on size. Patient data including gender, age, and presence of head injury was documented to assess for potential HO risk factors. Summary statistical analysis for continuous variables was performed as well as t-tests, chi squared tests, and Fischer exact tests. A p-value of less than 0.05 was used to deem results as statistically significant.

Results: Of the variables examined, only head injury was found to be a statistically significant risk factor for heterotopic ossification as it occurred in six of the nine patients with head injury compared to only 10 of the 44 patients without head injury ($p = 0.0159$). No patients at minimum of one-year follow up required excision of HO. Overall, there was a 30.2% incidence (16/53) of HO at external fixator pin sites. There were nine cases of grade 1 HO, six cases of grade 2 HO, and one case of grade 3 HO, and none of these required intervention for symptomatic HO.

Conclusions: Heterotopic ossification, while underreported in the literature, does occur at external fixator pin sites; however, the true incidence and clinical consequences have yet to be defined. Head injury was the only variable found to increase risk for HO at external fixator pin sites. Further study of HO at external fixator pin sites should include patient reported symptoms following fixator removal. Correlation of patient symptoms with HO grade may help predict need for prophylaxis for pin site HO in the future.

Introduction

Background

Heterotopic ossification (HO) refers to the formation of mature lamellar bone in non-osseous tissue.[13, 14, 16] Known causes include neurologic injuries, burns, ventilator dependence and critical illness, and skeletal trauma. Head trauma has been shown to be an independent risk factor even in the absence of skeletal trauma. Risk factors include duration of immobilization and degree of spasticity in the case of neurologic injury. Additionally, multiple studies have shown that increased muscular trauma during surgical dissection increases the risk of HO.[1, 6]

Heterotopic ossification has been cited to occur at rates of 30%, 17%, and 36% following total hip arthroplasty,[18] acetabular open reduction internal fixation,[2, 5] and floating elbow injuries,[3] respectively. A case report has also described HO at the site of distal femoral traction pins.[14]

Rationale

There is a lack of data regarding the occurrence of HO at external fixator pin sites. The authors of this paper have anecdotally noticed HO occurring at external fixator pin sites seen on follow-up radiographs long after fixator removal. It is unclear whether HO in these locations can affect quadriceps function, be a source of pain, and whether or not removal is helpful in symptomatic cases. This paper investigates the occurrence of HO occurring at external fixator pin sites as well as the risk factors and clinical implications.

Patients/Methods

A retrospective case series study was performed in an urban academic medical center over a five-year period from January 1, 2010 to January 1, 2015. All external fixators were placed during this period allowing for a minimum one-year follow up for all patients. Approval was received from the institutional review board to study all patients who were placed in pelvic, femur, or knee-spanning external fixators during this period. This resulted in 53 patients with pelvic, femur, or tibia plateau fractures who were placed in external fixators and had follow-up radiographs of the affected site at a minimum of three months following fixator removal. External fixator pin placement was individualized based on fracture location and morphology for all patients. Plain radiographs were reviewed and the location and size of heterotopic ossification was documented when present. A grading system was created to determine whether radiographic parameters can predict when symptomatic HO occurs. Heterotopic ossification was graded from zero to three as being absent, less than 2 cm growth, between 2 and 5 cm of growth, and greater than 5 cm of bone growth, respectively (Figures A–C). Grade was determined by measurement of the heterotopic ossification in its largest dimension. Need for symptomatic excision of heterotopic ossification was also documented by reviewing need for follow-up procedures at minimum one year. Additionally, gender, age, and presence of head injury were recorded to assess for risk factors with head injury defined as any cranial abnormality seen on computed tomography (CT) of the head. Multiple external fixators on a patient were treated as separate occurrences.

Summary statistical analysis for continuous variables was performed as well as t-tests, chi squared tests, and Fischer exact tests where applicable. A p-value of less than 0.05 was used to deem results as statistically significant.

Results

Heterotopic ossification at prior external fixator pin sites was found in 16 of 53 patients (overall 30.2% incidence of HO at external fixator pin sites). Six of nine patients with head injury were found to have HO at external fixator pin sites compared to 10 of the 44 patients who did not have injury ($p = 0.0159$), and this was the only statistically risk factor found (Table 1). Neither age nor gender were found to be risk factors.

Heterotopic ossification was recorded and documented based on size. There were nine cases of grade 1 HO, six cases of grade 2 HO, and one case of grade 3 HO. None of

Figure A. Grade 1 HO: 1 cm at supra-acetabular pin site in poly-trauma patient requiring temporary stabilization with pelvic external fixator.

Figure B. Grade 2 HO: 3.8 cm at distal femur pin site following knee-spanning external fixator for tibial plateau fracture requiring initial external fixator and four-compartment fasciotomy.

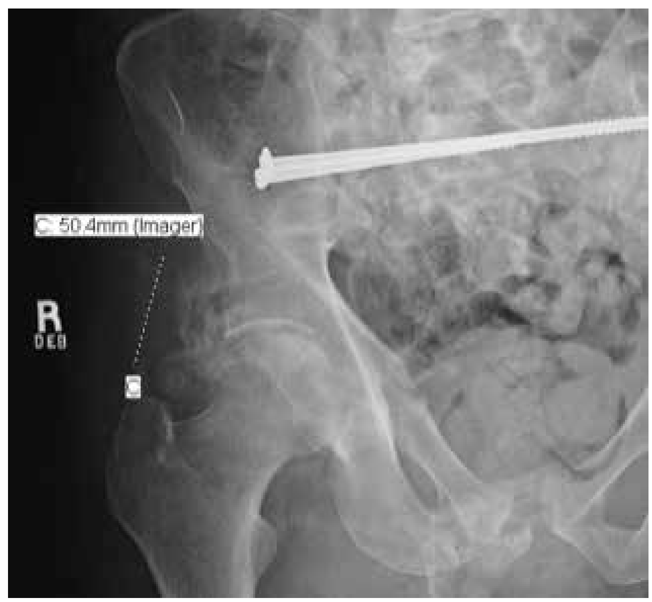


Figure C. Grade 3 HO: 5 cm at supra-acetabular pin sites following temporary pelvic external fixator in poly-trauma patient.

these patients had excision of symptomatic HO at minimum one-year follow up.

Table 1. Heterotopic Ossification Occurrence Compared to Other Factors

	Developed Heterotopic Ossification	No Heterotopic Ossification	P Value
Had Head Injury	6 (66.7%)	3 (33.3%)	0.0159
No Head Injury	10 (22.7%)	34 (77.3%)	

Discussion

Heterotopic ossification is a phenomenon known to occur at up to 40% incidence following burns, neurologic injury, critical illness with ventilator dependence and prolonged immobilization, total hip arthroplasty, and acetabular and elbow trauma.[2, 5, 13, 14, 16, 18] The authors have anecdotally noticed the occurrence of HO at external fixator pin sites and the lack of investigation of this phenomenon in the literature.

External fixators are an accepted treatment for early stabilization of pelvic, femur, and tibia plateau fractures in poly-trauma patients.[7, 10, 12] Pelvic external fixators can specifically be used to decrease hemorrhage, improve pain, and permit early patient mobilization. Femur and knee-spanning external fixators can be used for temporary stabilization in the poly-trauma patient or when soft tissue or vascular injury prevent early definitive fixation.

Despite the lack of literature describing HO at external fixator pin sites, increased muscular trauma during surgical exposure has been shown to increase the incidence of HO, with an incidence or 33.3%, 36.9%, and 42.1% following trochanteric flip, posterior, and anterior approaches to the hip, respectively.[1, 6] This may be indicative of why HO occurs at external fixator pin sites. Basic science studies have also shown that muscle-derived stem cells are major osteogenic precursor cells involved in the formation of heterotopic ossification following trauma to muscle specimens.[8, 9] This is thought to occur following muscle trauma and upregulation of alkaline phosphatase, which is similar to that which occurs in bone marrow derived stem cells. Traumatized muscle also shows increased BMP-4 and hypoxia-inducible factor expression leading to increased angiogenesis through vascular endothelial growth factor transcription and resultant osteogenesis.[9, 15] Damaged hypoxic muscle tissue also results in COX-2 upregulation which highlights the role of oral HO prophylaxis with nonsteroidal anti-inflammatory drugs (NSAIDs) to inhibit pro-inflammatory enzymes.[17] Circulating cytokines and growth factors including interlukin-5, growth hormone, and insulin like growth factor-1 are also implicated in the formation of HO in critically-ill patients.[14]

There are a number of limitations to this study given its retrospective nature. The study was limited by the data available at follow up, specifically the presence of standardized radiographs of prior external fixator pin sites at follow up. Femur pin sites were not routinely monitored following removal of knee spanning external fixators, so HO was only reported when seen on knee radiographs of tibia plateau fractures at follow up. For this reason, it should be understood that the incidence of HO at external fixator pin sites reported in this paper is only an estimate.

The only risk factor for HO in this study was head injury. Neurologic injury is a known risk factor for heterotopic ossification.[13] Of the risk factors investigated in this study, only head injury was found to be a significant predictor of heterotopic ossification at external fixator pin sites. This both shows concordance between the findings of this paper and prior literature, but also shows that heterotopic ossification can still occur at pin sites in patients who do not have neurologic injury as a risk factor.

This paper found a 30.2% incidence of heterotopic ossification occurring at external fixator pin sites. This is similar to the incidence of HO following total hip arthroplasty (30%)[18] and floating elbow injuries (36%).[3]

Grading of HO in this study did not predict need for excision as no patients required HO excision at one-year follow up. The Brooker Classification has been described for HO about the hip;[4] however, because it is specific to the hip joint, a new grading system was created to determine if the size of heterotopic ossification had prognostic value on patient symptoms. Due to the retrospective nature of the study, the only way to measure this was based on whether patients required HO excision at final follow up. This is a possible area for future study as the determination of not only the incidence of HO, but symptomatic HO, would help guide the need for prophylaxis with either NSAIDs or radiation therapy.[11] This would require a standardized assessment of patient symptoms at pin sites following external fixator removal.

Conclusions

This paper describes the occurrence of heterotopic ossification at external fixator pin sites, which has not been previously described in the literature. In concordance with the literature, head injury was found to be a risk factor for the occurrence of HO. Due to the retrospective nature of the study, the only way to identify symptomatic HO was based on need for excision and no patients at one-year follow up required excision of symptomatic HO. Future studies with standardized follow up to assess patient symptoms and standardized radiographs of external fixator pin sites would help to correlate patient symptoms with radiographic findings and also better quantify the incidence of HO at external fixator pin sites.

References

1. Anthonissen J, Ossendorf C, Hock JL, et al. The role of muscular trauma in the development of heterotopic ossification after hip surgery: An animal-model study in rats. *Injury.* 2016;47:613–6.
2. Baschera D, Rad H, Collopy D, Zellweger R. Incidence and clinical relevance of heterotopic ossification after internal fixation of acetabular fractures: retrospective cohort and case control study. *J Orthop Surg Res.* 2015;10:1.
3. Bauer AS, Lawson BK, Bliss RL, Dyer GS. Risk factors for posttraumatic heterotopic ossification of the elbow: case-control study. *J Hand Surg Am.* 2012;37:1422–9.e6.
4. Brooker AF, Bowerman JW, Robinson RA, Riley LH. Ectopic ossification following total hip replacement. *J Bone Joint Surg Am.* 1973;55:1629–32.
5. Elhassan Y, Abdelhaq A, Piggott RP, Osman M, McElwain JP, Leonard M. Heterotopic Ossification following acetabular fixation: Incidence and risk factors: 10-year experience of a tertiary centre. *Injury.* 2016;47:1332–6.
6. Guo JJ, Tang N, Yang HL, Qin L, Leung KS. Impact of surgical approach on postoperative heterotopic ossification and avascular necrosis in femoral head fractures: a systematic review. *Int Orthop.* 2010;34:319–22.
7. Haller JM, Holt D, Rothberg DL, Kubiak EN, Higgins TF. Does Early versus Delayed Spanning External Fixation Impact Complication Rates for High-energy Tibial Plateau and Plafond Fractures? *Clin Orthop Relat Res.* 2016;474:1436–44.
8. Jackson WM, Aragon AB, Bulken-Hoover JD, Nesti LJ, Tuan RS. Putative heterotopic ossification progenitor cells derived from traumatized muscle. *J Orthop Res.* 2009;27:1645.
9. Kluk MW, Ji Y, Shin EH, et al. Fibroregulation of mesenchymal progenitor cells by BMP-4 after traumatic muscle injury. *J Orthop Trauma.* 2012;26:693–8.
10. Pairon P, Ossendorf C, Kuhn S, Hofmann A, Rommens P. Intramedullary nailing after external fixation of the femur and tibia: a review of advantages and limits. *Eur J Trauma Emerg Surg.* 2015;41:25–38.
11. Pakos EE, Ioannidis JP. Radiotherapy vs. nonsteroidal anti-inflammatory drugs for the prevention of heterotopic ossification after major hip procedures: a meta-analysis of randomized trials. *Int J Radiat Oncol Biol Phys.* 2004;60:888–95.
12. Poenaru DV, Popescu M, Anglitoiu B, Popa I, Andrei D, Birsasteanu F. Emergency pelvic stabilization in patients with pelvic posttraumatic instability. *Int Orthop.* 2015;39:961–5.
13. Ranganathan K, Loder S, Agarwal S, et al. Heterotopic ossification: basic-science principles and clinical correlates. *J Bone Joint Surg Am.* 2015;97:1101–11.
14. Specht LM, Gupta S, Egol KA, Koval KJ. Heterotopic ossification of the quadriceps following distal femoral traction: a report of three cases and a review of the literature. *J Orthop Trauma.* 2004;18:241–6.
15. Sun X, Wei Y. The role of hypoxia-inducible factor in osteogenesis and chondrogenesis. *Cytotherapy.* 2009;11:261–7.
16. Van Kampen P, Martina J, Vos P, Hoedemaekers C, Hendricks H. Potential risk factors for developing heterotopic ossification in patients with severe traumatic brain injury. *J Head Trauma Rehabil.* 2011;26:384–91.
17. Winkler S, Niedermair T, Füchtmeier B, et al. The impact of hypoxia on mesenchymal progenitor cells of human skeletal tissue in the pathogenesis of heterotopic ossification. *Int Orthop.* 2015;39:2495–501.
18. Zhu Y, Zhang F, Chen W, Zhang Q, Liu S, Zhang Y. Incidence and risk factors for heterotopic ossification after total hip arthroplasty: a meta-analysis. *Arch Orthop Trauma Surg.* 2015;135:1307–14.

Original Research

Significant Intraoperative Neuromonitoring Alerts in Patients Undergoing Fusion for Adolescent Idiopathic Scoliosis: What Are the Outcomes of Surgery?

James T. Bennett, MD;[1] Robert J. Ames, MD;[1] Amer F. Samdani, MD;[2] Jahangir K. Asghar, MD;[3] Giuseppe Orlando, MD;[4] Joshua M. Pahys, MD;[2] Burt Yaszay, MD;[5] Firoz Miyanji, MD;[6] Baron S. Lonner, MD;[7] Ronald K. Lehman, MD;[8] Peter O. Newton, MD;[5] Patrick J. Cahill, MD;[9] Randal R. Betz, MD[10]

[1]Temple University School of Medicine, Philadelphia, PA; [2]Shriners Hospitals for Children, Philadelphia, PA; [3]Nicklaus Children's Hospital, Miami, FL; [4]Department of Orthopaedics and Traumatology, University of Messina, Messina, Italy; [5]Rady Children's Hospital, San Diego, CA; [6]BC Children's Hospital, Vancouver, British Columbia, Canada; [7]Mount Sinai Beth Israel Medical Center, New York, NY; [8]Washington University School of Medicine, St. Louis, MO; [9]Children's Hospital of Philadelphia, Philadelphia, PA; [10]The Institute for Spine and Scoliosis, Lawrenceville, NJ

Abstract

Summary: Intraoperative neurophysiologic monitoring (IONM) is widely used during the surgical treatment of patients with adolescent idiopathic scoliosis (AIS). We sought to determine the effect of IONM alerts on outcomes in these patients. IONM alerts occurred in 5.3% of patients undergoing fusion for AIS. These patients had larger preoperative deformity, longer operative times, more levels fused, increased estimated blood loss (EBL), and more cell saver transfused. Outcomes for patients having IONM alerts resulted in no permanent neurological deficits, similar Cobb correction, and comparable two-year SRS scores as those without alerts.

Hypothesis: Patients undergoing surgery for AIS who experience an IONM alert have similar outcomes as to those with no alert.

Design: Retrospective review of prospectively collected multicenter database of patients with AIS with a minimum two-year follow-up.

Introduction: Intraoperative neurophysiologic monitoring (IONM) is widely used during spinal fusion for AIS. Confidence in IONM data can allow surgeons to proceed with surgery even after an alert, assuming the data recovers. We sought to determine the outcomes of surgery after a significant IONM alert.

Methods: A prospectively collected multicenter database was retrospectively reviewed to identify patients with AIS who were surgically treated with IONM and had at least two years of follow-up. Those patients who experienced a significant loss of IONM (≥50% drop in SSEPs ± tcMEPs) were identified. Six hundred and seventy-six patients were divided into two cohorts: those who experienced IONM changes in the lower extremities ("A" Group) and those who did not ("NA" Group).

Results: 5.3% (36/676) of the patients experienced IONM alerts. The alert group had larger major preoperative Cobb angles (A = 61 ± 13°, NA = 55 ± 12°, $p < 0.01$), more levels fused (A = 12 ± 2, NA = 11 ± 2, $p < 0.01$), longer operative times (A = 357 ± 157 min, NA = 298 ± 117 min, $p < 0.01$), higher EBL (A = 1857 ± 1323 mL, NA = 999 ± 796 mL, $p < 0.01$), and more cell saver transfused (A = 527 ± 525 mL, NA = 268 ± 327 mL, $p < 0.01$). After intervention, IONM signals improved in 97% (35/36) of patients with return of data averaging 20 minutes. Two procedures were aborted, one in the patient where IONM signals did not improve initially. This patient experienced unilateral weakness that recovered within 72 hours. In those patients where the procedure was completed, postoperative percent Cobb correction (A = 66 ± 13%, NA = 64 ± 19%, $p = 0.53$), percent rib prominence correction (A = 49 ± 36%, NA = 47 ± 46%, $p = 0.83$), and sagittal profile (A = 23 ± 10°, NA = 22 ± 2°, $p = 0.58$) was similar to those without an IONM change. Two-year SRS-22 outcome scores were similar between the two cohorts.

Conclusion: Significant IONM changes occurred in 5.3% of patients undergoing fusion for AIS. These patients had larger preoperative deformity, longer operative times, more levels fused, increased EBL, and more cell saver transfused. Return of IONM data guided the surgeon to safely complete the procedure with similar correction as to those without a change.

Introduction

The reported incidence of spinal cord injury following scoliosis surgery varies from 0.3% to 1.4%.[1–5] MacEwen et al.[3] first evaluated this complication in a report for the Scoliosis Research Society (SRS) from 1965−1971, reporting a 0.72% incidence of neurologic complications. Of the 74 patients identified, 55% were reported as having a complete paraplegia and 45% as having an incomplete injury. In 2006, the SRS Morbidity and Mortality Committee identified a 0.5% incidence of postoperative neurologic deficits in 31 of 6,334 cases performed for AIS, none of which were complete injuries.[6] Full recovery occurred in 61% of those patients.

Nash et al.[7] introduced the technique of intraoperative neuromonitoring (IONM) to detect spinal cord injury utilizing somatosensory evoked potentials (SSEPs) to monitor dorsal column function in 1977. Somatosensory data are recorded at baseline and periodically throughout the case to monitor for changes in amplitude and latency. A decrease in amplitude of 50−80%, or increased latency of >10% from baseline, are considered significant for spinal cord compromise.[8–11] SSEPs have been used in spinal deformity surgery and have been shown to improve neurologic outcome.[12–14] However, SSEPs may be unable to detect injuries to the descending anterior motor tracts or anterior horn leading to high false negative rates.[15, 16]

In the 1980s, motor-evoked potentials with either electrical or magnetic stimulation of the cortex or spinal cord were used to depolarize the pyramidal tract neurons to produce compound muscle action potentials measured by needle electrodes placed in the distal muscle groups.[17, 18] Studies have shown that transcranial motor-evoked potentials (TcMEPs) may provide up to 100% sensitivity but may also result in some false positive results.[19, 20]

Hence, multimodality neuromonitoring with SSEPs and tcMEPs are often used in combination to improve the sensitivity and specificity of neuromonitoring in scoliosis surgery.[10, 21–23] Kundnani et al.[20] reported a sensitivity of 100%, a specificity of 98.5%, and a positive predictive value of 85% when combined multimodality neuromonitoring was used for the surgical treatment of AIS. Neuromonitoring changes can occur in 13% of patients undergoing surgery for scoliosis,[11] with most recovering with appropriate intervention. Confidence in IONM data may allow surgeons to proceed with surgery even after an alert, assuming the data recover. Although the surgical procedure may be completed, it is unclear how the outcomes compare to those patients without an alert; determining this is the purpose of this study.

Materials and Methods

IRB approval for the study was obtained locally from each contributing institution's review board, and consent was obtained from each patient prior to data collection. A prospectively collected multicenter database was retrospectively reviewed to identify patients with AIS surgically treated with IONM with at least two years of follow-up.

Allowing for institutional differences, patients were given total intravenous anesthetic agents conducive to IONM, and muscle relaxants were either not used or avoided following exposure of the spine so as not to compromise neuromonitoring data. Neuromonitoring with SSEPs and tcMEPs was performed by each individual institution's protocol by trained surgical neurophysiologists and was achieved successfully in all patients. Serial monitoring was performed from the time of positioning to the time the patient was awakened from anesthesia in both lower and upper-extremities, with stimulus amplitude adjusted according to each individual patient. The upper extremities served as a neurophysiologic control and could also be used to identify positional brachial plexopathy. Both cortical and subcortical SSEPs were elicited most commonly using the posterior tibial and ulnar nerves. Cortical potentials were recorded from subdermal needle electrodes attached to standard cranial locations. Transcranial motor evoked potentials were recorded bilaterally, most commonly from the first dorsal interosseous muscles in the upper extremity and bilaterally from the anterior tibialis, quadriceps, and gastrocnemius muscles in the lower extremities (specific muscle groups varied by institution). Patients who experienced a significant loss of IONM (≥50% reduction in SSEPs and/or tcMEPs) were identified.

In those patients that experienced a critical reduction of signals, a sequence of events was initiated based on each individual center's protocol and patient specifics.[24] The triggering event was prospectively recorded as one of the following: hypotension, placement of instrumentation, curve correction maneuver, anesthesia related, and other. The intervention was also recorded in one or more of the following categories: blood pressure elevation, wake-up test, removal of instrumentation, reduction of correction, steroids administered, operation aborted.

Radiographic and clinical measurements were recorded preoperatively and at two years after surgery. Data fields included age, gender, Lenke curve type, major coronal Cobb angle, kyphosis (T5-T12), rib prominence, number of levels fused, osteotomies performed, operating time, estimated blood loss (EBL), and volume of cell saver blood transfused.

The patients were divided into two cohorts: those who experienced IONM changes in the lower extremities ("A" Group) and those who did not experience an alert ("NA" Group). Patients with an upper extremity alert or those undergoing intraoperative traction were excluded. The two cohorts were compared using clinical and radiographic measures. Statistical analysis was performed using SPSS 12.0.2 statistical package (SPSS Inc., Chicago, IL). Results were reported as means ± standard deviation (SD) with a significance level of less than 0.05.

Results

Patient Demographics (Table 1)

Six hundred and seventy-six patients were identified, of which 81.2% of the patients were female. The plurality of the curves (42.9%) were Lenke type 1, followed by Lenke type 2 (23.4%), Lenke type 5 (13.6%), Lenke type 6 (10.2%), Lenke type 3 (6.4%), and Lenke type 4 (3.6%). The average major Cobb angle for the cohort was 58° ± SD, with an average kyphosis from T5-T12 of 23° ± SD. The majority of the patients (76.8%) underwent posterior single column osteotomies.

Table 1. Patient Demographics

Patients (N)	676
Females N (%)	542 (81.2)
Lenke Type N (%)	
1	290 (42.9)
2	158 (23.4)
3	43 (6.4)
4	24 (3.6)
5	92 (13.6)
6	69 (10.2)
Ponte Osteotomy N (%)	519 (76.8)
Major Cobb (°)	58
Kyphosis (T5-T12) (°)	23

Alert vs. No Alert Comparison (Table 2)

Thirty-six of the patients (5.3%) experienced IONM alerts. The alert ("A") group had larger preoperative main Cobb angles than the no-alert ("NA") group (A = 61 ± 13°, NA = 55 ± 12°, p < 0.01), more levels fused (A = 12 ± 2, NA = 11 ± 2, p < 0.01), longer operative times (A = 357 ± 157 min, NA = 298 ± 117 min, p < 0.01), higher EBL (A = 1857 ± 1323 mL, NA = 999 ± 796 mL, p < 0.01), and more cell saver blood transfused (A = 527 ± 525 cc, NA = 268 ± 327 cc, p < 0.01). The frequency of posterior column osteotomies were similar between the two groups (A = 83.3%, NA = 75.3%, p = 0.32). After the intervention in response to the alert, IONM signals improved in 97% (35/36) of patients with the time for return of data averaging 20 minutes. In those patients where the procedure was completed, postoperative percent main Cobb correction (A = 66 ± 13%, NA = 64 ± 19%, p = 0.53), percent rib prominence correction (A = 49 ± 36%, NA = 47 ± 46%, p = 0.83), and sagittal profile (A = 23 ± 10°, NA = 22 ± 2°, p = 0.58) were similar to those without an IONM change. In addition, two-year SRS-22 patient reported outcome scores were similar between the two cohorts.

Table 2. Comparison Alert vs. No Alert

	Alert "A"	No Alert "NA"	P-value
Patients N (%)	36 (5.3)	640 (80.1)	—
Levels Fused	12 ± 2	11 ± 2	<0.01
EBL (cc)	1857 ± 1323	999 ± 796	<0.01
Cell Saver Transfused (cc)	527 ± 525	268 ± 327	<0.01
Ponte Osteotomy N (%)	30 (83.3)	482 (75.3)	0.32
Operative Time (min)	357 ± 157	298 ± 117	<0.01
Pre-op Main Cobb (°)	61 ± 13	55 ± 12	<0.01
2 Yr Post-op Cobb % Correction (%)	66 ± 13	64 ± 19	0.53
2 Yr Rib Prominence % Correction (%)	49 ± 36	47 ± 46	0.83
2 Yr Post-op Thoracic Kyphosis (T5-T12) (°)	23 ± 10	22 ± 2	0.58
2 Yr Post-op SRS Total Scores	4.4 ± 0.5	4.5 ± 0.4	0.51

Triggering Event (Table 3)

The surgeon reported triggering event for the alert included: placement of implants in eight patients (22.2%), hypotension in seven patient (19.4%), curve correction maneuvers in six patients (16.7%), anesthesia related events in two patients (5.6%), "other" events in six patients (16.7%), and were unknown or not reported in seven patients (19.4%).

Table 3. Triggering Event

Triggering Event	N (%)
Placement of Instrumentation	8 (22.2)
Hypotension	7 (19.4)
Curve Correction Maneuvers	6 (16.7)
Other	6 (16.7)
Anesthesia Related	2 (5.6)
Not Reported	7 (19.4)

Intervention (Table 4)

The majority of IONM signals improved by increasing the mean arterial pressure in 22 patients (61%). Ten patients (28%) underwent a Stagnara wake-up test, seven patients (19%) underwent removal of instrumentation, three patients (8%) had release of their correction, three patients (8%) were administered steroids, and two procedures (6%) were aborted (one in which IONM signals did not return).

Table 4. Intervention

Intervention	N (%)
BP Elevation	22 (61)
Wake-up Test	10 (28)
Removal of Instrumentation	7 (19)
Reduction of Correction	3 (8)
Steroids Administered	3 (8)
Operation Aborted	2 (6)

SRS-22 Scores (Table 5)

Preoperatively, the two groups had similar SRS-22 scores in all categories except for satisfaction, where the alert group had higher satisfaction scores (A = 4.1 ± 0.90, NA = 3.67 ± 0.94, p = 0.02). Postoperatively, the two groups had similar SRS-22 scores in all categories including total scores (A = 4.41 ± 0.47, NA = 4.47 ± 0.42, p = 0.43).

Aborted Procedures

Of the two cases that were aborted, one of the patients had return of signals. In this patient, motor signals were lost but returned after blood pressure was increased; however, the

Table 5. SRS-22 Scores

	Preoperative Mean ± SD (range)			2 Year Postoperative Mean ± SD (range)		
	Alert "A"	No Alert "NA"	P-value	Alert "A"	No Alert "NA"	P-value
Pain	4.00 ± 0.62	4.10 ± 0.69	0.34	4.32 ± 0.73	4.44 ± 0.56	0.37
Self-Image	3.44 ± 0.82	3.41 ± 0.67	0.82	4.48 ± 0.49	4.46 ± 0.54	0.84
General Function	4.34 ± 0.64	4.46 ± 0.54	0.29	4.61 ± 0.59	4.68 ± 0.43	0.52
Mental Health	3.93 ± 0.74	4.04 ± 0.70	0.38	4.13 ± 0.67	4.28 ± 0.68	0.23
Satisfaction	4.10 ± 0.90	3.67 ± 0.94	0.02	4.73 ± 0.44	4.61 ± 0.64	0.14
Total	3.92 ± 0.52	3.96 ± 0.47	0.66	4.41 ± 0.47	4.47 ± 0.42	0.43

surgeon decided to abort the procedure and complete it at a later date. In the other case, motor signals were lost and did not return. A wake-up test was performed and the patient was noted to have right lower extremity weakness. The case was aborted, and the patient recovered full power of her right lower extremity within 72 hours.

Discussion

Given the known risk of neurological compromise during complex spinal surgery, IONM aids the surgeon by providing real time data on the patient's neurologic status. The goal of IONM is to prevent neurologic injury and permit change of intraoperative strategy to minimize or reverse any deficit. The advent of IONM also potentially allows for more aggressive maneuvers than might otherwise have been undertaken such as maximal deformity correction. Our results show that the majority of posterior spinal fusions for AIS can be completed safely with the help of IONM, and even when an alert is detected, those patients have similar clinical and radiographic results to those patients who did not experience a change in IONM.

In 2002, Noonan et al.[25] attempted to determine the factors related to changes in SSEPs with or without motor evoked potentials in a retrospective review of patients with AIS undergoing surgery. False-positive readings were found in 4.5% of the patients and was seen more frequently in those patients with labile mean arterial pressures; they recommended using the Stagnara wake-up test when threshold monitoring changes occur due to the possibility that spinal cord injury may exist even when monitored values return to baseline. However, others argue that the wake-up test is not effective at identifying subtle weakness, timing, or location of injury, especially in those patients who are unable to follow commands due to intellectual/developmental disabilities or preoperative weakness.[26] In addition, the wake-up test risks self-extubation, loss of IV access, loss of positioning, air embolus, and/or event recollection.[26]

In 2010, Vitale et al.[11] studied the clinical factors associated with IONM changes utilizing multimodality IONM in 162 pediatric patients undergoing fusion for scoliosis and reported an incidence of changes in 13% of their patients. They identified cardiopulmonary comorbidity as an independent risk factor for sustaining a change and found the most common cause of an alert was curve correction followed by hypotension. Our study showed different results, with placement of instrumentation followed by hypotension being the most common causes of neuromonitoring changes. Their paper included patients with congenital scoliosis, thus tempering direct comparison. In the same year, Kamerlink et al.[27] assessed the risk factors for neuromonitoring changes in consecutive pediatric and adult spinal deformity patients treated at a single institution. They found that in patients with scoliosis, neuromonitoring changes increased with larger BMI, EBL, operative time, and postoperative coronal thoracolumbar curve magnitude. Our study showed similar results, with neuromonitoring changes occurring in patients with longer operative times, higher EBL, and more cell saver transfused. It is important to note that intraoperative alerts may have caused extended operative times, due to surgeons spending time identifying and treating the neuromonitoring changes, and in general proceeding cautiously.

In 2012, Feng et al.[28] evaluated the efficacy of multimodal IONM for predicting iatrogenic neurologic injury during correction of spinal deformity and evaluated the risks factors for neuromonitoring changes. They found that multimodal IONM can predict events of neurologic injury and, with adjustment of surgical strategy, help prevent irreversible deficits. They found that surgeries involving an osteotomy procedure, correcting kyphosis, and a preoperative Cobb angle of more than 90° were risk factors for possible neuromonitoring changes. Our study showed similar results where patients with larger preoperative main Cobb angles and more levels fused were more likely to experience an IONM alert. Unlike their paper, we did not find an association between increased alerts and osteotomies, likely because the highest grade in our cohort was a Ponte, versus the more aggressive pedicle subtraction osteotomy in the Feng et al. series.

Although many studies have evaluated the efficacy and risk factors of IONM, to our knowledge, this is the first study to analyze the radiographic and clinical outcomes of those patients with neuromonitoring alerts. We anticipated that following the IONM change and appropriate surgical response, surgeons may be more cautious with respect to correction or some might abort the procedure even after the return of signals. Interestingly, in those patients who experienced an alert, postoperative percent main Cobb correction, percent rib prominence correction, and sagittal profile were similar to those without an IONM alert. In addition, two-year SRS scores were similar between the two cohorts. This suggests that IONM is not only beneficial at preventing postoperative neurological injury but also reassures the surgeon that she or he may often be able to continue the case without the need to abort and can generally achieve similar correction in all three planes, with similar HRQoL outcomes in those patients who experience alerts.

The current study was limited because it was a retrospective review of a prospectively collected multicenter database. Due to the multicenter nature of the study, some variability in anesthesia protocols exist, and surgeons performed different interventions when an alert was encountered. However, this may better represent the diverse surgical practices involved with modern scoliosis surgery. In addition, the multiple centers were required to collect enough patients for a meaningful analysis.

In conclusion, significant IONM changes occurred in 5.3% of patients undergoing posterior spinal fusion without intraoperative traction for AIS. These patients had larger preoperative deformity, longer operative times, more levels fused, increased EBL, and more cell saver transfused. Outcomes for patients having IONM alerts resulted in no permanent neurological deficits, similar correction in all three planes, and comparable two-year SRS scores as those without alerts.

References

1. Carreon LY, Puno RM, Dimar JR, 2nd, Glassman SD, Johnson JR. Perioperative complications of posterior lumbar decompression and arthrodesis in older adults. *J Bone Joint Surg Am.* 2003 Nov;85-A(11): 2089–92.
2. Owen JH. The application of intraoperative monitoring during surgery for spinal deformity. *Spine (Phila Pa 1976).* 1999;24(24):2649–62.
3. MacEwen GD, Bunnell WP, Sriram K. Acute neurological complications in the treatment of scoliosis. A report of the Scoliosis Research Society. *J Bone Joint Surg Am.* 1975;57:404–8.
4. Wilbur RG, Thompson GH, Shaffer JW, Brown RH, Nash CL. Postoperative neurological deficits in segmental spinal instrumentation. A study using spinal cord monitoring. *J Bone Joint Surg Am.* 1984;66A: 1178–87.
5. Bridwell KH, Lenke LG, Baldus C, Blanke K. Major intraoperative neurologic deficits in pediatric and adult spinal deformity patients. Incidence and etiology at one institution. *Spine (Phila Pa 1976).* 1998 Feb 1;23(3):324–31.
6. Coe JD, Arlet V, Donaldson W, Berven S, Hanson DS, Mudiyam R, et al. Complications in spinal fusion for adolescent idiopathic scoliosis in the new millennium. A report of the Scoliosis Research Society Morbidity and Mortality Committee. *Spine (Phila Pa 1976).* 2006 Feb 1; 31(3):345–9.
7. Nash CL, Jr., Lorig RA, Schatzinger LA, Brown RH. Spinal cord monitoring during operative treatment of the spine. *Clin Orthop Relat Res.* 1977 Jul-Aug(126):100–5.
8. Dawson EG, Sherman JE, Kanim LE, Nuwer MR. Spinal cord monitoring. Results of the Scoliosis Research Society and the European Spinal Deformity Society survey. *Spine (Phila Pa 1976).* 1991 Aug;16(8 Suppl):S361–4.
9. Langeloo DD, Lelivelt A, Louis Journee H, Slappendel R, de Kleuver M. Transcranial electrical motor-evoked potential monitoring during surgery for spinal deformity: a study of 145 patients. *Spine (Phila Pa 1976).* 2003 May 15;28(10):1043–50.
10. Schwartz DM, Auerbach JD, Dormans JP, Flynn J, Drummond DS, Bowe JA, et al. Neurophysiological detection of impending spinal cord injury during scoliosis surgery. *J Bone Joint Surg Am.* 2007 Nov;89(11): 2440–9.
11. Vitale MG, Moore DW, Matsumoto H, Emerson RG, Booker WA, Gomez JA, et al. Risk factors for spinal cord injury during surgery for spinal deformity. *J Bone Joint Surg Am.* 2010 Jan;92(1):64–71.
12. Nuwer MR, Dawson EG, Carlson LG, Kanim LE, Sherman JE. Somatosensory evoked potential spinal cord monitoring reduces neurologic deficits after scoliosis surgery: results of a large multicenter survey. *Electroencephalogr Clin Neurophysiol.* 1995 Jan;96(1):6–11.
13. Quraishi NA, Lewis SJ, Kelleher MO, Sarjeant R, Rampersaud YR, Fehlings MG. Intraoperative multimodality monitoring in adult spinal deformity: analysis of a prospective series of one hundred two cases with independent evaluation. *Spine (Phila Pa 1976).* 2009 Jun 15; 34(14):1504–12.
14. Machida M, Weinstein SL, Yamada T, Kimura J. Spinal cord monitoring. Electrophysiological measures of sensory and motor function during spinal surgery. *Spine (Phila Pa 1976).* 1985 Jun;10(5):407–13.
15. Lesser RP, Raudzens P, Luders H, Nuwer MR, Goldie WD, Morris HH, 3rd, et al. Postoperative neurological deficits may occur despite unchanged intraoperative somatosensory evoked potentials. *Ann Neurol.* 1986 Jan;19(1):22–5.
16. Chen ZY, Wong HK, Chan YH. Variability of somatosensory evoked potential monitoring during scoliosis surgery. *J Spinal Disord Tech.* 2004 Dec;17(6):470–6.
17. Calancie B, Harris W, Brindle GF, Green BA, Landy HJ. Threshold-level repetitive transcranial electrical stimulation for intraoperative monitoring of central motor conduction. *J Neurosurg.* 2001 Oct;95(2 Suppl):161–8.
18. MacDonald DB, Al Zayed Z, Khoudeir I, Stigsby B. Monitoring scoliosis surgery with combined multiple pulse transcranial electric motor and cortical somatosensory-evoked potentials from the lower and upper extremities. *Spine (Phila Pa 1976).* 2003 Jan 15;28(2):194–203.
19. Kim DH, Zaremski J, Kwon B, Jenis L, Woodard E, Bode R, et al. Risk factors for false positive transcranial motor evoked potential monitoring alerts during surgical treatment of cervical myelopathy. *Spine (Phila Pa 1976).* 2007 Dec 15;32(26):3041–6.
20. Kundnani VK, Zhu L, Tak H, Wong H. Multimodal intraoperative neuromonitoring in corrective surgery for adolescent idiopathic scoliosis: Evaluation of 354 consecutive cases. *Indian J Orthop.* 2010 Jan;44(1): 64–72.
21. Pelosi L, Lamb J, Grevitt M, Mehdian SM, Webb JK, Blumhardt LD. Combined monitoring of motor and somatosensory evoked potentials in orthopaedic spinal surgery. *Clin Neurophysiol.* 2002 Jul;113(7): 1082–91.
22. Padberg AM, Wilson-Holden TJ, Lenke LG, Bridwell KH. Somatosensory- and motor-evoked potential monitoring without a wake-up test during idiopathic scoliosis surgery. An accepted standard of care. *Spine (Phila Pa 1976).* 1998 Jun 15;23(12):1392–400.
23. Fehlings MG, Brodke DS, Norvell DC, Dettori JR. The evidence for intraoperative neurophysiological monitoring in spine surgery: does it make a difference? *Spine (Phila Pa 1976).* 2010 Apr 20;35(9 Suppl): S37–46.
24. Pahys JM, Guille JT, D'Andrea LP, Samdani AF, Beck J, Betz RR. Neurologic injury in the surgical treatment of idiopathic scoliosis: guidelines for assessment and management. *J Am Acad Orthop Surg.* 2009 Jul;17(7):426–34.
25. Noonan KJ, Walker T, Feinberg JR, Nagel M, Didelot W, Lindseth R. Factors related to false- versus true-positive neuromonitoring changes in adolescent idiopathic scoliosis surgery. *Spine (Phila Pa 1976).* 2002 Apr 15;27(8):825–30.
26. Mooney JF, 3rd, Bernstein R, Hennrikus WL, Jr., MacEwen GD. Neurologic risk management in scoliosis surgery. *J Pediatr Orthop.* 2002 Sep-Oct;22(5):683–9.
27. Kamerlink J, Errico T, Xavier S, Patel A, Patel A, Cohen A, et al. Major intraoperative neurologic monitoring deficits in consecutive pediatric and adult spinal deformity patients at one institution. *Spine (Phila Pa 1976).* 2010;35:240–5.
28. Feng B, Qiu G, Shen J, Zhang J, Tian Y, Li S, et al. Impact of multimodal intraoperative monitoring during surgery for spine deformity and potential risk factors for neurological monitoring changes. *J Spinal Disord Tech.* 2012 Jun;25(4):E108–14.

Original Research

Robotic-Assisted Total Hip Arthroplasty: Is It the Future Yet?

James R. Lachman, MD; Christopher Haydel, MD; Easwaran Balasubramanian, MD

Department of Orthopaedic Surgery and Sports Medicine, Temple University Hospital, Philadelphia, PA

Abstract

Introduction: Robotic-assisted total hip arthroplasty (THA) is a more and more common method of cup implantation in the United States. The technique is being advertised as a way to improve accuracy in acetabular component placement. This is thought to improve outcomes and survivorship in current THAs. Prior studies have demonstrated the benefits of robotic assistance and have recommended that practicing orthopaedists who are not "high volume" joint reconstructive surgeons may benefit from using the robot. This study aims to compare the radiographic and clinical outcomes of manual versus robotic assisted total hip arthroplasty.

Methods: One hundred and two conventional manual THAs were retrospectively compared to 102 robotic assisted THAs. The groups were matched for age, sex, BMI, rates of DM, and rates of HCV/HIV. The variables analyzed included operating room (OR) time, estimate blood loss (EBL), acetabular component version and inclination, length of stay (LOS), early dislocation and need for early revision. The student t-test was used to compare means across groups.

Results: See table for complete results. OR time was 39 minutes longer in the robotic-assisted THA (RA) group. EBL was 220 mL more in the RA group. Both of these data were statistically significant ($p < 0.05$). The readmission rate for the RA group (8.8%) was significantly greater in the RA group. No differences were found in anteversion and inclination between groups. LOS and rates of early revision were not different between the two cohorts.

Discussion and Conclusion: These data suggest no improvement in outcomes with robotic-assistive technology in total hip arthroplasty. Increases in OR time, EBL, and readmission rates were significantly higher in the robotic-assisted cohort. When the first 50 (chronologically) RA THAs were removed from the data set, neither EBL nor OR time differed significantly from the manual group. This suggests a learning curve is present for RA total hip arthroplasty and that the low volume surgeon may need to use caution prior to considering initiating a robotic-assisted arthroplasty program at their institution.

Introduction

Robotic-assisted surgery is becoming increasingly popular in many surgical specialties and orthopeadics is following suit. Computer navigation has enabled robotic systems to "view" patients in a three-dimensional way enabling coordinated surgeon robot collaboration. The importance of acetabular cup position (acetabular anteversion and inclination) in total hip arthroplasty (THA) has been shown time and time again. Robotic systems have been developed in an attempt to minimize variability in cup placement and improve acetabular component position accuracy.

Multiple robotic systems are available across the globe. Each of these uses a reference point system to establish where the patient is in space. The surgeon positions the robot through a series of reference points and, when there is confirmation of accuracy through check points, the robotic arm allows for single stage reaming and placement for the acetabular component within a predetermined (through pre-op planning) location. These systems are advertised to improve outcomes and eliminate inaccurate cup placement.

No studies of this sample size are available in the literature that examine the outcomes of robotic-assisted (RA) total hip arthroplasty when compared to standard conventional cup placement manually. The purpose of this study was to provide objective data to compare RA THA and conventional THA outcomes, both radiographic and clinical, in a high-volume center.

Materials and Methods

All patients undergoing elective total hip arthroplasty during a four-year period were evaluated retrospectively for inclusion in this institutional review board (IRB) approved chart-review study. The study population was generated from a single high-volume center and operated on by a single joint replacement surgeon over a four-year period during which a robotic total hip replacement program was started. A standard posterior surgical approach to the hip with the patient in the lateral decubitus position was utilized for all patients and 2 grams cephalosporin was given preoperatively and two more doses post-operatively for prophylaxis against infection. The inclusion criteria included those patients undergoing primary elective THA, minimum of six months of follow-up, and all patients must have available antero-posterior (AP) radiographs of the pelvis. Exclusion criteria included those patients who underwent THA secondary to trauma, those patients lost to follow-up, and those undergoing revision surgery.

Two groups were generated from these patients. The control group was made up of 102 patients who underwent conventional THA with manual cup placement. The experimental group was made up of 102 patients who underwent RA THA with robotic-assisted cup placement. The groups were matched for demographic information including age, sex, and body mass index (BMI). Groups were analyzed on medical comorbidities including smoking status, human immune deficiency virus positive and/or hepatitis C positive patients, and presence of diabetes mellitus.

Clinical outcomes including operative time, estimated blood loss, American Society of Anesthesia (ASA) physical classification system, acetabular component position (anteversion and inclination), length of stay in the hospital, and readmission rates were collected for both groups. Operative time, ASA, and estimated blood loss were collected from the intra-operative anesthesia record. Length of stay, early dislocations, readmissions, and need for early revision were obtained from a comprehensive review of the electronic medical record.

Acetabular component position was measured using previously validated methods. The method described by Liaw et al. measures anteversion on an AP pelvis radiograph. Two measurements (S and TL) are used for calculations. S is the short axis of the ellipse in the acetabular component and TL is the total length of the projected cross-section of the component along its short axis. The ratio of S/TL is then used to convert to a corresponding anteversion in a standardized table. These measurements were then confirmed using the method described by Lewinnek et al. where anteversion = arcsin (short axis/long axis). These measurements can be made easily in the PACS imaging system. Using the same AP pelvis radiograph and the method described by Lewinnek et al., inclination is the angle between the line on which the long axis of the ellipse is located and the inter-teardrop line.

The two groups were compared using univariate analysis and, where applicable, the two sample independent t-test was used to compare means across the groups. Categorical variables (non-numerical) were analyzed across groups using the chi-squared test. A p-value of <0.05 was used to establish statistical significance. All statistical analysis were conducted using the SAS® 9.4 interface.

Results

Two-hundred and four patients (204) met the inclusion criteria and were included in the study. Demographic information and medical comorbidities of patients in each group are summarized in Table 1. Males represented 52.7% of the study population with no difference between the manual group and the RA group. No differences existed between the two groups with respect to age, BMI, HCV/HIV status, rates of diabetes and smoking status.

Table 1. Demographics and Medical Comorbidities Between Groups

	Manual Group	Robotic-Assisted Group
Total No.	102	102
Mean Age	62.8	61.9
Mean BMI	29.1	31.6
HCV/HIV (%)	13	16
Diabetes (%)	18	22
Smoking Status (%)	41	50

Table 2 summarizes the data collected from the operating room and includes analysis across the groups for any statistical differences (*). The mean ASA was similar between groups. Operative times were significantly longer for the RA THA group ($p = 0.032$) and estimated blood loss was significantly greater in the RA THA group ($p = 0.022$).

Table 2. Operating Room Data

	OR Statistics		
	Manual Group	Robotic-Assisted Group	Difference (p-Value)
Mean ASA	2.4	2.7	
OR time (mins)	127 ± 37.3	166.2 ± 40.2	39* (p = 0.032)
EBL (mL)	372 ± 47.4	592 ± 45.5	220* (p = 0.022)

Table 3 illustrates the radiographic measurements of acetabular anteversion and inclination. The manual group had an average anteversion of 18.1 ± 6.1 degrees and an inclination of 39.3 ± 8.3 degrees. The RA THA group had an average anteversion of 20.8 ± 7.2 degrees and an inclination of 40.3 ± 5.6 degrees. Neither of these values had a difference that was statistically significant (anteversion $p = 0.431$, inclination $p = 0.674$).

Table 3. Radiographic Measurements from Anteroposterior X-rays

	Radiographic Data		
	Manual Group	Robotic-Assisted Group	Difference (p-Value)
Anteversion (degrees)	18.1 ± 6.1	20.8 ± 7.2	2.7 (p = 0.431)
Inclination (degrees)	39.3 ± 8.3	40.3 ± 5.6	1 (p = 0.674)

Table 4 summarizes the post-operative course for patients in each group. The average length of stay for the manual group was 3.2 ± 1.7 days while the robotic group had a LOS of 2.4 ± 1.4 days ($p < 0.033$). The readmission rate for the manual group was 4.9% (5/102) and 8.8% (9/102) for the RA group ($p = 0.048$). The dislocation rates for each group were identical at 1.9% (2/102) and each group had only one

Table 4. Clinical Data from Post-Operative Course

	Clinical Data		
	Manual Group	Robotic-Assisted Group	Difference (p-Value)
LOS (days)	3.2 ± 1.7	2.4 ± 1.4	0.8* (p = 0.033)
Readmissions	5/102 (4.9%)	9/102 (8.8%)	4* (p = 0.048)
Dislocations	2/102 (1.9%)	2/102 (1.9%)	~
Revision within six months	1/102 (0.98%)	1/102 (0.98)	~

early revision (revision within six months) which represented 0.98% (1/102).

To determine if there was a correlation between OR time and RA THA chronologically, each case was plotted and analyzed using the Kendall Tau b Correlation test. The p = 0.043 suggests that there was a significant association between the date of the RA THA and the OR time.

Discussion

With the numbers available, no significant differences were found with regard to the distribution of patients in either group with regard to age (p = 0.911), gender (p = 0.144), BMI (p = 0.967), medical comorbidities, dislocations, and acetabular component position (anteversion p = 0.431, inclination p = 0.674). The percentage of patients with HIV/HCV (14.5%) and with diabetes (20%) was higher than in any study of similar design demonstrating the high risk nature of the patient population. There were a number of significant differences between the groups with regard to OR time (p = 0.032), EBL (p = 0.22), readmission rate (p = 0.048) and length of stay (0.033).

There was a notable learning curve associated with the initiation of a robotic-assisted THA program. The Kendall tau b correlation test (p = 0.043) demonstrates a correlation between the months after initiation of a robotic-assisted total hip replacement program and the OR time. The initial OR time for the first 51 (chronologically) RA THAs was significantly longer that the second 51 in the sample (p = 0.034). When the second 51 THAs were compared with the manual group, the difference in OR time was only 17 minutes and the EBL was only 50 mL greater. Neither of these differences were significant (OR time p = 0.347 and EBL p = 0.089).

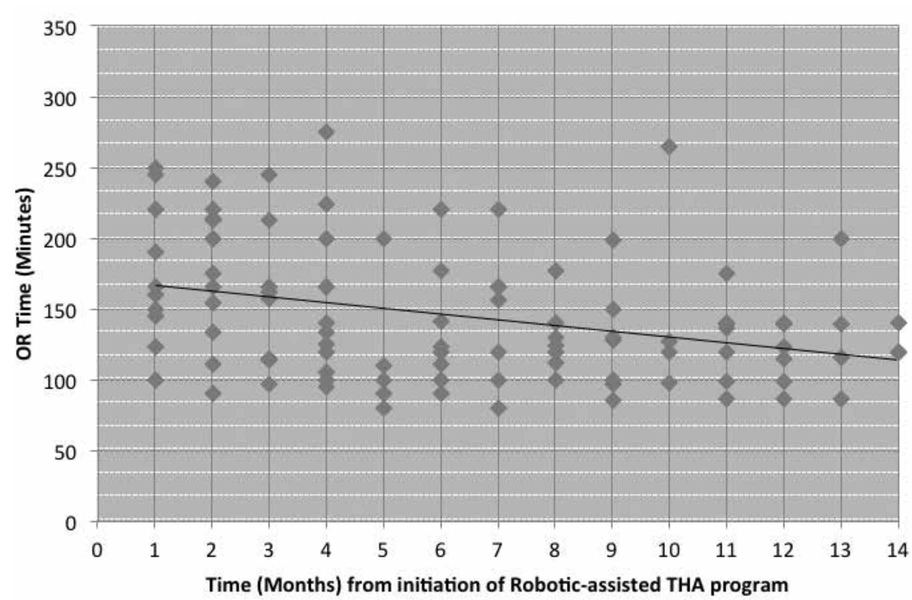
The data in this study did not suggest robotic-assisted total hip arthroplasty provides the surgeon with a more accurate and precise method for acetabular cup placement. There was no difference between groups in cup placement. Using the "zone of safety" suggested by Lewinek, both groups average anteversion and inclination were within range.

Initiation of a robotic-assisted total hip replacement program takes time. The data in this study suggests that surgeons with low volume hip replacement must use caution when attempting to utilize the robotic-assisted technology due to a significant learning curve. High volume joint replacement surgeons are placing acetabular components with very high precision and reproducibility. The increase in OR time may be unattractive to host institutions.

At the time of the conclusion of this study, only about half of the robotic-assisted total hip arthroplasties completed at the host institution met inclusion criteria for follow-up of at least six months. A follow-up review of the subsequent patients will be published in the future.

This study had a few limitations. It was a retrospective chart review at one center with one surgeon. The length of follow-up for clinical outcomes was only six months in this initial data review. The study only included those cases where robotic-assisted implantation of the acetabular com-

Graph 1. Effect of Experience on OR Time



ponent was not aborted. Those cases where robotic implantation was deemed impossible intra-operatively were excluded from the study which may effect the data if included in analysis. No intra-operative complications were observed in either group.

References

1. Abdel MP, von Roth P, Jennings MT, Hanssen AD, Pagnano MW. What safe zone? The vast majority of dislocated THAs are within the lewinnek safe zone for acetabular component position. *Clin Orthop Relat Res.* 2015. doi: 10.1007/s11999-015-4432-5 [doi].
2. Domb BG, El Bitar YF, Sadik AY, Stake CE, Botser IB. Comparison of robotic-assisted and conventional acetabular cup placement in THA: A matched-pair controlled study. *Clin Orthop Relat Res.* 2014;472(1):329–336. doi: 10.1007/s11999-013-3253-7 [doi].
3. El Bitar YF, Jackson TJ, Lindner D, Botser IB, Stake CE, Domb BG. Predictive value of robotic-assisted total hip arthroplasty. *Orthopedics.* 2015;38(1):e31–7. doi: 10.3928/01477447-20150105-57 [doi].
4. Elmallah RK, Cherian JJ, Jauregui JJ, Padden DA, Harwin SF, Mont MA. Robotic-arm assisted surgery in total hip arthroplasty. *Surg Technol Int.* 2015;26:283–288.
5. Gandhi R, Marchie A, Farrokhyar F, Mahomed N. Computer navigation in total hip replacement: A meta-analysis. *Int Orthop.* 2009; 33(3):593–597.
6. Health Quality Ontario. Computer-assisted hip and knee arthroplasty. Navigation and active robotic systems: An evidence-based analysis. *Ont Health Technol Assess Ser.* 2004;4(2):1–39.
7. Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg Am.* 1978;60(2):217–220.
8. Nakamura N, Sugano N, Nishii T, Kakimoto A, Miki H. A comparison between robotic-assisted and manual implantation of cementless total hip arthroplasty. *Clin Orthop Relat Res.* 2010;468(4):1072–1081. doi: 10.1007/s11999-009-1158-2 [doi].
9. Nawabi DH, Conditt MA, Ranawat AS, et al. Haptically guided robotic technology in total hip arthroplasty: A cadaveric investigation. *Proc Inst Mech Eng H.* 2013;227(3):302–309.
10. Nomura T, Naito M, Nakamura Y, et al. An analysis of the best method for evaluating anteversion of the acetabular component after total hip replacement on plain radiographs. *Bone Joint J.* 2014;96-B(5):597–603. doi: 10.1302/0301-620X.96B.33013 [doi].
11. Prymka M, Hassenpflug J. Clinical outcome, 6 years after robot assisted hip endoprostheses implantation — a prospective study. *Z Orthop Unfall.* 2009;147(6):675–682. doi: 10.1055/s-0029-1186059 [doi].
12. Tarwala R, Dorr LD. Robotic assisted total hip arthroplasty using the MAKO platform. *Curr Rev Musculoskelet Med.* 2011;4(3):151–156. doi: 10.1007/s12178-011-9086-7 [doi].
13. Werner SD, Stonestreet M, Jacofsky DJ. Makoplasty and the accuracy and efficacy of robotic-assisted arthroplasty. *Surg Technol Int.* 2014; 24:302–306. doi: sti24/23 [pii].

Original Research

"Hidden" Pre-operative Blood Loss with Extracapsular Versus Intracapsular Hip Fractures — What Is the Difference?

Katharine D. Harper, MD; Paul Navo, MPH; Frederick Ramsey, PhD; Saqib Rehman, MD

Department of Orthopaedic Surgery and Sports Medicine, Temple University Hospital, Philadelphia, PA

Abstract

Purpose: Excessive blood loss with hip fracture management has been shown to result in increased rates of complications. Whereas traditional teaching is that extracapsular hip fractures (EC) have more blood loss preoperatively (i.e., "hidden") than intracapsular fractures (IC), this difference, the degree of difference, and difference in transfusion rates have not been well-studied in the literature. Our goal is to compare blood loss and transfusion rates between patients with intracapsular and extracapsular (both intertrochanteric and subtrochanteric) hip fractures.

Methods: Four hundred and seventy-two patients were evaluated retrospectively at a level 1 trauma center over a five-year period from January 1, 2010 to December 31, 2014. All adult patients who presented to the hospital with a proximal femur fracture (femoral neck, intertrochanteric (IT) or subtrochanteric fracture (ST)) were considered for this study. Subjects were identified using CPT codes. Exclusion criteria included polytrauma, a concomitant lower extremity or pelvic fracture, gunshot injuries, periprosthetic fractures, and non-operative management. Primary endpoint was hemoglobin (Hgb) drop from admission to day of surgery (DOS); secondary endpoint was need for pre-op transfusion and discharge location. Statistical significance was defined as a p-value <0.05.

Results: Following application of exclusion criteria, we were able to analyze data from 304 patients who sustained either an intracapsular or extracapsular hip fracture. Median IC Hgb drop was 0.6 g/dL, while median EC Hgb drop was 1.1 g/dL from admission to DOS. This was statistically significant with a p-value of 0.0272. Rate of pre-operative transfusions was significantly higher in EC fractures (36/194 = 18.6%) compared to IC fractures (5/105 = 4.5%) ($p = 0.0006$), and overall transfusion rates remained significantly higher throughout hospital stay (55.7% EC vs. 32.7% IC; $p = 0.0001$). Further breakdown of admission to DOS IT Hgb loss (1.12 g/dL) and ST Hgb loss (1.30 g/dL) was not clinically significant ($p = 0.07$). Further breakdown of transfusion in IT (94/168 = 56%) and ST fractures (16/25 = 64%) was also not clinically significant ($p = 0.4483$). Extracapsular hip fracture patients were more likely to be discharged to a skilled nursing facility (SNF) than intracapsular patients (84.4% EC vs. 73.8% IC; $p = 0.027$).

Conclusion: Intracapsular hip fractures have significantly less pre-operative blood loss and fewer pre-operative transfusions than their extracapsular counterparts. With the trend toward hospitals establishing hip fracture treatment protocols, these findings can be used to establish appropriate pre-operative resuscitative efforts, ensuring that protocols account for the increased likelihood of blood loss in extracapsular fractures.

Keywords: Hip fractures, anemia, blood loss, intertrochanteric fracture, femoral neck fracture, subtrochanteric fracture.

Introduction

Hip fractures in the elderly are common, with more than 250,000 people sustaining hip fractures annually in the United States. The National Osteoporosis Foundation estimates over 500,000 hip fractures will occur annually by 2040.[1] Excessive blood loss after long bone fractures have been shown to result in increased complications,[17] but current studies have not addressed the fracture pattern which poses the greatest risk of blood loss anemia following injury. If we were able to better identify which fracture patterns have a greater risk for blood loss, resuscitative efforts may be improved and modified in order to minimize morbidity associated with blood loss.

Intracapsular hip fractures account for 45% of all acute hip fractures, while intertrochanteric fractures account for an additional 45%.[1] For anatomic reasons, historical belief is that intracapsular fractures tend to have a smaller pre-operative hemoglobin drop than extracapsular fractures. In the clinical setting, it is common to see a patient with a hip fracture present with a low postoperative hemoglobin level that is largely unexplained by the operative blood loss.[8] Most of this blood loss is felt to occur preoperatively,[14] and up to 80% of this blood loss may be unaccounted for by medical teams.[18] Preoperative anemia is a risk factor for perioperative death[14] and need for blood transfusions.[3, 16, 18] Alternatively, higher postoperative hemoglobins have been associated with better overall outcomes[8] and shorter hospital stays.[9]

Whereas traditional teaching is that extracapsular hip fractures (EC) have more hidden blood loss preoperatively than intracapsular fractures (IC), this difference, the degree of difference, and transfusion rates have not been well-studied in the literature. Our goal is to compare blood loss and transfusion rates between patients with intracapsular and extracapsular (intertrochanteric and subtrochanteric) hip fractures and assess patients to accurately identify those at risk for perioperative anemia based on fracture type, medical co-morbidities, and time to surgery in an effort to minimize any associated complications.

Methods

A retrospective study was performed at a level 1 trauma center over a five-year period from January 1, 2010 to December 31, 2014 where 472 patients with hip fractures were evaluated. All adult patients who presented to the hospital with a proximal femur fracture (femoral neck, intertrochanteric or subtrochanteric fracture) were considered for this study. A subtrochanteric femur fracture was considered any fracture within 5 cm of the lesser trochanter — per AO guidelines. Subjects were identified using the CPT codes 27235, 27236, 27244, 27245. Exclusion criteria included polytrauma patients, any patient who had a concomitant lower extremity or pelvic fracture, gunshot injuries, periprosthetic fractures, pathologic fractures, patients with delayed presentation (>24 hours), and fractures treated non-operatively. Patients who did not have an available electronic medical record (EMR) or were missing key data points (hemoglobin values, operative note, etc.) were also excluded.

Following application of exclusion criteria, we were able to analyze data from 304 patients who sustained either an intracapsular or extracapsular hip fracture. All patients were followed from the time of admission/injury until time of discharge from orthopedic care. Epidemiological information, as well as mechanism (high vs. low energy), fracture type and fixation type were collected. Hemoglobin values were analyzed from admission complete blood count (CBC) taken at time of initial presentation and then via daily AM CBC or hemoglobin and hematocrit (H&H) — all AM labs are drawn at 4 AM. Additional labs in the form of PT, PTT and INR were used to assess possible risk factors to increased blood loss. The primary endpoint for the study was hemoglobin (Hgb) drop from admission to day of surgery. Secondary endpoint was a need for pre-operative transfusion.

Statistical analysis was undertaken using both parametric (t-test and Analysis of Variance) and non-parametric (Wilcoxon and Kruskal-Wallis) testing. Chi Square analysis was used for need for transfusion and discharge location. Non-parametric analysis was used for Hgb drops from admission to day of surgery, time to surgery and Hgb drop in patients receiving transfusion. Statistical significance was defined as a p-value <0.05.

Results

Four hundred and seventy-two patients received surgical intervention during this time period, of which 168 were excluded due to: polytrauma patients (80), concomitant lower extremity or pelvic fracture (four), gunshot injuries (29), periprosthetic fractures (12), pathologic fractures (10), delayed presentation (>24 hours) (23), and fractures treated nonoperatively (zero). Patients who did not have an available electronic medical record (EMR) (two) or were missing key data points (hemoglobin values, operative note, etc.) were also excluded (eight). Majority of patients missing data points (6/8) were due to transfers from outside hospitals where we did not have access to initial labs, or pre-surgical Hgb was not drawn (2/8). This left 304 patients for statistical analysis. Of these 304 patients, 110 had intracapsular hip fractures and 194 had extracapsular hip fractures. The extracapsular hip fractures were further divided into 168 intertrochanteric (IT) and 26 subtrochanteric (ST). Per standard hip fracture protocol, admission labs were drawn prior to IV fluid administration, and patients were all started on IV maintenance fluids at midnight of the first hospital day due to being NPO for surgery (even if not medically cleared at the time). All patients received chemical DVT prophylaxis at time of presentation at our institution (lovenox or heparin — depending on renal function). Refer to Table 1 for complete demographic information.

To estimate blood loss, admission hemoglobin was compared to pre-surgery hemoglobin through subtraction of the pre-surgery hemoglobin from the admission hemoglobin. Time to surgery was calculated between the two groups and was found to be statistically insignificant (28.8 hours in IC vs. 27.5 hours IT and 27.0 hours in ST; p = 0.716). The Wilcoxon test was used for comparison of the admission hemoglobin minus the pre-surgery hemoglobin for intracapsular vs. extracapsular hip fractures. Median intracapsular Hgb drop was 0.6 g/dL, while median extracapsular Hgb drop was 1.1 g/dL from admission to day of surgery. This was statistically significant with a p-value of 0.0272. This rejects our null hypothesis and states more Hgb was lost from admission to surgery in extracapsular fractures compared to intracapsular fractures, and therefore suggests that there is more blood lost from extracapsular hip fractures than intracapsular hip fractures. Further breakdown shows IT Hgb loss (1.12 g/dL) and ST Hgb loss (1.30 g/dL) (p = 0.07). Refer to Table 2 and Figure 1 for complete breakdown of Hgb changes and histogram representation of such changes.

Table 1. Patient Demographic Data

No. of Patients	304
Age (years)	74.0 ± 14.4
Gender	
Female	181 (59.5%)
Male	123 (40.5%)
Discharge location	
SNF/Rehab	241 (79.3%)
Home	58 (19.1%)
Unknown	5 (1.6%)
Injury Statistics	
Fracture Location	
Intracapsular	110 (36.2%)
Extracapsular	194 (63.8%)
Extracapsular Fracture Breakdown	
Intertrochanteric	168 (86.6%)
Subtrochanteric	26 (13.4%)

Summary of patient demographic data including age ranges and gender, as well as injury statistics including site of injury and fracture classification.

The two categorical variables (intracapsular and extracapsular) were assessed relative to whether the patient received a blood transfusion pre-operatively, and separately throughout their hospital stay. Strict transfusion protocols are adhered to at our institution and patients are transfused if Hgb <7 mg/dL or <8 mg/dL if symptomatic (tachycardia) — patients are transfused a single unit at a time. Transfusion analysis was conducted using the Chi-Square test. The rate of pre-operative transfusions was significantly higher in EC fractures (36/194 = 18.6%) compared to IC fractures (5/105 = 4.5%) ($p = 0.0006$). For the entirety of their hospital stay, 32.7% of IC patients, (36/110 patients) received a transfusion. In contrast, 55.7% of EC patients (108/194 patients) received a transfusion ($p = 0.0001$). Therefore, we can conclude that not only is the amount of blood loss in extracapsu-

Table 2. Summary Statistics and Significance Testing for Pre-surgical Blood Loss for Intracapsular and Extracapsular Fractures

Classification Variable	N	Mean	StdDev	Min	Q1	Median	Q3	Max	p-Value	Statistical Method
Admission Hgb minus Pre-Surgery Hgb, by Intracapsular									0.0238	Wilcoxon
Extracapsular	194	1.14	1.25	–2.80	0.20	1.10	1.90	5.50		
Intracapsular	110	0.93	1.23	–1.10	0.00	0.60	1.60	5.90		
Admission Hgb minus Pre-Surgery Hgb, by Extracapsular									0.0709	Kruskal-Wallis
IT	168	1.11	1.19	–2.80	0.25	1.10	1.85	5.10		
ST	26	1.30	1.59	–0.50	0.00	0.80	2.00	5.50		
Intracapsular	110	0.93	1.23	–1.10	0.00	0.60	1.60	5.90		

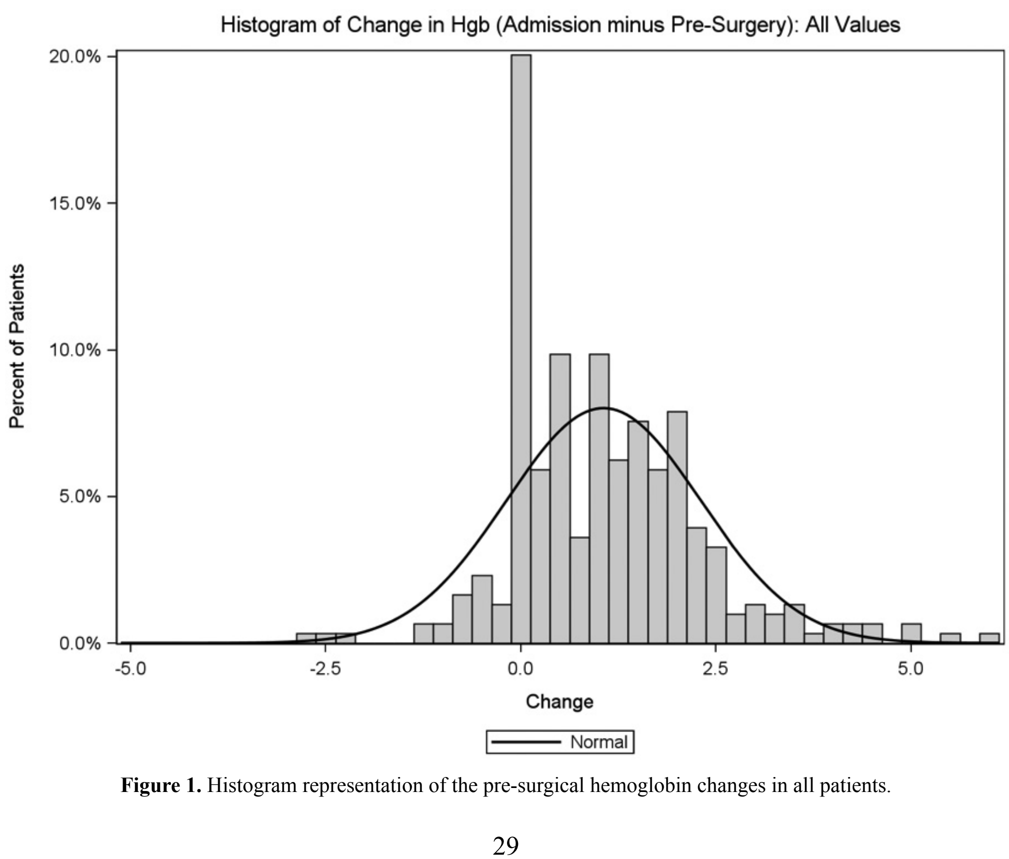


Figure 1. Histogram representation of the pre-surgical hemoglobin changes in all patients.

lar fractures more significant, but also that the requirement for transfusion is also significantly higher in the pre-operative period. Further breakdown of transfusion rates in IT (92/168 = 54.8%) and ST fractures (16/26 = 61.5%) was not clinically significant (p = 0.4483). Refer to Table 3 for summary of transfusion rate demographics and results.

Finally, the two categorical variables (intracapsular and extracapsular) were assessed for discharge location to determine if a fracture pattern would be more likely to require further rehab. 84.4% (162/192) of the extracapsular patients were discharged to a SNF while only 73.8% (79/107) of the intracapsular patients were discharged to a SNF (p = 0.027). Further breakdown of extracapsular fractures show that 86.7% (144/166) of the IT patients are discharged to a SNF while only 69.2% (18/26) and 73.8% (79/107) of the ST and intracapsular patients (respectively) are discharged to a SNF (p = 0.0096).

Discussion

Hidden blood loss from a fracture after injury and/or following surgery has been a matter of debate. Anemia in the peri-operative patient has been shown to produce poorer functional scores and decrease a patient's ability to walk independently. This, in turn, is theorized to affect their ability to participate in post-operative rehabilitation, further increasing their complications post-operatively.[5] A study from Denmark addressing the "hidden" blood loss *after* hip fracture surgery had unaccounted blood losses anywhere from 547 mL (screws/pins) to 1437 mL (intramedullary hip nail and screw).[4] Orthopaedic surgeons underestimate the amount of blood loss occurring before and during surgery, and as previously mentioned, up to 80% of this loss may be unaccounted for by medical teams.[18] Unfortunately, there are insufficient high-quality studies to inform practitioners in regards to pre-operative blood transfusions in intracapsular or extracapsular fractures.[12]

Studies determining pre-operative blood loss between the two fracture types are also insufficient to guide clinical practice. Most are extrapolated from studies for different purposes. A study from the UK assessed femoral head blood flow for avascular necrosis between intracapsular and extracapsular hip fractures. They found that a tamponade effect does occur in intracapsular fractures. This was determined by measuring intra-osseus pressures in both intraccapsular and extracapcular fractures, where it determined an increased intra-osseus pressure in the intracapsular fractures was due to the intact capsular tamponade effect.[7] This can be extrapolated that this increase intra-osseus pressure would also result in a slowing of bleeding and therefore less blood loss. An additional study assessing patients at risk for pre-operative blood transfusions in an effort to decrease unnecessary cross-matching found peritrochanteric fractures to be an independent risk factor for pre-operative transfusions.[3] Finally, a study from the London, England showed that patients with femoral neck fractures should be managed the same as high-risk surgical patients — whose outcomes were

Tables 3. Demographics, Summary Statistics and Significance Testing for Transfusion Rates

Transfusion Demographics

Transfusion, n (%)	
Yes	146 (48.0%)
No	158 (52.0%)
PRBCs, n(%)	
Yes	144 (47.4%)
No	160 (52.6%)
FFP	
Yes	7 (2.3%)
No	297 (97.7%)
Platelets	
Yes	4 (1.3%)
No	300 (98.7%)

Clinical Significance of Transfusion Rates

Attribute	Transfusion = Yes	Transfusion = No	Total	p-Value	Test Method	Significance
Pre-Op EC/IC, n (%)				0.0006	Chi Square	Highly Significant
Extracapsular	36 (18.6%)	158 (81.4%)	194 (100.0%)			
Intracapsular	5 (4.5%)	105 (95.5%)	110 (100.0%)			
Total	41 (13.5%)	263 (86.5%)	304 (100.0%)			
Entire Hospital Stay EC/IC, n (%)				0.0001	Chi Square	Highly Significant
Extracapsular	108 (55.7%)	86 (44.3%)	194 (100.0%)			
Intracapsular	36 (32.7%)	74 (67.3%)	110 (100.0%)			
Total	144 (47.4%)	160 (52.6%)	304 (100.0%)			
IT or ST, n (%)				0.4483	Chi Square	Not Significant
IT	94 (56.0%)	74 (44.0%)	168 (100.0%)			
ST	16 (61.6%)	10 (38.4%)	26 (100.0%)			
Total	110 (56.7%)	84 (43.3%)	194 (100.0%)			

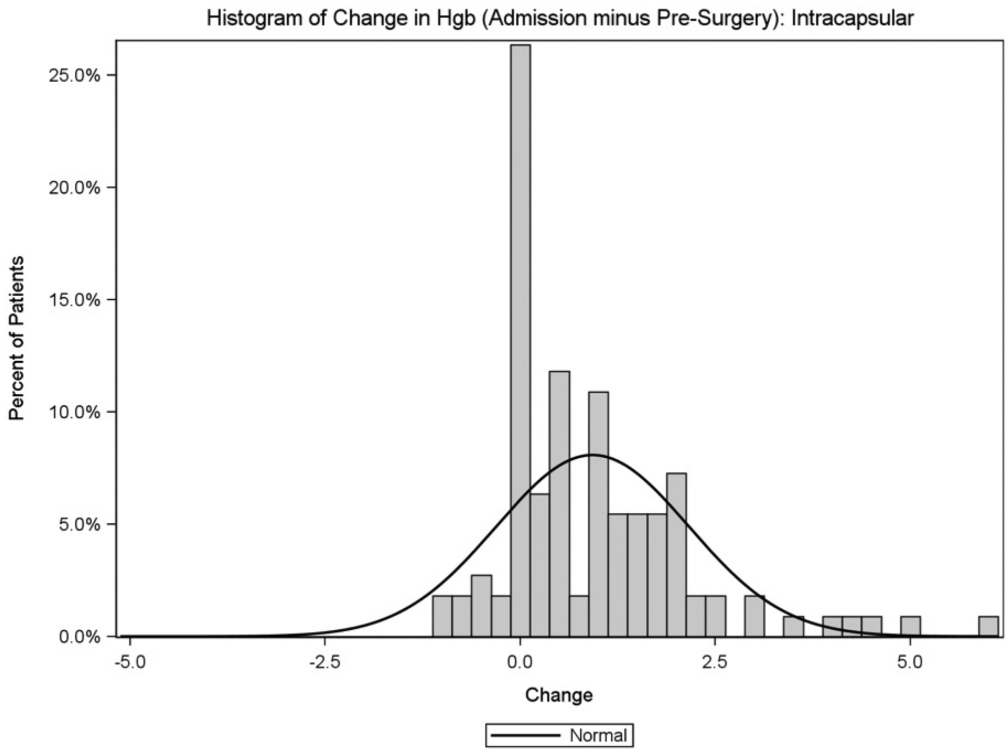


Figure 2. Histogram representation of the pre-surgical hemoglobin changes in intracapsular fracture patients.

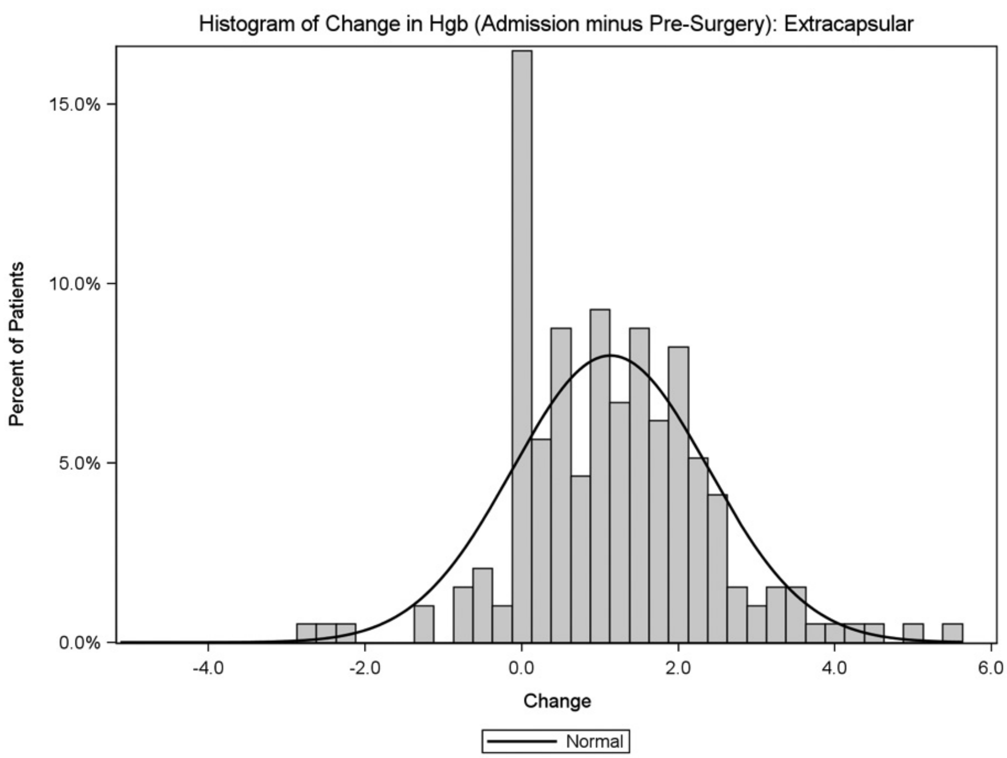


Figure 3. Histogram representation of the pre-surgical hemoglobin changes in extracapsular fracture patients.

significantly improved by haemodynamic optimisation in the perioperative period.[13] This outcome was unable to be attributed back to pre-operative blood loss due to lack of information.

The importance of identifying those patients at risk of excessive bleeding is also important in regards to timing of surgical management. Delays in appropriate resuscitative efforts simply cause a chain reaction in delays further down the line. Up to 44% of delays from 25–48 hours after hospitalization to surgery and 42% of delays greater than 48 hours from hospitalization to surgery can be attributed to hematologic abnormalities, most commonly an unacceptable Hgb for surgery.[11] Furthermore, a study by Gdalevich et al. showed that delays greater than 48 hours after injury resulted in increased one-year mortality, mental deterioration and post-operative mobility.[6] However, it is important to note that aggressive transfusion of patients prophylactically or in anticipation of excessive blood loss is also not appropriate. A study by Carson et al. examined the outcome differences between transfusing patients at a Hgb <10 g/dL vs. <8 g/dL, and showed no difference in complication rates, in-hospital mortality, 60-day post-operative mortality or 60-day post-operative rehabilitation outcomes, even in those deemed high cardiovascular risk.[2]

With a push for centers to develop geriatric hip fracture programs to better serve patients, information such as this can be invaluable. In recent years, outcomes within geriatric hip fracture protocols have shown vast improvements in complications rates. A study by Mercantonio et al. showed that delirium rates in patients co-managed by a geriatrics team decreased significantly.[10] An additional study showed that all-cause mortality and medical complications were reduced in patients assigned to geriatric hip fracture protocols.[15] Yet studies have been unable to determine optimal resuscitation protocols due to this gap in blood loss knowledge.

Our center feels that a comprehensive and consistent monitoring process is the key to balancing the pre-operative Hgb levels. In our experience, drawing Hgb and Hematocrit (H&H) labs every eight hours for the first 48 hours after injury ensures that anemia is caught early and treated promptly, without delaying the OR or transfusing patients unnecessarily. Trends may be followed as well to better understand the hematologic profile of the patient and better anticipate resuscitation demands in the post-operative period. With this new knowledge of the increased risk of blood loss in extracapsular fractures, further research could address the discrepancy in blood loss and how this should shape our resuscitative efforts. Namely, should patients who sustain extracapsular fractures undergo more rigorous monitoring and aggressive resuscitation than their intracapsular counterparts?

There were several limitations in this current study. Due to its retrospective design data was limited and could only be obtained from what was presented in the medical record. Missing data and inconsistencies could contribute a source of error in data collection. Additionally, since there was some variability in when hemoglobin blood draws were performed, it is difficult to make a complete comparison. Since this variability was present in both groups, we do not feel it affects the overall significance of our values. A subgroup analysis was not performed in regards to presence of pre-injury blood thinners, and as such these variables may affect results. The number of patients on anticoagulation prior to injury between the two groups was not statistically significant (38.7% EC vs. 40.9% IC; $p = 0.6998$), therefore unlikely to affect the overall outcomes.

Conclusion

Our study suggests that intracapsular fractures have significantly less drop in hemoglobin than extracapsular fractures, which can be correlated to less blood loss. They also are shown to require significantly fewer pre-operative blood transfusions than their extracapsular counterparts. These findings should be used to establish appropriate pre-operative resuscitative efforts, ensuring that protocols account for the increased likelihood of blood loss in extracapsular fractures. By doing this, we ensure patients are able to undergo surgical fixation in a more appropriate time frame and ensure better outcomes through the post-operative period.

References

1. Bateman L, Vuppala S, Porada P, et al. Medical management in the acute hip fracture patient: A comprehensive review for the internist. *Ochsner J.* 2012;12(2):101–110.
2. Carson JL, Terrin ML, Noveck H, Sanders DW, Chaitman BR et al. Liberal or Restrictive Transfusion in High-Risk Patients after Hip Surgery. *N Engl J Med.* 2011;365:2453–62.
3. Dillon MF, Collins D, Rice J, Murphy PG, Nicholson P, Mac Elwaine J. Preoperative characteristics identify patients with hip fractures at risk of transfusion. *Clin Orthop Relat Res.* 2005;439:201–206. doi: 00003086-200510000-00035 [pii].
4. Foss NB, Kehlet H. Hidden blood loss after surgery for hip fracture. *J Bone Joint Surg Br.* 2006;88-B:1053–9.
5. Foss NB, Kristensen MT, Kehlet H. Anaemia impedes functional mobility after hip fracture surgery. *Age and Ageing* 2008;37:173–178. doi:10.1093/ageing/afm161.
6. Gdalevich M, Cohen D, Yosef D, Tauber C. Morbidity and mortality after hip fracture: the impact of operative delay. *Arch Orthop Trauma Surg.* 2004;124:334–340. DOI 10.1007/s00402-004-0662-9.
7. Harper WM, Barnes MR, Gregg PJ. Femoral Head Blood Flow in Femoral Neck Fractures: An analysis using intra-osseous pressure measurement. *J Bone Joint Surg Br.* 1991;73-B:73–5.
8. Kumar D, Mbako AN, Riddick A, Patil S, Williams P. On admission haemoglobin in patients with hip fracture. *Injury.* 2011;42(2):167–170. doi: 10.1016/j.injury.2010.07.239 [doi].
9. Madsen CM, Jorgensen HL, Norgaard A, et al. Preoperative factors associated with red blood cell transfusion in hip fracture patients. *Arch Orthop Trauma Surg.* 2014;134(3):375–382. doi:10.1007/s00402-013-1906-3 [doi].
10. Mercantonio ER, Flacker JM, Wright RJ, Resnick NM. Reducing Delirium After Hip Fracture: A Randomized Trial. *J Am Geriatr Soc.* 2001;49:516–522.

11. Orosz GM, Hannan EL, Magaziner J, Koval K, Gilbert M, Aufses A, Strauss E, Vespe E, Siu AL. Hip Fracture in the Older Patient: Reasons for Delay in Hospitalization and Timing of Surgical Repair. *J Am Geriatr Soc.* 2002;50:1336–1340.
12. Potter LJ, Doleman B, Moppet IK. A systematic review of pre-operative anemia and blood transfusion in patients with fractured hips. *Anaesthesia.* 2015;70:483–500.
13. Sinclair S, James S, Singer M. Intraoperative intravascular volume optimisation and length of hospital stay after repair of proximal femoral fracture: randomized control trial. *BMJ.* 1997;315:909–12.
14. Smith GH, Tsang J, Molyneux SG, White TO. The hidden blood loss after hip fracture. *Injury.* 2011;42(2):133–135. doi: 10.1016/j.injury.2010.02.015 [doi].
15. Vidan M, Serra JA, Moreno C, Riquelme G, Ortiz J. Efficacy of a Comprehensive Geriatric Intervention in Older Patients Hospitalized for Hip Fracture: A Randomized, Controlled Trial. *J Am Geriatr Soc.* 2005;53:1476–1482.
16. Willems JM, de Craen AJ, Nelissen RG, van Luijt PA, Westendorp RG, Blauw GJ. Haemoglobin predicts length of hospital stay after hip fracture surgery in older patients. *Maturitas.* 2012;72(3):225–228. doi: 10.1016/j.maturitas.2012.03.016 [doi].
17. Zeideman H, Wray JB, Schneider AJ. Alterations in vascular volume after long bone fracture. *Arch Surg.* 1963;87:907–911.
18. Zhu XZ, Tao YL, Ma Z. Routine blood tests as predictors of mortality in hip fracture patients. *Injury.* 2013 Nov;44(11):1659.

Medical Student Research Project

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Joint Preservation Surgery for Secondary Osteonecrosis of the Knee: A Presentation of Two Cases and Literature Review

Caroline Jolstad, BA;[1] Eric J. Kropf, MD;[2] Frederick V. Ramsey, PhD;[3] Joseph Torg, MD[2]

[1]*Temple University School of Medicine;* [2]*Temple University Hospital, Department of Orthopaedic Surgery;* [3]*Temple University School of Medicine, Department of Clinical Sciences, Philadelphia, PA*

Introduction

True avascular necrosis (AVN) — also called ischemic, idiopathic, atraumatic, or corticosteroid-associated necrosis[1] — is a degenerative condition that can lead to extensive bone death and severe osteoarthritis. It is found most often in patients younger than 45 years of age, who present with gradual onset of pain over the affected area.[2] Osteonecrosis can appear in the epiphysis, metaphysis, or diaphysis of the femur, or the tibial plateau, usually bilaterally.[2] Unlike the single localized lesions seen in patients with postarthroscopic and spontaneous osteonecrosis, in true AVN of the knee, there are usually multiple lesions throughout the bone, and similar patterns of necrosis are often found in other large joints.[1]

True AVN of the knee is most commonly seen following long-term use of corticosteroids, but is also associated with long-term alcohol and tobacco use; conditions such as sickle cell disease, caisson disease, Gaucher's disease, myeloproliferative disorders, thrombophilia-hypofibrinolysis; and genetic factors, including variations in factor V Leiden, prothrombin 20210A, PAI-1, and ABCB1 genes.[2–5] The exact etiology remains unknown, but it is thought to involve ischemia secondary to abnormal lipid metabolism or blood coagulation. The most common risk factor, corticosteroid use, is associated with enlarged bone marrow fat cells,[6] which may increase intraosseous pressure to the point of causing ischemia. Many other risk factors increase chances of vascular occlusion by various mechanisms, which can also contribute to ischemia.[2]

There are several treatment options for AVN, and indication often depends on disease progression. Nonsurgical management is recommended only for asymptomatic cases.[1] On the other hand, total knee arthroplasty (TKA) is usually considered a last resort, since a revision will likely be necessary in the lifetime of these young patients. Unicompartmental knee arthroplasty[7] and high tibial osteotomy[8] are both contraindicated by the frequency of multiple condylar involvement. This paper reviews the outcomes of four joint-preserving surgical treatments for AVN of the knee: arthroscopic debridement, chondroplasty and microfracture; core decompression; allograft reconstruction; and autograft reconstruction. In addition, we also present the treatment of two patients with steroid-induced AVN of the knee treated at Temple University Hospital, and their outcomes at latest follow-up.

Methods and Materials

The data for our literature review was collected from a PubMed search for papers that included "osteonecrosis" or "necrosis" and "knee" or "distal femur" or "proximal tibia" or "patella" in the title. Papers were excluded if they were not about medically-induced osteonecrosis, or if they did not differentiate the different types in their study. Papers were also excluded if the patients were less than 18 years of age, if osteonecrosis of the knee was not the primary topic, and if they were not written in English. Case studies and case series were excluded. Additional resources were found in the references of the papers we reviewed. The data for our case studies was collected from the patient records at Temple University Hospital, and their treatment is described below.

Case Reports

Patient 1

A 37-year-old female presented to our department with persistent dull aching pain of her bilateral knees that worsened with significant fluctuations in barometric pressure. Her past medical history included lung nodules and Hodgkin's lymphoma just over a year previously. Her therapy included bone marrow transplantation, and high doses of chemotherapeutics and steroids; however, all medications had been discontinued at the time of her clinical presentation and subsequent surgery. MRI of her bilateral knees two months before her first surgical procedure revealed significant avascular necrosis of the distal femoral condyle, proximal tibia, and patella. Ligamentous structures appeared normal, and there was no evidence of subchondral collapse or arthritic changes. The patient had exhausted physical therapy, behavior modification, and anti-inflammatory treatment options. Subchondroplasty was chosen as the next course of action, with the goal being to address the insufficiency of her distal femur and proximal tibia that was believed to be primarily responsible for her pain.

Diagnostic arthroscopy at the beginning of the procedure on the patient's left knee revealed grade 2 chondromalacia of the proximal pole of the patella, and chronic scar formation at the insertion of the quadriceps tendon on the distal pole of the patella. Arthroscopic chondroplasty and debridement of the distal pole of the patella, as well as a focal microfracture using a K-wire was performed. The percutaneous portion of the procedure was then carried out under fluoroscopic guidance using the Knee Creations subchondroplasty system. In both the distal femur and proximal tibia, 10 mL of calcium phosphate bone cement substitute was injected into the defect simultaneously from the medial and lateral side, in order to achieve a uniform pressure distribution. The patient underwent contralateral right knee surgery six months later. A diffuse softening in the medial compartment cartilage was noted in the right knee, but otherwise all findings and operative procedures were similar to the surgery on the patient's left knee.

The patient was placed on crutches immediately after surgery and range of motion and quadriceps strengthening rehabilitation initiated. She progressed rapidly with little pain. At three-month postop period, the patient reported a significant decrease in pain in her bilateral knees. She progressed well with physical therapy without complaints. Range of motion was 0 to 130 degrees with well-maintained patellar mobility, and she was able to perform a straight leg raise test. She continued with strengthening for 3–6 months without difficulty. At six months postop, the patient was interviewed via phone and continued to report that her knees were doing well.

Patient 2

A 19-year-old female referred to our department had taken high-dose steroids for over two years for idiopathic pulmonary hemosiderosis. She developed severe avascular necrosis of the distal femur with delamination of the trochlear cartilage, multiple loose bodies, and a reactive effusion in her bilateral knees. She was followed by a pulmonologist and gradually weaned off steroids. At the time of surgical intervention, she was on no medications. Radiographs taken three months pre-operatively showed well-maintained tibiofemoral and patellofemoral joint spaces with normal contour of the articular cartilage. Her symptoms of bilateral knee pain and swelling were exacerbated by physical activity, especially walking up and down stairs, and actually worsened by a course of formal physical therapy. The patient underwent staged bilateral surgery with a plan to excavate necrotic bone and either microfracture or bone graft the defect dependent on depth of disease.

The procedure on the patient's right knee began with a thorough diagnostic arthroscopy, the findings of which included a full-thickness chondral defect of the lateral trochlea that measured 3.2 cm by 1.9 cm. Initial attempts at microfracture did not penetrate the sclerotic bone and could not stimulate bleeding. A small burr was then used to remove necrotic bone to a depth of nearly 1 cm. Several loose bodies comprised of delaminating cartilage were arthroscopically removed. A small medial parapatellar arthrotomy was performed and the defect bone grafted with 5 mL of demineralized bone matrix putty. Core decompression of the medial femoral condyle was next performed using a K-wire under arthroscopic and fluoroscopic guidance. The trochlear cartilage had already delaminated and therefore the open bone graft procedure was appropriate. For the medial femoral condyle, antegrade core decompression as performed so as not to violate the healthy normal cartilage.

Three months later after undergoing early rehabilitation of the right knee, the patient underwent similar procedure on the contralateral left knee. The extent of disease on preoperative imaging was believed to be similar to that found on the right side. Diagnostic arthroscopy again revealed complete loss of the lateral trochlear cartilage with significant underlying avascular subchondral bone in an area roughly 2.5–3 cm by 3.5 cm. After removing all loose bodies, an attempt at microfracture was unsuccessful. Open arthrotomy was performed followed by evacuation of the avascular bone. The edges of bad cartilage were curetted away and a burr used to reach healthy bleeding bone, at a depth of about 1.5 cm. In this case, the defect was unshouldered laterally so a decision was made to secure the bone graft with a collagen membrane and suture anchors. The defect was again filled with demineralized bone matrix bone and secured with a porcine derived collagen membrane (Geistlich; Wolhusen Switzerland) and five Micro SutureTak anchors (Arthrex; Naples, FL).

The patient progressed well through rehabilitation without complication. At most recent follow-up (12 and nine months respectively), the patient reported only intermittent pain that was 4/10 at greatest severity. She did not require medication for this. She noted mild grinding and crepitation in her left knee primarily but no instability. Physical exam found range of motion to be 0 degrees maximum extension and 130 degrees maximum flexion in both knees. Provocative testing was negative for anterior drawer, posterior drawer, varus and valgus testing, but positive for medial joint line tenderness and mildly painful patellofemoral grind test in both knees. Follow-up radiographs and MRI were obtained to evaluate for consolidation of bone graft. Based upon those findings, we discussed cartilage restoration options including cell based therapies with the patient. She elected to delay further surgery at this time so that she could return to school without interruption.

Literature Review

A total of 12 papers met our review criteria: two on arthroscopic debridement, chondroplasty, and microfracture; four on core decompression; two on allograft reconstruction; and four on autograft reconstruction (Table 1).

Arthroscopic Debridement/Chondroplasty and Microfracture

Wiede[l9] reported pain and impingement symptom relief an average of 40 months (range 16–84 months) after debridement and light abrasion of subchondral lesions in all 10 knees operated on between 1976 and 1982. The four male and four female patients were on average 32 years (range 18–44 years) of age, and all had a history of long-term corticosteroid use: six for renal transplantation, one for systemic lupus erythematosus, and one for asthma. Subchondral bone sclerosis and collapse was seen radiographically in the lateral condyle of eight knees (six patients), with medial condylar involvement in three knees and tibial involvement in four knees. All had full-thickness loss of articular cartilage on the lateral femoral condyle with moderate to severe degeneration of the lateral meniscus. Occasional discomfort and crepitation remained a complaint, but these symptoms appeared to the authors to be well-tolerated. A 15-month follow-up arthroscopic examination of one knee revealed some cartilage regeneration but considerable fraying of the underlying meniscus. While this result is promising in terms of potential for healing and avoiding joint replacement, we need more long-term follow-up for definitive information, as well as more patients for a representative picture, of how this operation affects disease progression.

Akgun et al.[10] reported that 14 of 15 patients diagnosed between 1996 and 2002 were satisfied with the results of curettage and microfracture at an average final follow-up of 37 months (range 12–65 months) post-operatively. The average Lysholm score increased from 41 to 75, and the

Table 1. Summary of Literature Review

Date	First Author	Patients (Knees)	Success Rate	Success Criteria	Follow-Up Time
Arthroscopy					
1985	Wiedel	8 (10)	N/A	Subjective	40 months (18–64 months)
2005	Akgun	15	N/A	Lysholm and Cincinnati Activity scores, Koshino's radiographic stages, subjective patient satisfaction	37 months (12–65 months)
Core Decompression					
1989	Jacobs	18 (28)	52% (18/28)	No or minimal pain, no restriction of function, no need for further surgery	54 months (20–140 months)
1997	Mont	25 (47)	72% (34/47)	Knee Society score >80	11 years (4–16 years)
2000	Mont	57 (91)	79% (72/91)	Knee Society score >80	7 years (2–24 years)
2006	Marulanda	38 (61)	92% (56/61)	Knee Society score >80	37 months (24–50 months)
Allograft					
1989	Meyers	3 (3)	100% (3/3)	Radiographic: evidence of graft incorporation, no evidence of collapse or degenerative arthritis Clinical: Merle d'Aubigne and Postel score >11	3.6 years (2–10 years)
1994	Flynn	6 (8)	75% (6/8)	Improvement in pain and function, no graft revision or total knee arthroplasty	4.2 years (24–109 months)
Autograft					
2002	Fukui	8 (10)	90% (9/10)	Improved Knee Society score	79 months (31–159 months)
2006	Rijen	6 (9)	Clinical: 75% (6/8) Radiographic: 78% (7/9)	Clinical: Knee Society score >80 Radio-graphic: no progression of osteoarthritis or collapse	51 months (29–93 months)
2010	Matsusue	8 (10)	N/A	International Cartilage Repair Society (ICRS) Evaluation Form, arthroscopic findings, MRI findings	42 months (range N/A)
2015	Goodman	12 (14)	N/A	Knee Society scores, radiographic stages of Aglietti et al.	5 years (1–11 years)

average Cincinnati Activity score increased from 2.67 to 11.73 ($p < 0.05$). No correlation was found between functional results (Lyscholm and Activity scores) and necrotic lesion size. MRI revealed significant healing in four patients, healing with bone marrow edema and filling in the treated defect of seven patients, and increased necrosis and sclerosis in the remaining four patients. Using Koshino's radiographic classification,[11] six of eight stage III knees and one of six stage IV knees showed radiographic improvement; no radiographic changes were seen in the other eight knees. While the authors did not specify which patients achieved the most healing according to MRI, it is clear from the radiographic results that those patients with lesions consisting of a radiolucent area and sclerotic halo that have not yet progressed to degenerative changes, such as osteophytes and osteosclerosis, benefit the most from this procedure. The authors noted that while three years is not adequate follow-up time to determine long-term effects, an important advantage of this procedure is that it does not preclude future operations. The patients' average age was 32 years (range 20–64 years) and comorbidities consisted of systemic lupus erythematosus in four patients, malignancy in three patients, Takayasu's arteritis in two patients, postmeniscectomy in two patients, inflammatory arthritis in two patients, coagulation disorder in one patient, and renal transplant in one patient.

Core Decompression

Jacobs et al.[12] performed 28 core decompressions on the distal femurs of four men and 14 women between 1974 and 1981. The average age of these patients was 33.5 years (range 19–66 years), and all but two patients (two knees) had AVN-associated risk factors: 11 patients (17 knees) had SLE and had taken or were on steroids at the time of surgery, two patients (four knees) had renal failure, two patients (four knees) were taking steroids following kidney transplant, and one patient (one knee) had steroid therapy as part of treatment for a benign brain tumor. All 28 knees were preoperatively staged according to Ficat's[13] system adapted to the knee: one knee had stage I disease, six knees had stage II, and 21 knees had stage III. At an average final follow-up of 54 months (range 20–140 months), all stage I and II knees, and 11 stage III knees, had successful clinical outcomes with no or minimal pain, no function restrictions, and no further surgeries on the affected knee. Of the 10 stage III knees with poor clinical outcomes, four continued to experience pain and six had undergone total knee replacement an average of 23.8 months (range 6–40 months) post-operatively. Despite this poor success rate in stage III knees, the authors believe that there may still be a role for core decompression in this population, considering the procedure's relative simplicity and low complication rate. Radiographically, disease progression was seen in three of the stage II knees, and at least three of the stage III knees with good clinical results, characterized primarily by increasing collapse of the femoral condyles. The authors regret that radiographic imaging was not sensitive enough to accurately measure lesion size, and that their sample population was too small to look for a relationship between steroid therapy parameters and surgical outcome.

Between 1978 and 1989, Mont et al.[14] treated 47 knees in 25 patients with core decompression: 20 knees had stage I disease, 20 stage II, and seven stage III, according to the Ficat and Arlet staging system of the hip adapted for the knee. At final follow-up of 11 years (range 4–16 years), a Knee Society objective score of 80 or more was achieved in 34 of 47 knees: 14 Ficat stage I, 14 stage II, and six stage III. Results were stratified by co-morbidities: success was achieved in 20 of 32 knees with SLE, six of seven with renal transplantation failure, eight of eight with "steroid and other diagnosis," and four of 15 with "nonlupus." Of the seven knees that eventually required TKA, the average time between operations was 73 months (range 2–187 months); three patients delayed joint replacement for over 11 years. A group of 26 patients treated with core decompression and a group of 26 patients treated non-operatively were matched for disease stage, patient age, diagnosis, and length of follow-up: 19 knees in the core decompression group achieved a successful outcome, compared with six knees in the non-core decompression group. Radiographic progression was halted in 65% of all knees treated with core decompression compared to 25% of knees treated non-operatively.

Three years later, Mont et al.[1] published another paper that describes the results of core decompression of 91 knees in 57 patients treated between 1974 and 1998. Seventy-two knees had a Knee Society objective score of 80 or more at an average final follow-up of seven years (range 2–24 years). Of these, nine had undergone repeat core decompression, and six had arthroscopic debridement performed when symptoms persisted after the initial core decompression procedure. The authors found that in the femur and the tibia, the quadrant in which the lesion was located (medial, lateral, or both) and the size of the lesion therein did not affect the clinical outcome. However, lesions located in the epiphyseal periarticular region were associated with a higher failure rate in both the femur ($p < 0.01$) and the tibia ($p < 0.001$), and prognosis was significantly worse for lesions with a combined necrotic angle of 250 degrees or more ($p < 0.05$). The patients treated with core decompression were part of a larger group of 106 female and 30 male patients (248 knees) with AVN of the knee. At initial presentation, 69 knees had stage I disease, 106 had stage II, 38 had stage III, and 35 had stage IV. One hundred and one of these patients had a disease that affected the immune system, including SLE (67 patients), IBD (11 patients), nephrosis (seven patients), and lymphoma (five patients). The authors found no relationship between outcome and number of risk factors, or the use of alcohol, tobacco, or corticosteroids.

Marulanda et al.[15] performed 61 core decompressions using a small-diameter drilling technique between 2000 and 2003. The 31 women and seven men were on average 42 years (range 21–55 years) of age, and had either stage I or stage II disease according to Ficat and Arlet as modified for the knee. Eighteen patients (29 knees) had previously received high doses of steroids for at least three months. At average final follow-up of 37 months (range 24–50 months), 56 knees had a Knee Society objective score of 80 or more, which the authors defined as a successful outcome. The average Knee Society score for the entire group increased from 48 points (range 40−63 points) pre-operatively to 92 points (range 74−100 points) at final follow-up. In terms of size and location, all 24 knees with lesions smaller than 20 cc in volume were successfully treated, compared to 32 of the 37 knees with larger lesions. Knees with lesions only in the femur had a slightly higher success rate (19 of 20) than knees with both femoral and tibial involvement (37 of 41). The authors determined that gender, age, multiple joint involvement, length of symptoms, and associated co-morbidities had no significant effect on outcome. However, it was noted that patients with SLE tended to have a higher failure rate (12.5%) compared to other risk factors, such as corticosteroid use without SLE (9%). The authors acknowledge that their small sample size, relatively short-term average follow-up, and lack of a control group, were among the limitations of this study.

Allograft Reconstruction

In 1989, Meyers et al.[16] published the results of fresh osteochondral allograft transplantation in 39 patients with a variety of knee pathologies. Of these, only five patients had avascular necrosis, and of those, only three patients (three knees) were available for evaluation. Two knees were followed for more than three years, and one knee for more than four years. At final follow-up, all three knees were rated at least “fair” according to the Merle d’Aubigne-Postel rating system adapted for the knee, and showed evidence of incorporation of the graft without collapse, narrowing of the joint space, or disintegration. Allografts were harvested within 24 hours of death from fresh cadavera of individuals between 16 and 45 years of age, stored at 4° Celsius until transplantation, which occurred two to six days after the death of the donor.

Between 1980 and 1992, Flynn et al.[17] treated six patients (eight knees) with true AVN of the knee using fresh-frozen allografts. The size of the articular defects ranged from five square centimeters to the entire medial or lateral condyle. Outcomes were assessed based on pain relief and restoration of function: an excellent result was “absent or mild and rare pain; unlimited activity; full range of motion;” a good result was “occasional pain, clicking, catching or other knee complaint; unlimited walking without aids; and functional range of motion;” and a poor result was “pain or function the same or worse than preoperatively.” Two male patients (two knees, ages 33 and 35 at time of operation) had taken steroids following renal transplants; both had excellent results at 48- and 65-month follow-ups, respectively. One patient with IBD (two knees, age 31 and 36 at time of each operation) had an excellent result 109 months post-operatively in the first knee, and a poor result in the second knee that was revised to TKA 34 months post-operatively. The only other poor outcome was a female patient with SLE (39 years old at time of operation) who underwent TKA 70 months post-operatively. The remaining three knees had good outcomes: one knee from a female patient with IBD (45 years old at time of operation, 24-months follow-up), and two knees from a female patient with SLE (20 and 21 years old at time of operation, 51 and 40 months follow-up, respectively). The authors noted that infection, nonunion, and failure of fixation did not occur in this series, but that these complications would compromise future TKA.

Autograft Reconstruction

Between 1987 and 2000, Fukui et al.[18] treated 10 knees of eight patients with autologous osteoperiosteal grafts harvested from the ipsilateral iliac crest. All patients had a history of systemic steroid treatment for either SLE (six knees), bone marrow transplant for lymphoblastic lymphoma (two knees), IBD (one knee), or nephrotic renal disease (one knee). The patients’ average age at time of surgery was 31.9 years (range 17–55 years), and average final follow-up was 79 months (range 31–159). Although necrosis was present in both condyles in nine of 10 knees, grafts were only placed on the one side with significant cartilage lesions. The average size of these lesions was 11.3 cm^2 (range 7.5–15.0 cm^2). The average Knee Score improved from 119 points pre-operatively (range 79–145) to 180 points at final follow-up (range 100–195). Knee pain diminished considerably with the surgery (average pain score improvement from 22 to 45 points), while range of motion and joint space were well-preserved and no obvious difference in outcome observed between knees with medially-placed grafts and those with laterally-placed grafts. Early migration of the graft in one patient with extensive necrosis led the authors to conclude that it is necessary for at least half of the graft surface to contact unaffected, normal bone in the condyle to have a successful outcome. Due to the shape of the grafts, knees with lesions that are more extensive in the AP plane are good candidates for this procedure, while careful consideration is necessary for lesions wider than 3 cm. Since this procedure allows patients to retain good bone stock, the authors conclude that it seems advantageous even if another surgery is necessary.

Between 1994 and 2002, Rijen et al.[19] treated nine knees (three male, three female patients) with bone impaction grafting. The patients’ average age was 31 years (range 16−47), and all had a history of systemic corticosteroids administration: three for Crohn’s disease, two for SLE, two for polymyalgia rheumatica, one for renal insufficiency, and one for subarachnoidal bleeding. The procedure consisted of removing all necrotic bone, covering the exposed subchondral bone with autogenous trabecular bone chips that were compacted layer by layer, and then filling the remaining cavity volume with solidly impacted trabecular bone chips made from fresh-frozen allograft femoral heads. The periosteum removed at the beginning of the procedure was put back over the graft and impacted in place. The autogenous trabecular bone chips were harvested from either the iliac crest or metaphyseal area, and the allograft femoral heads were obtained from a bone bank. Pre-operatively, three knees were in stage II and six in stage III, according to the Ficat and Arlet classification system, and all knees had a lesion involving the femoral epiphysis. Four knees had tibial involvement as well. At time of final follow-up, incorporation of the impacted bone grafts was seen radiographically in all knees. None of the stage III knees had progression of collapse. Minimal osteoarthritis was observed in three knees, all of which had a Kellgren score of one, and one of which had presented with osteoarthritis preoperatively. The authors defined radiographic success as absence of progression of osteoarthritis or collapse, which was achieved in seven of nine knees. The average objective Knee Society score increased from 63 (range 43–90) pre-operatively to 89 (range 70–100) post-operatively, and the average functional Knee Society score improved from 19 (range 0–70) to 81 (range 50–100). No conversion to TKA was performed. The average visual analog scale functional score increased from 27 (range 10–50) to 85 (range 50–100), and the average visual analog scale pain score improved from 78 (range 50–90) to 25 (range 10–70) at the time of final follow-up. The authors defined clinical success as a minimal objective score of 80 points and no conversion to TKA, which was achieved in six of eight knees.

Matsusue et al.[20] used osteochondral autografts to treat 10 knees in eight patients with steroid-induced osteonecrosis between 1997 and 2003. Unfortunately, the usefulness of this paper in discussing these patients' results is very limited because the authors do not distinguish them from the 23 patients (25 knees) with idiopathic osteonecrosis. Within this larger group of 31 patients (35 knees), the patients' average age was 48 years (range 21–76), and average lesion size was 481 mm^2 (range 156–1080 mm^2). All knees were clinically evaluated according to the International Cartilage Repair Society (ICRS) Evaluation Form: eight knees were found to be Abnormal, and 11 knees Severely Abnormal preoperatively; 11 improved to Normal, 22 to Nearly Normal, and eight knees were found to be Abnormal an average of 42 months postoperatively. Again, the authors did not specify which of these knees were diagnosed with steroid-induced osteonecrosis and which were idiopathic. Second-look arthroscopy was carried out on 24 knees, and MRI on 33 knees. At final follow-up, no patient complained of donor site symptoms or needed additional surgery. The authors were concerned about donor site morbidity because of the many osteochondral plugs required to repair the larger cartilage defects seen in steroid-induced osteonecrosis. Autografts were applied when the lesion was not massive and grafts could be taken from the patellofemoral joint, but the authors decided that any massive lesion, for which insufficient donor sites could be obtained, was indicated for an allograft.

In 2015, Goodman et al.[21] reported on the outcome of 12 patients (14 knees) whose AVN of the distal femur was treated with open debridement and grafting of concentrated osteoprogenitor cells harvested from the iliac crest. All patients had a history of long-term corticosteroid use for either SLE (five knees), leukemia/lymphoma (three knees), Crohn's disease (three knees), cardiac transplantation (one knee), DRESS syndrome (one knee), or psuedomotor cerebri (one knee). Average age at time of surgery was 23 years (range 13–37 years). Four of five SLE patients and the single DRESS patient were still taking steroids at the time of surgery. Using radiographs and MRI scans, the authors determined that all knees had stage III lesions according to the Aglietti classification system, and were considered large according to the ratio method since they involved more than 0.32 of the condyle width. No collapse or degradation of the cartilage surface, a contraindication to this operation, was visible on pre-operative MRI. After an average follow-up of five years (range 1–11 years), Knee Society scores averaged 87 degrees (range 52–100) for the knee score and 85 degrees (range 15–100) for the knee function score. Pre-operative Knee Society scores were not available for the majority of knees, but even so, the authors indicate that this scoring system has not been validated for young patients with multifocal osteonecrosis and systemic disease. The one patient with a function score of 15 was awaiting a similar operation on the contralateral knee, and had ongoing pain and disability from SLE. None of the patients had undergone further surgery on their operated knee, and none were taking pain medication for pain from the operative knee. The authors discuss that the number and quality of osteoprogenitory cells harvested vary among individuals, which has direct implications for clinically-relevant outcomes, and that the quality and quantity of grafted cells have not been determined using analysis of colony forming units.

Conclusion

Several joint-preserving surgical options are available for treating AVN of the knee. Which approach is most appropriate may depend on the features and severity of disease at presentation. Core decompression is the simplest approach, but may not be enough to prevent disease progression in knees that present at a more advanced stage. Arthroscopic debridement with microfracture and chondroplasty was the treatment modality we chose for our two patients. This option may provide more reinforcement and opportunity for healing in those with more diseased bone. Unfortunately, we were not able to learn much about the success rate of this method from our literature review. Despite being featured in our oldest paper, only 23 patients' results have been published, with their average follow-up time being the shortest of all four modalities. Use of bone graft has had some very promising results, but application is limited by the size of the defect to be covered. Overall, more studies with long-term follow-up, standardized success criteria, and stratified disease severity at presentation, are needed to determine the best treatment option for patients with AVN of the knee. Until enough data has been compiled to perform such an analysis, each patient can only be addressed on a case-by-case basis.

References

1. Mont MA, Baumgarten KM, Rifai A, Bluemke DA, Jones LC, Hungerford DS. Atraumatic osteonecrosis of the knee. *J Bone Joint Surg Am.* 2000;82(9):1279–1290.
2. Karim AR, Cherian JJ, Jauregui JJ, Pierce T, Mont MA. Osteonecrosis of the knee: Review. *Ann Transl Med.* 2015;3(1):6-5839.2014.11.13. doi: 10.3978/j.issn.2305-5839.2014.11.13 [doi].
3. Gong LL, Fang LH, Wang HY, et al. Genetic risk factors for glucocorticoid-induced osteonecrosis: A meta-analysis. *Steroids.* 2013;78(4):401–408. doi: 10.1016/j.steroids.2013.01.004 [doi].
4. Glueck CJ, Freiberg RA, Wang P. Medical treatment of osteonecrosis of the knee associated with thrombophilia-hypofibrinolysis. *Orthopedics.* 2014;37(10):e911–6. doi: 10.3928/01477447-20140924-59 [doi].
5. Bjorkman A, Burtscher IM, Svensson PJ, Hillarp A, Besjakov J, Benoni G. Factor V leiden and the prothrombin 20210A gene mutation and osteonecrosis of the knee. *Archives of Orthopaedic and Trauma Surgery.* 2005;125(1):51–55.
6. Motomura G, Yamamoto T, Miyanishi K, Yamashita A, Sueishi K, Iwamoto Y. Bone marrow fat-cell enlargement in early steroid-induced osteonecrosis — a histomorphometric study of autopsy cases. *Pathology — Research and Practice.* 2005;200(11-12):807–811. doi: http://dx.doi.org/10.1016/j.prp.2004.10.003.
7. Mont MA, Marker DR, Zywiel MG, Carrino JA. Osteonecrosis of the knee and related conditions. *J Am Acad Orthop Surg.* 2011;19(8):482–494. doi: 19/8/482 [pii].
8. Gorczynski C, Meislin R. Osteonecrosis of the distal femur. *Bull Hosp Jt Dis.* 2006;63(3-4):145–152.
9. Wiedel JD. Arthroscopy in steroid-induced osteonecrosis of the knee. *Arthroscopy.* 1985;1(1):68–72.
10. Akgun I, Kesmezacar H, Ogut T, Kebudi A, Kanberoglu K. Arthroscopic microfracture treatment for osteonecrosis of the knee. *Arthroscopy.* 2005;21(7):834–843. doi: S0749806305005505 [pii].
11. Koshino T, Okamoto R, Takamura K, Tsuchiya K. Arthroscopy in spontaneous osteonecrosis of the knee. *Orthop Clin North Am.* 1979;10(3): 609–618.
12. Jacobs MA, Loeb PE, Hungerford DS. Core decompression of the distal femur for avascular necrosis of the knee. *J Bone Joint Surg Br.* 1989;71(4):583–587.
13. Ficat RP. Idiopathic bone necrosis of the femoral head. Early diagnosis and treatment. *J Bone Joint Surg Br.* 1985;67(1):3–9.
14. Mont MA, Tomek IM, Hungerford DS. Core decompression for avascular necrosis of the distal femur: Long term followup. *Clin Orthop Relat Res.* 1997;(334)(334):124–130.
15. Marulanda G, Seyler TM, Sheikh NH, Mont MA. Percutaneous drilling for the treatment of secondary osteonecrosis of the knee. *J Bone Joint Surg Br.* 2006;88(6):740–746. doi: 88-B/6/740 [pii].
16. Meyers MH, Akeson W, Convery FR. Resurfacing of the knee with fresh osteochondral allograft. *J Bone Joint Surg Am.* 1989;71(5): 704–713.
17. Flynn JM, Springfield DS, Mankin HJ. Osteoarticular allografts to treat distal femoral osteonecrosis. *Clin Orthop Relat Res.* 1994;(303)(303):38–43.
18. Fukui N, Kurosawa H, Kawakami A, Sakai H, Nakamura K. Iliac bone graft for steroid-associated osteonecrosis of the femoral condyle. *Clin Orthop Relat Res.* 2002;(401)(401):185–193.
19. Rijnen WH, Luttjeboer JS, Schreurs BW, Gardeniers JW. Bone impaction grafting for corticosteroid-associated osteonecrosis of the knee. *J Bone Joint Surg Am.* 2006;88 Suppl 3:62–68. doi: 88/suppl_3/62 [pii].
20. Matsusue Y, Kubo M, Nakagawa Y. Autogenous bone-cartilage transplantation. *Techniques in Knee Surgery.* 2010;9(2):85–94.
21. Goodman SB, Hwang KL. Treatment of secondary osteonecrosis of the knee with local debridement and osteoprogenitor cell grafting. *J Arthroplasty.* 2015. doi: S0883-5403(15)00382-4 [pii].

Medical Student Research Project

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Literature Review of ACL Prevention Programs Among Female Basketball Players

Patrick Hugh Donaghue, BS; Michelle Noreski, DO

Department of Orthopaedic Surgery, Lewis Katz School of Medicine at Temple University, Philadelphia, PA

Introduction

The 1972 enactment of Title IX exponentially increased female participation in sports, particularly in women's basketball. According to the National Federation of State High School Associations, 450,000 females played basketball at the high school level alone last season (2015). However, increased participation in women's basketball has uncovered a disturbing trend. Female basketball players are at 3–6 times greater risk of rupturing an ACL as compared to their male counterparts.[1] Additionally, women's basketball trails only men's American football, women's gymnastics, and women's soccer in ACL injuries per 1,000 athletic exposures (AE), with an athletic exposure (AE) defined as one practice or game.[2]

The ACL is one of the four knee ligaments that provides stability to the knee by preventing the combined motions of anterior tibial translation and internal tibial rotation.[3] A healthy joint, with an intact ACL, protects an athlete's menisci from the shearing forces applied to the knee during basketball. A ruptured ACL costs female basketball players much more than their season. The surgical procedure and extensive rehab required to repair a ruptured ACL costs between $17,000 and $25,000.[4] These factors, combined with the deleterious effects on the athlete's mental well-being, have led the sports medicine community to develop and implement ACL rupture preventative training programs.

The literature has studied why female athletes are at an inherently higher risk for rupturing an ACL. This research indicates that anatomical, neuromuscular, and biomechanical factors all play a significant role in ACL rupture. With this knowledge, researchers have moved to develop comprehensive preventative training programs to mitigate the risk of ACL ruptures for female athletes. Many studies have analyzed the incidence of ACL rupture pre- and post-training intervention across multiple team sports. However, few studies to this date have looked at these preventative training programs exclusively in women's basketball. Via a review of the literature, this paper aims to analyze the efficacy of these programs by examining ACL rupture incidence before and after preventative training intervention in women's basketball.

Non-Contact ACL Rupture

This review focuses on the prevention of non-contact ACL ruptures in women's basketball. Figure 1 displays an image produced by Mary Ireland MD, from the Kentucky Sports Medicine Clinic.[5] The image depicts "position of no return," the anatomical knee position that causes non-contact ACL ruptures in female basketball players. The literature demonstrates that female athletes that rupture an ACL land in this position at a disproportionate rate when compared to their uninjured female counterparts.[6] ACL rupture prevention programs aim to reduce the risk of this occurrence via different strength, plyometric, balance, flexibility, and educational training components.

Materials and Methods

For this review, we employed a PubMed and Embase database literature search. Only English studies were included. All articles under the subjects of "ACL injury prevention programs," "ACL injuries and basketball players," and "injury prevention in women's basketball" from 1999–2015 were considered. The following inclusion criteria were applied: (1) Only studies that included female basketball players as test subjects were considered; (2) Studies required a preventative training program that aimed to reduce ruptures of the ACL in female basketball players; (3) Studies considered were Randomized Controlled Trials and Prospective Cohort Studies. In addition, reference lists from each selected source were crosschecked to ensure relevant articles were not excluded.

Our literature search discovered five studies that observed the incidence of knee injuries both before and after training intervention in women's basketball (Table 1).

A 2006 study from Pfeiffer et al. examined a cohort of high school female athletes playing soccer, basketball, and volleyball.[7] For the purpose of this study, only the basketball statistics were considered. This study implemented the season-long KLIP or Knee Ligament Injury Prevention Program. The KLIP program develops proper body mechanics for athletes during change of direction movements. The "progressive and sequential program" requires an athlete to

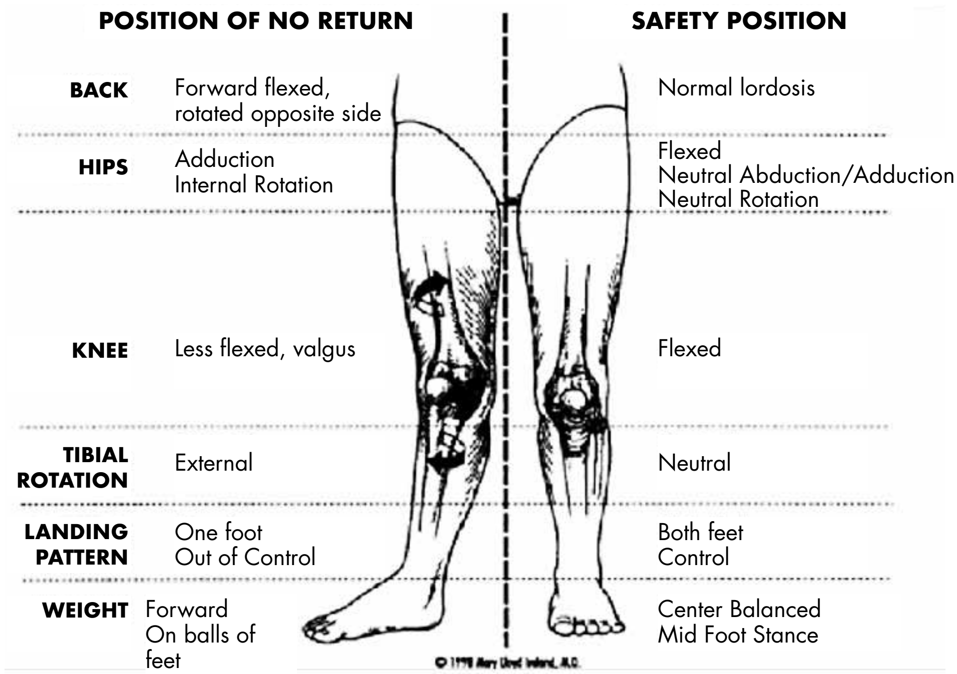


Figure 1

Table 1. Incidence Rate of Non-Contact Knee Injury

Study	Study Type	Training Intervention	Population Tested	Results
Pfeiffer et al.	Prospective non-randomized	KLIP	510 female high school basketball players	Inconclusive
Labella et al.	Cluster randomized control	NMTP	1492 female high school basketball and soccer players	Decreased incidence of non-contact ACL rupture
Hewett et al.	Prospective non-randomized	Jump training	273 female high school basketball players	Decreased incidence of non-contact ACL rupture
Emery et al.	Cluster randomized control	Pre-game training	456 female high school basketball players	Decreased incidence of LE injury
Henning (abstract only)	Prospective non-randomized	Agility training	Division II female basketball players	89% decrease in non-contact ACL rupture

master one phase of the program before she moves to the next level of skill and difficulty. The selected training teams completed the 20-minute KLIP program before and after practice. To measure the efficacy of this program, the incidence of ACL rupture was observed over two seasons for a selected group of control and trial teams. Female basketball players in the control group experienced 18,076 athletic exposures with an incidence of .078 ruptures per 1,000 exposures. The trial KLIP group experienced 6,302 athletic exposures with an ACL rupture incidence of .476 per 1,000 athletic exposures. Though more ACL ruptures were observed in the trial population, this study did not produce significant results. As noted by the authors, this study contained several limitations. First and foremost, the incidence of ACL rupture found in this study was lower than expected based on several epidemiological studies.[8, 9] A larger study population could have aided this issue. The authors also indicated that their program did not emphasize flexibility and strength training, two staples of other training programs. Overall, this study provided inconclusive data on the efficacy of the KLIP program in reducing ACL rupture incidence in women's basketball.

Emery et al. examined the efficacy of a sports-specific balance-training program to reduce lower extremity injuries in Calgary area high school basketball programs.[10] Both the training and control groups learned a 10-minute warm-up routine that included aerobics, static stretching, and dynamic stretching. The training group received an additional five-minute basketball specific warm-up component for practice and games in addition to a 20-minute home exercise program that utilized wobble board balance exercises. Once a week a member of the study group checked in on the training teams in order to ensure compliance. This study did not specifically examine the incidence of ACL rupture; however, the data produced from this randomized controlled trial demonstrated that a basketball-specific training program reduced injury rates for acute lower extremity injuries in female basketball players. In the study, ankle sprains occurred most frequently, followed by acute knee injuries at nine percent. For the female cohort specifically, injury rates (per 100 athletes) dropped from 35 percent in the control group to just above 25 percent in the trained group. The most intriguing part of this study was that it was basketball-specific in nature.

Although the researchers did not study the incidence of ACL rupture specifically, they did monitor the frequency of acute lower extremity injuries. With the implementation of their training, the authors observed a significant decrease in acute lower extremity injuries for the female basketball athletes. This study provides promising data for future research in women's basketball injury prevention programs and a possible platform to study ACL ruptures specifically.

In a non-published, abstract-only paper from 1990, Henning implemented an injury-prevention program for collegiate female basketball players. The program utilized drills to improve agility, landing techniques (in order to prevent knee valgus), and deceleration techniques that reduce stress on the knee joint. The abstract-only paper reported an 89% decrease in non-contact ACL ruptures in collegiate female basketball players after the first season of training.

In 1999, Hewett et al. prospectively evaluated the effects of a jump training injury prevention program on the incidence of ACL rupture for a group of female high school basketball, volleyball, and soccer players.[11] For this purpose of this review, only the statistics of the basketball players were considered. The six-week training program was started in the preseason and was performed 60 to 90 minutes a day, three days a week. The training was designed to instruct athletes on proper jumping and landing techniques in order to increase vertical jump height and muscle strength. Eight girls' basketball teams participated in the study: three teams in the training group and five in the control group. For the control group, there were 10,370 AE and 4,767 AE for the trained group. For the basketball control group, four athletes ruptured an ACL, in contrast to the training group where no athletes experienced a rupture. This data indicated a trend (P = .019) that untrained female athletes were at a higher risk for a non-contact ACL rupture when compared to their untrained counterparts. Also, across the entire study (basketball, soccer, volleyball), an untrained athlete was at a 2.4 to 3.6 greater chance of an ACL rupture when compared to trained athletes. A disparity existed in this study between the number of athletes in the control group and the number of athletes in the trained group, which could have distorted the data. Also, the sample size for the basketball cohort was small (eight teams). However, this study demonstrated statistically significant data that a preventative training program could reduce non-contact ACL rupture incidences in women's basketball.

In 2011, Labella et al. produced the most convincing data in support of ACL preventative training programs.[12] This study observed the effectiveness of a neuromuscular warm-up on lower extremity injuries (LE) in female basketball and soccer players from Chicago-area public schools. It provided the first Level 1 evidence for the reduction of non-contact ACL rupture after the implementation of a preventative training program. The program was implemented two weeks prior to the start of the season by athletic trainers selected by the study team. There were 755 athletes in the control group and 737 athletes in the training group. For this intervention, coaches were taught a 20-minute neuromuscular warm-up to be implemented before team practices, and an abbreviated version for before games. The main aim of the program was to teach the athletes to avoid knee valgus by landing with flexed hips and knees. The program was started within three months of the 2006–2007 season and the athletes were monitored for injury throughout the subsequent season. For the control group, 22,935 athletic exposures led to 11 knee sprains, six ACL sprains, and four ACL ruptures for injury rates of .48, .36, and .17 per 1,000 exposures. In the training group, 28,023 athletic exposures led to six knee sprains, two ACL sprains, and zero ACL ruptures with concurrent incidence rates of .21, .07, and zero per 1,000 AE. This data provides the best evidence to date in support of ACL rupture prevention programs. To prevent one ACL rupture, 189 athletes needed to complete this program. At a cost of $1,280 dollars, this expense pails in comparison to the cost of a surgical reconstruction ($17,000 to $25,000). Though the program was not basketball specific, this randomized control trial provided convincing evidence of the efficacy of a preventive training program for non-contact ACL rupture in women's basketball.

Discussion

Although the literature has demonstrated that preventative training programs can lower the incidence of ACL ruptures in women's basketball, recent data indicates that the level of ACL ruptures in the sport remains high. A 2013 high school injury surveillance study from Ohio State found that from the 2007–2008 to 2011–2012 seasons, the incidence of ACL rupture for female high school basketball players was 10.3 per 100,000 athletic exposures, with ACL ruptures accounting for over five percent of all injuries, higher than any other sport, male or female.[13] A study from Mihata et al., on collegiate female basketball players, showed that from the years 1989 to 2004, the rate of ACL injuries (not just ruptures) per 1,000 athletic exposures remained constant over the timeframe of the study.[14] It appears that the knowledge and benefits of these preventative training programs have yet to affect the rate of ACL ruptures in women's basketball. The literature has highlighted a few factors to explain this phenomenon.

Certain studies have focused on implementing sport-specific training programs to lower the incidence of ACL rupture. In a prospective non-randomized trial over two seasons, Mandelbaum et al. designed a sport-specific preventative training program for female soccer players that decreased ACL ruptures by 88 percent in the first season and 74 percent in the second season.[15] Myklebust et al. developed a prevention program for female Norwegian handball players. The prospective intervention study measured the number of ACL ruptures per season over three seasons. After a control season (season 1), the intervention program significantly dropped the number of ACL ruptures in subsequent seasons via a neuromuscular preventative training program.[16]

The data from these studies indicates that sports-specific preventative training programs for ACL rupture could provide a major benefit to the field. In high school female athletes, researchers have observed differences in ground reaction forces, valgus angle, and valgus movements during a maximum vertical jump and sidestep at a 45-degree angle (movements associated with non-contact ACL rupture) between basketball and soccer players. These findings led the researchers to recommend different training programs for each set of athletes. The authors emphasized a program that developed proper jumping and landing techniques for the basketball players and a program that emphasized safe cutting techniques for the soccer players.[17] Even with these studies available, a majority of the present literature still focuses on implementing these programs across multiple team sports. However, these studies demonstrate that sport-specific preventative training programs have the benefit of both increasing athletic performance and reducing the rate of ACL rupture. Data demonstrating reduced ACL ruptures with sport-specific preventative training, in conjunction with research that indicates athletes from different sports are at risk for ACL rupture due to unique factors, suggests that sport-specific preventative training programs may be necessary. Future research in women's basketball should focus on the development of sport-specific training to increase program effectiveness.

Another issue observed in the literature pertains to the lack of knowledge about the risk of ACL rupture in women's basketball. A study out of Massachusetts General Hospital developed an educational program on ACL rupture prevention and evaluated its effectiveness on high school female basketball players' ACL injury knowledge, attitudes, and practices.[18] First, the authors determined the athletes' baseline knowledge via a questionnaire distributed to 118 female basketball players across eight teams in southern Massachusetts. Players demonstrated a baseline knowledge of 57.3 on the anatomy and function of the ACL, and the mean reported the use of injury prevention practices at 58.4 (out of a possible 100 points). The intervention consisted of a 45-minute didactic presentation on the anatomy and function of ACL and risk factors associated with ACL ruptures, in addition to a skills clinic focused on injury reduction techniques. Following the intervention, players' knowledge about the ACL and rupture risk factors increased by 4.5 points (5%). Also, videotape analysis of players' performance of correct landing techniques (without valgus) during games indicated a 5.5% increased in the number of correct landings performed. No ACL injuries occurred over the duration of this study. This brief 45-minute intervention yielded statistically significant results that could be easily scaled to a larger amount of teams. The study highlighted that knowledge about the risks of ACL rupture in women's basketball remains low and that future prevention programs should require an educational component.

The literature demonstrates that a successful prevention program requires compliance. Lim et al. developed the SIPTP prevention program to mitigate biomechanical risk factors for female basketball players.[19] The authors claimed a successful program "must be feasible and practical in terms of their applicability to younger populations because compliance is vital." If a program does not fit into the daily practice routine of the athletes and coaches, compliance drops rendering the program useless. This lends credence to basketball-specific training programs. Authors have speculated that programs that focus on both performance enhancement and injury prevention achieve the greatest participation and compliance.[20] To ensure that more athletes reap the benefits of prevention programs, future research should develop succinct basketball centric programs that fit into the routine of the sport.

Conclusion

As previously noted, the literature has highlighted why females are at an inherently higher risk for non-contact ACL ruptures during basketball. The existing literature indicates that ACL rupture prevention programs provide the best means to reduce the incidence of ACL ruptures in women's basketball by mitigating predisposed risks. Future research should focus on holistic basketball-specific training programs. These programs should involve workouts to improve athletic performance metrics and educational components for both players and coaches to increase program compliance and success.

References

1. Brent JL, Myer GD, Ford KR, Paterno MV, Hewett TE. The effect of sex and age on isokinetic hip-abduction torques. *J Sport Rehabil.* 2013;22(1):41–46.
2. Renstrom P, Ljungqvist A, Arendt E, et al. Non-contact ACL injuries in female athletes: An international olympic committee current concepts statement. *Br J Sports Med.* 2008;42(6):394–412.
3. Stojanovic MD, Ostojic SM. Preventing ACL injuries in team-sport athletes: A systematic review of training interventions. *Res Sports Med.* 2012;20(3-4):223–238.
4. LaBella CR, Hennrikus W, Hewett TE, Council on Sports Medicine and Fitness, and Section on Orthopaedics. Anterior cruciate ligament injuries: Diagnosis, treatment, and prevention. *Pediatrics.* 2014;133(5): e1437–50.
5. Ireland ML. Anterior cruciate ligament injury in female athletes: Epidemiology. *J Athl Train.* 1999;34(2):150–154.

6. Hewett TE, Torg JS, Boden BP. Video analysis of trunk and knee motion during non-contact anterior cruciate ligament injury in female athletes: Lateral trunk and knee abduction motion are combined components of the injury mechanism. *Br J Sports Med.* 2009;43(6):417–422.
7. Pfeiffer RP, Shea KG, Roberts D, Grandstrand S, Bond L. Lack of effect of a knee ligament injury prevention program on the incidence of noncontact anterior cruciate ligament injury. *J Bone Joint Surg Am.* 2006;88(8):1769–1774.
8. Gomez E, DeLee JC, Farney WC. Incidence of injury in texas girls' high school basketball. *Am J Sports Med.* 1996;24(5):684–687.
9. Powell JW, Barber-Foss KD. Sex-related injury patterns among selected high school sports. *Am J Sports Med.* 2000;28(3):385–391.
10. Emery CA, Rose MS, McAllister JR, Meeuwisse WH. A prevention strategy to reduce the incidence of injury in high school basketball: A cluster randomized controlled trial. *Clin J Sport Med.* 2007;17(1):17–24.
11. Hewett TE, Lindenfeld TN, Riccobene JV, Noyes FR. The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study. *Am J Sports Med.* 1999;27(6):699–706.
12. LaBella CR, Huxford MR, Grissom J, Kim KY, Peng J, Christoffel KK. Effect of neuromuscular warm-up on injuries in female soccer and basketball athletes in urban public high schools: Cluster randomized controlled trial. *Arch Pediatr Adolesc Med.* 2011;165(11):1033–1040.
13. Joseph AM, Collins CL, Henke NM, Yard EE, Fields SK, Comstock RD. A multisport epidemiologic comparison of anterior cruciate ligament injuries in high school athletics. *J Athl Train.* 2013;48(6):810–817.
14. Mihata LC, Beutler AI, Boden BP. Comparing the incidence of anterior cruciate ligament injury in collegiate lacrosse, soccer, and basketball players: Implications for anterior cruciate ligament mechanism and prevention. *Am J Sports Med.* 2006;34(6):899–904.
15. Mandelbaum BR, Silvers HJ, Watanabe DS, et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med.* 2005;33(7):1003–1010.
16. Myklebust G, Engebretsen L, Braekken IH, Skjolberg A, Olsen OE, Bahr R. Prevention of anterior cruciate ligament injuries in female team handball players: A prospective intervention study over three seasons. *Clin J Sport Med.* 2003;13(2):71–78.
17. Cowley HR, Ford KR, Myer GD, Kernozek TW, Hewett TE. Differences in neuromuscular strategies between landing and cutting tasks in female basketball and soccer athletes. *J Athl Train.* 2006;41(1):67–73.
18. Iversen MD, Friden C. Pilot study of female high school basketball players' anterior cruciate ligament injury knowledge, attitudes, and practices. *Scand J Med Sci Sports.* 2009;19(4):595–602.
19. Lim BO, Lee YS, Kim JG, An KO, Yoo J, Kwon YH. Effects of sports injury prevention training on the biomechanical risk factors of anterior cruciate ligament injury in high school female basketball players. *Am J Sports Med.* 2009;37(9):1728–1734.
20. Noyes FR, Barber-Westin SD, Smith ST, Campbell T, Garrison TT. A training program to improve neuromuscular and performance indices in female high school basketball players. *J Strength Cond Res.* 2012;26(3):709–719.

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Factors Impacting Access to Surgical Care of Distal Radius Fractures

Sourodeep Banerjee, BS; Saqib Rehman, MD

Department of Orthopaedic Surgery, Lewis Katz School of Medicine at Temple University, Philadelphia, PA

Introduction

Distal radius fractures are amongst the most common fractures with an annual incidence of 16.1 fractures per 10,000 persons.[1] Falling onto an outstretched arm is a frequent cause of distal radius fractures, and the burden of these fractures on healthcare is expected to increase as the US population ages and increases.[2, 3]

Delayed presentation and treatment of fractures can make surgical repair more difficult and lengthen the period of disability.[4, 5] Performing surgery earlier leads to significantly better wrist range of motion (ROM), measurement of grip strength (GS), and a Disability of the Arm, Shoulder and Hand score (DASH).[6]

There are several possible reasons for the delayed interval between injury and presentation to clinic, including insurance status, misunderstanding the importance of timely treatment, racial and socioeconomic disparities, and language barriers.[7–11] Access to care continues to be one of the problems that healthcare policy attempts to address, and access may be dependent on many factors including age and geographical location.[10] In the United States, the Census Bureau estimated that 42 million people had no medical insurance, and over 54 million people were covered by Medicaid. Several studies demonstrate the detrimental effect of Medicaid coverage or uninsured status on the ability to receive timely medical care in both adults and children.[12–14] Whereas many operative lower extremity fractures are treated with inpatient admission and surgery, distal radius fractures are typically managed as outpatient procedures. As such, issues impacting access to care could be more likely to create delays in surgical management of distal radius fractures. Although distal radial fractures are one of the most extensively studied group of fractures, there are no studies to our knowledge evaluating the time between injury and presentation in an orthopaedic surgeon's clinic and for surgical care for this category of fractures. There is also no literature comparing a delay in presentation to an increased risk of complications.[15]

The present study seeks to identify the length of time between injury and presentation in clinic for distal radius fractures, and also explore risk factors that could account for a delay.

Methods

Institutional review board approval was obtained to collect data about patients who presented to Temple University Hospital between January 2010 to March 2016 with distal radius fractures. To be included in the study, patients had to have suffered no other fractures besides the distal radius fracture. Out of 300 patients over the age of 18 who suffered distal radius fractures, 70 were included in our study. Data obtained included: the date of injury, date of presentation to the ED and clinic, dates of surgical treatment, insurance status, any reported reason for a delay, any language barriers, and any complications after surgery.

Results

The patients were divided by insurance status into two groups: (1) insured and (2) underinsured (Medicaid or no insurance). The patients were also divided by language spoken: (1) English and (2) non English. Continuous variables for elapsed time were compared using the Wilcoxan rank sum test. Significance was defined as $p < 0.05$.

The final cohort included 70 patients, 29 of whom were insured (I) and 41 underinsured (U). Out of those 70 patients, 58 were English speakers (E) and 12 did not speak English (N). Although the difference in the length of time between injury and presentation for those insured versus underinsured was not found to be statistically significant (I: average 8.6 days, range 0–30 days; U: average 14.3 days, range 0–76; $p = 0.0642$), the p-value approached 0.05 (Table 1). The length of time between presentation and surgery was not found to be statistically different between the insured and underinsured groups. The non-English speaking group experienced significant delays during treatment compared to the English speaking group (Table 2). The length of time between injury and presentation in an orthopaedic surgeon's clinic was significantly increased for non-English speakers (E: average 10.4 days, range 0–58 days; N: average 19.4

days, range 7–76 days; p = 0.0091). The length of time between presentation and surgery was not found to be significantly different.

Table 1. Time Intervals for Insured Versus Underinsured

Time Interval	Insured	Underinsured	p-value
Injury to presentation to the treating orthopaedic surgeon	8.6 ± 8.0	14.3 ± 15.2	0.0642
Presentation to surgery	6.1 ± 3.2	7.1 ± 8.3	0.7986

Values are in days and given as the mean ± standard deviation.

Table 2. Time Intervals for English Speakers Versus Non-English Speakers

Time Interval	English	No English	p-value
Injury to presentation to the treating orthopaedic surgeon	10.4 ± 11	19.4 ± 18.9	0.0091
Presentation to surgery	5.9 ± 3.5	11.2 ± 14.8	0.5685

Values are in days and given as the mean ± standard deviation.

Discussion

The language barrier is a major cause of delay for presentation to an orthopaedic clinic following a visit to the emergency department. The non-English speaking group had a significantly greater average length of time between injury and presentation in clinic. According to this study, non-English speakers take almost double the time to present their injury to an orthopaedic surgeon compared to English speakers. While the average time between presentation in an orthopaedic surgeon's clinic and surgery was longer for non-English speakers, there was no statistical difference.

The underinsured group was found to take longer on average to present their injury to an orthopaedic surgeon than the insured group. While the p value was only 0.0642, a larger sample size may have made the difference between the two groups being statistically different. The length of time between presentation and surgery for the underinsured was also found to be on average longer than for the insured, but the data was also not found to be significant.

Causes for a delay in presentation for patients who speak a foreign language could include a relative lack of physician-to-patient communication regarding health literacy, instructions the patient needs to follow after discharge from the emergency department, referral to an orthopaedic surgeon, the fears and concerns of the patient, and support and care. A lack of communication in any of these crucial parts necessary for a healing relationship could lead to longer recovery times and undesired outcomes.

One strategy that could be employed to improve physician-to-patient communication should include being able to provide discharge document in the patient's native language. With the increasing prevalence of electronic medical records in hospitals around the country, being able to provide translated documents should become not only simpler but also standard practice. Another strategy that could be used concurrently is a follow up call to the patient via translator after discharge to ensure proper communication regarding the next steps needed to complete the treatment regimen.[16]

This study has some weaknesses worth discussing. Due to this study being retrospective, the dates of injury and physician appointments at outside institutions were dependent on patient recollection and proper documentation. This introduced an element of recall bias, especially for patients whose injuries were remote from the presentation to this clinic. Another weakness of this study is that all of the data was compiled from a single setting in urban North Philadelphia. Extrapolations to all settings throughout the United States cannot be made without further studies that include multiple regions. A third weakness was that the relatively small sample size decreased the power of the study such that while some differences between groups could be clearly seen by comparing averages the differences were statistically insignificant. Further studies with larger sample sizes could show that there is a statistically significant difference in the length of time to presentation for insured versus underinsured patients.

Conclusion

When compared to English speakers, patients who speak a foreign language on average experienced statistically significant delays in care for a distal radius fracture based on length of time between injury and presentation in an orthopaedic surgeon's clinic. Future studies should be directed towards identifying the specific causes of miscommunication between physicians and foreign language speaking patients so resources can be directed towards eliminating those barriers to care. We should aim to reduce systemic factors such as inability of patients to receive information and care in their first language.

References

1. Karl JW, Olson PR, Rosenwasser MP. The epidemiology of upper extremity fractures in the united states, 2009. *J Orthop Trauma.* 2015; 29(8):e242–4.
2. Shauver MJ, Yin H, Banerjee M, Chung KC. Current and future national costs to medicare for the treatment of distal radius fracture in the elderly. *J Hand Surg Am.* 2011;36(8):1282–1287.
3. Kakarlapudi TK, Santini A, Shahane SA, Douglas D. The cost of treatment of distal radial fractures. *Injury.* 2000;31(4):229–232.
4. Weil YA, Mosheiff R, Firman S, Liebergall M, Khoury A. Outcome of delayed primary internal fixation of distal radius fractures: A comparative study. *Injury.* 2014;45(6):960–964.
5. Jupiter JB, Ring D. A comparison of early and late reconstruction of malunited fractures of the distal end of the radius. *J Bone Joint Surg Am.* 1996;78(5):739–748.
6. Yamashita K, Zenke Y, Sakai A, Oshige T, Moritani S, Maehara T. Comparison of functional outcome between early and delayed internal fixation using volar locking plate for distal radius fractures. *J UOEH.* 2015;37(2):111–119.
7. Clark S, Mangram A, Ernest D, Lebron R, Peralta L. The informed consent: A study of the efficacy of informed consents and the associated role of language barriers. *J Surg Educ.* 2011;68(2):143–147.

8. Comber AJ, Brunsdon C, Radburn R. A spatial analysis of variations in health access: Linking geography, socio-economic status and access perceptions. *Int J Health Geogr.* 2011;10:44-072X-10-44.
9. Fanuele J, Koval KJ, Lurie J, Zhou W, Tosteson A, Ring D. Distal radial fracture treatment: What you get may depend on your age and address. *J Bone Joint Surg Am.* 2009;91(6):1313–1319.
10. Dy CJ, Lane JM, Pan TJ, Parks ML, Lyman S. Racial and socioeconomic disparities in hip fracture care. *J Bone Joint Surg Am.* 2016; 98(10):858–865.
11. Rosenbaum AJ, Uhl RL, Rankin EA, Mulligan MT. Social and cultural barriers: Understanding musculoskeletal health literacy: AOA critical issues. *J Bone Joint Surg Am.* 2016;98(7):607–615.
12. Asplin BR, Rhodes KV, Levy H, et al. Insurance status and access to urgent ambulatory care follow-up appointments. *JAMA.* 2005;294(10): 1248–1254.
13. Lasser KE, Himmelstein DU, Woolhandler S. Access to care, health status, and health disparities in the united states and canada: Results of a cross-national population-based survey. *Am J Public Health.* 2006; 96(7):1300–1307.
14. Skaggs DL, Lehmann CL, Rice C, et al. Access to orthopaedic care for children with medicaid versus private insurance: Results of a national survey. *J Pediatr Orthop.* 2006;26(3):400–404.
15. Mathews AL, Chung KC. Management of complications of distal radius fractures. *Hand Clin.* 2015;31(2):205–215.
16. Zheng MC, Zhang JE, Qin HY, Fang YJ, Wu XJ. Telephone follow-up for patients returning home with colostomies: Views and experiences of patients and enterostomal nurses. *Eur J Oncol Nurs.* 2013;17(2): 184–189.

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Utility of MRI to Define Anatomical Features of the Anterior Inferior Iliac Spine

Alex Pandelidis, BS;[1] Megan Reilly, MD;[2] Justin Ly, BA;[2]
Frederick Ramsey, PhD;[3] Eric Kropf, MD[2]

[1]*Temple University School of Medicine;* [2]*Temple University School of Medicine, Department of Orthopaedic Surgery and Sports Medicine;* [3]*Department of Clinical Sciences, Temple University School of Medicine, Philadelphia, PA*

Abstract

Background: Subspine impingement is a common cause of hip pain in young athletes. Radiographs fail to fully define the anatomy of the anterior inferior iliac spine (AIIS) often necessitating need for computed tomography (CT). The purpose of this study is to determine the utility of magnetic resonance imaging (MRI) to define AIIS anatomy and compare our findings to previously reported values obtained using CT scans.

Methods: Pelvic MRI including bilateral hips of 50 asymptomatic patients were evaluated, which included 31 females (average height, 1.62 m; BMI, 28.9 kg/m^2) and 19 males (average height, 1.74 m; BMI, 27.6 kg/m^2). Axial sequence measures included: width and the angle of the AIIS relative to the ilium. MRIs of 58 asymptomatic patients were also evaluated. Measures included: AIIS length, width, and the horizontal, vertical, and straight distances from the AIIS to the acetabular rim. Thirty-eight females (average height, 1.61 m; BMI, 28.9 kg/m^2) and 20 males (average height, 1.81 m; BMI, 28.4 kg/m^2) were included in this portion. Values were normalized for height and BMI. Two observers independently obtained all measures which were then averaged and compared to literature reported CT values.[1]

Results: Measures of AIIS anatomy were successfully obtained on all MRI sequences (Table 1). Male values showed statistical consistency with literature values in all BMI-normalized measures except length and height of AIIS. Comparison of female values to literature values was statistically different in all BMI-normalized measures except for angle to ilium.

Conclusions: MRI is a sound method to evaluate AIIS anatomy. The results of MRI measurements demonstrate statistical consistency with previously reported literature values in the male population but not the female population. This small statistically significant difference may be of little clinical significance and likely reveals a subtle difference between the female populations studied.

Introduction

Femoroacetabular impingement (FAI) has been proposed as a cause of osteoarthritis of the hip, possibly due to excessive force on the anterosuperior portion of the hip joint. Bony abnormalities lead to collision of the femoral head with the anterior acetabulum and potential damage to cartilage and/or labrum. This can be due to a number of reasons such as coxa profunda, retroversion, subclinical epiphyseal slip/displacement, protrusion acetabuli, or post-traumatic deformities. An impingement test can be done to help diagnose, in which the patient is supine, the hip is internally rotated, passively flexed to 90 degrees, and then adducted. If there is pain during these motions, FAI could be an issue.[1]

Two kinds of FAI have been well-described, cam and pincer-type impingements. Cam impingement is more common in young, athletic males and results from a femoral head with a larger radius than normal protruding painfully into the acetabulum during forceful flexion. This leads to avulsion of acetabular cartilage and possible subsequent detachment of labrum. On the other hand, pincer impingements occur in older women who show a desire for athletic activities and result from an acetabular abnormality making linear contact with the femoral head-neck junction. This can lead to damage to the labrum as well as ossification of acetabular rim.[1]

However, increasing evidence has shown that causes of FAI can also be extra-articular. Hetsroni et al. studied 10 patients that presented with FAI symptoms but the pain did not subside an hour after intra-articular injection of local anesthetic, suggesting some kind of impingement outside of the hip joint. Seven of the 10 patients were involved in sports involving kicking or sprinting such as basketball, soccer, or football.[2] Some sources of extra-articular FAI include ischiofemoral, iliopsoas, and our research focus, the anterior inferior iliac spine (AIIS).[3] Since the rectus femoris is used heavily in the activities previously stated and attaches at the AIIS, this appears to be an important site for FAI, especially in young athletes.[2] Patients normally present with: 1) anterior hip or groin pain upon straight hip flexion; 2) anterior pain with prolonged hip flexion; 3) limited range of motion during flexion; and 4) specific tenderness over AIIS upon palpation. Radiographs often show an avulsion injury or calcification at the point of attachment of the rectus femoris. Additionally, impingement cysts appear on the femoral neck more distal than typically seen in cam or pincer types of impingement.[3]

Due to the increase in cases reported as AIIS type of FAI, it is vital to obtain measurements for the normal size of the AIIS. Despite the fact that favorable outcomes for FAI have increased due to surgery, some patients have recurring symptoms and a revision surgery is necessary.[5] Therefore, average reported size of the AIIS enables a successful surgery to reduce the size of the AIIS and avoid revision surgery, while also assisting in diagnosis. This study will use MRI and seeks to determine a normalized average size and distance from the acetabular rim of the anterior inferior iliac spine, as well as angles in the hip joint, in order to assist in the diagnosis and surgical treatment. By comparing the values to previous values found in CT studies, we hope to show that using MRI, and therefore less radiation, can effectively determine the AIIS size as well.

Figure 1. Measurement of the length (10.3 mm) and height (30.7 mm) of the anterior inferior iliac spine using sagittal view MRI.

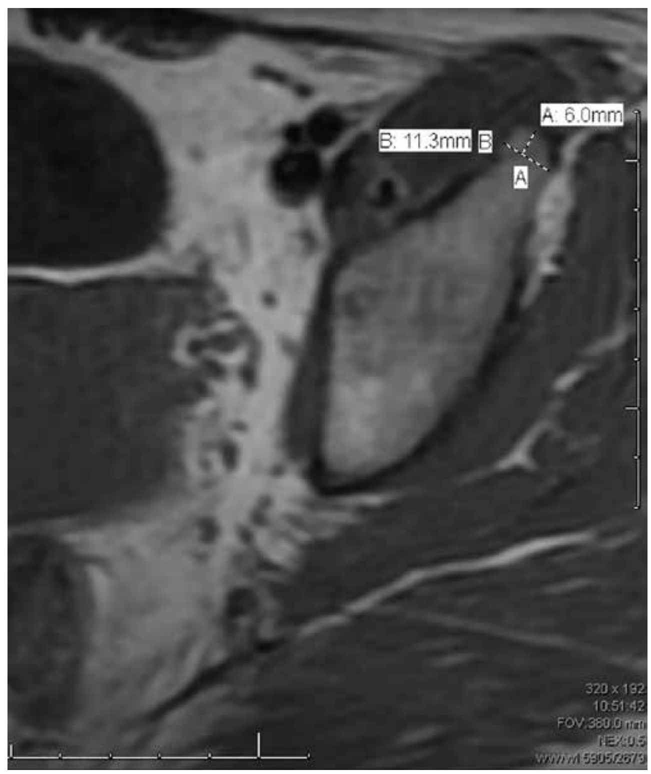


Figure 2. Measurement of the width (11.3 mm) of the anterior inferior iliac spine using axial view MRI.

Methods

MRIs of 50 asymptomatic patients collected between January 2008 and June 2015, for a total of 100 hips, were obtained through the Temple PACS radiograph system. The patients were between 18 and 50 years of age. These MRIs only contained axial views, so a separate patient list was generated to obtain measurements from sagittal views. This list included 58 MRIs of the lateral part of the hip, collected between January 2008 and June 2015, and the patients were between 18 and 50 years old. The patients' heights and BMIs were obtained using the Epic chart service.

Measurements

The size of the AIIS in each hip was measured using the length, or distance from the end ilium to the most anterior point of the AIIS. The height of the AIIS described the vertical expanse of the AIIS while the width described the horizontal expanse. The length and height of the AIIS were measured by MRI on a sagittal view (Figure 1) and the width was measured 6 mm from the edge of the AIIS, looking at an axial MRI view (Figure 2). In order to quantify how close the AIIS is normally to impinging on acetabulum and femur, the straight, horizontal, and vertical distances from the most prominent, inferior part of the AIIS to the rim of the acetabulum were measured. These values were obtained using a sagittal view MRI, with the straight distance along the ilium. The three measurements make a triangle, with the straight distance being the hypotenuse and the vertical and horizontal distances acting as legs. The horizontal distance is from the aforementioned part of the AIIS straight out and in line with the acetabular rim. The vertical distance is from the acetabular rim to the intersection with the horizontal distance line (Figure 3). This data collected was normalized in two ways simply by dividing each measurement by both the patient's BMI in kg/m^2 and height in meters.

Other aspects of AIIS anatomy measured included one angle of the hip to look at the degree of version, or to what extent the acetabulum and other structures encroach on the

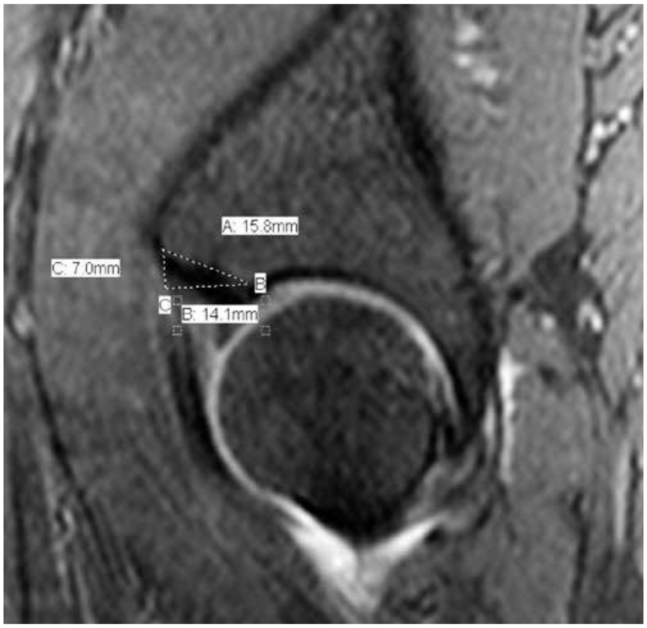


Figure 3. Measurement of the vertical (7.0 mm), horizontal (14.1 mm), and straight (15.8 mm) distances of the anterior inferior iliac spine from the acetabulum using sagittal view MRI.

head and neck of the femur. On an axial MRI view, the angle between a midaxis line through the AIIS and a midaxis line through the ilium was obtained (Figure 4).

Two different analyses were performed due to the fact that MRIs available did not have proper axial and sagittal views necessary to measure the AIIS anatomy. Therefore, axial views were used to determine: 1) width of AIIS; 2) mid axis line of ilium and mid axis line of AIIS angle; 3) mid axis line of AIIS and plumb line angle; and 4) acetabular version angle. A different set of MRIs were used to measure 1) length and height of AIIS and 2) straight, horizontal, and vertical distance of the AIIS from the acetabulum. The distances and angles in both analyses were measured by two separate observers and averaged. The values were then compared to normal values obtained by Amar et al.[6] from asymptomatic patients using CT scans in order to validate the use of MRI in measuring the AIIS in FAI diagnosis and surgery.

Statistical Analysis

Statistical analysis was performed by the Department of Clinical Sciences at the Temple University School of Medicine. A two-sample t-test was used to compare the means of the measurements between males and females of the experimental groups, and those of the previously described normal values, with a significance level of 0.05 used.

Results

The axial data set n = 50 contained 31 females and 19 males for a total of 100 hips. Females had a mean age of 38.6 with a minimum age of 20 and a maximum age of 50 years old, an average height of 1.62 m, and an average BMI of 28.9 kg/m^2. Males had a mean age of 33.4 with a minimum age of 18 and a maximum age of 50 years old, an average height of 1.74 m, and an average BMI of 27.6 kg/m^2. The sagittal data set n = 58 contained 38 females and 20 males. Females had a mean age of 34.7 with a minimum age of 19 and a maximum age of 49 years old, an average height of 1.61 m, and an average BMI of 28.9 kg/m^2. Males had a mean age of 33.5 with a minimum age of 18 and a maximum age of 45 years old, an average height of 1.81 m, and an average BMI of 28.4 kg/m^2.

Table 1 shows the measurements of the AIIS length, height, and width along with the vertical, horizontal, and straight distance of the AIIS from the acetabulum which were all standardized by the height of patient. Additionally, the angle of the AIIS with the ilium is shown, which is not normalized. The measurements are averaged and the p values are shown, which indicate that there is a difference between the average value of the our measurements and the literature values from Amar et al.[6] In addition, Table 2 presents the same measurements except they are normalized by the patient's BMI.

Based on the p values calculated, the following height-normalized data collected for females did not differ significantly from the expected values: horizontal distance of AIIS from the acetabular rim and the angle of the AIIS with the ilium (not normalized). For males, the following height-normalized data collected did not differ significantly from the expected values: vertical, horizontal, and straight distances of AIIS from the acetabular rim. Additionally, for

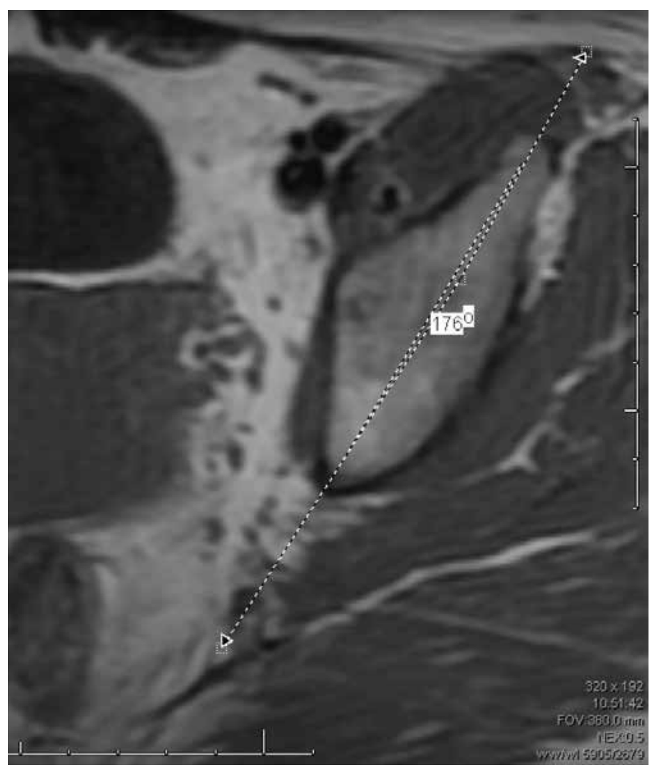


Figure 4. Measurement of the angle between the mid axis line of the ilium and the mid axis line of the anterior inferior iliac spine using MRI.

Table 1. Measurements of Anterior Inferior Iliac Spine Anatomy Normalized by Height (m)

Measurement	Males	Amar et al.	P Value	Females	Amar et al.	*P* Value
Length	16.54 ± 0.34	18.1 ± 0.40	0.0044	15.72 ± 0.27	17.1 ± 0.31	0.0016
Height	6.20 ± 0.22	3.5 ± 0.21	<0.0001	6.11 ± 0.14	3.5 ± 0.16	<0.0001
Width	5.74 ± 0.10	6.7 ± 0.18	<0.0001	5.38 ± 0.09	5.9 ± 0.15	0.0035
Vertical distance	8.21 ± 0.26	7.6 ± 0.36	0.1776	8.55 ± 0.26	7.2 ± 0.40	0.0012
Horizontal distance	9.53 ± 0.43	9.6 ± 0.38	0.9168	9.51 ± 0.21	8.9 ± 0.40	0.1807
Straight distance	12.72 ± 0.42	12.3 ± 0.43	0.4821	12.80 ± 0.23	11.6 ± 0.31	0.0026
Angle with ilium	8.14 ± 0.67	9.2° ± 1.15°	0.4297	7.98 ± 0.49	8.1° ± 1.31°	0.9296

All values are in mm except for the angles.

Table 2. Measurements of Anterior Inferior Iliac Spine Anatomy Normalized by BMI (kg/m^2)

Measurement	Males	Amar et al.	P Value	Females	Amar et al.	*P* Value
Length	1.08 ± 0.05	1.23 ± 0.05	0.0336	0.91 ± 0.03	1.35 ± 0.04	<0.0001
Height	0.41 ± 0.02	0.25 ± 0.02	<0.0001	0.35 ± 0.01	0.26 ± 0.02	0.0002
Width	0.38 ± 0.01	0.42 ± 0.02	0.0797	0.32 ± 0.01	0.50 ± 0.02	<0.0001
Vertical distance	0.54 ± 0.03	0.51 ± 0.03	0.4798	0.50 ± 0.02	0.58 ± 0.03	0.0230
Horizontal distance	0.63 ± 0.04	0.64 ± 0.04	0.8859	0.55 ± 0.02	0.72 ± 0.04	0.0003
Straight distance	0.84 ± 0.05	0.83 ± 0.04	0.4821	0.74 ± 0.03	0.93 ± 0.04	0.0002
Angle with ilium	8.14 ± 0.67	9.2° ± 1.15°	0.4297	7.98 ± 0.49	8.1° ± 1.31°	0.9296

All measurements in mm except for the angles.

males, there are BMI-normalized values that did not differ significantly from the expected values which included: width of AIIS and vertical, horizontal, straight distance of AIIS from the acetabular rim, and the non-standardized angle of AIIS with the ilium.

Conclusions

Femoral acetabular impingement is most often caused by intra-articular sources, either cam or pincer-type. Cam impingement happens when the widening of the head-neck junction of the femur enters the joint upon hip flexion, so it is an inclusion-type injury. Pincer impingement is more of an impaction injury because over coverage of the acetabulum on the femoral head causes impaction upon flexion.[7] Extra-articular FAI is less common and, therefore, less well-defined and includes anterior inferior iliac spine impingement. This can happen in patients playing sports requiring kicking or sprinting, or possibly from an avulsion injury.[2] All FAI types can be treated by performing an osteoplasty on the area of the hip that is impinging on the hip joint. If an AIIS impingement is not taken into account during surgery, a revision surgery may be necessary to alleviate symptoms if only the acetabular or cam part of the impingement is reduced.[8] Therefore, we aimed to measure normal AIIS anatomy using MRI, allowing surgeons to better diagnose an extra-articular FAI leading to better outcomes of FAI surgery.

Our anatomical measurements obtained from MRIs were not as consistent with Amar et al. data as we would have hoped. However, some values obtained were not significantly different from the literature values. For the most part, the measurements for males were consistent with the literature results. The height and BMI-normalized AIIS length, as well as the height-normalized AIIS width were statistically different than the literature values. However, a statistically significant difference does not necessarily equate to a clinically significant difference. For example, since the average male BMI was 27.6, the difference between the two values for length of the AIIS was only roughly 4 mm which may not be a large difference with respect to surgery or diagnosis. The height-normalized AIIS width may have had a similar characteristic. On the other hand, in both normalizations (and for men and women) of the AIIS height, the values were much higher than expected. This was not much of a surprise because it was difficult to consistently measure the height of the AIIS on MRI with the examples given in the Amar et al. paper.

With respect to the females, only two measurements were consistent with the literature results: height-normalized horizontal distance of AIIS from the acetabular rim and the angle of the AIIS with the ilium. There were a few measurements that may have been statistically different but not clinically significant. However, most of the values were entirely different. Because the measurements were not done any differently with the males and females, we are inclined to believe that this could have been due to a difference in patient population rather than measurement quality.

Our study could have been improved in a few ways that may have yielded more consistent results. One glaring difference between the literature study and ours was the fact that we used two different observers separately and averaged the values while the Amar et al. study used two different observers doing the measurements together. If we could have had the two observers working together to agree on different points for measurements of the AIIS, we may have gotten more similar results to the literature values. Along the same lines, if we had more than two observers complete the measurements, we believe the averages could have been closer to the literature values as well.

Although there was not perfect consistency between the measurements obtained in this study and those of Amar et al., additional studies could show that using MRI to measure the aspects of the anterior inferior iliac spine anatomy and normalize the measurements by a patient's height can be a useful and less harmful way to diagnose and treat femoral acetabular impingement.

Limitations

There were some limitations with the study. Since this was a comparative, cross sectional study, the expected values were already known. Therefore, it is possible there was some bias in the measurements since we expected that the values we measured on MRI would not be different from those of CT. However, by having two independent investigators completing the measurements, we hope that this source of bias was lessened. Additionally, for the sagittal MRIs used for length, height, and distances from acetabular rim, some symptomatic patients were used. Normal axial MRI views in the Temple Health System came from pelvic MRIs, which could be from a myriad of diagnoses. Unfortunately, the sagittal views taken in those orders were not lateral enough to obtain the other necessary measurements. Therefore, a new patient list had to be generated based on specific hip MRIs. This inevitably included patients symptomatic for femoral acetabular impingement, among other things. However, we did not expect this to affect the results too much because the incidence of the AIIS impingement is relatively rare as compared to other intra-articular impingement types.[2] Our results showed consistent results in both the sagittal and axial view measurements for males, and similar inconsistencies in both views with the female measurements. This indicates that obtaining sagittal views from patients with hip problems did not affect the results, although no specific statistical analysis was done.

References

1. Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: A cause for osteoarthritis of the hip. *Clin Orthop Relat Res.* 2003;(417):112–120.
2. Hetsroni I, Larson CM, Dela Torre K, Zbeda RM, Magennis E, Kelly BT. Anterior inferior iliac spine deformity as an extra-articular source for hip impingement: A series of 10 patients treated with arthroscopic decompression. *Arthroscopy.* 2012;28(11):1644–1653.
3. Blankenbaker DG, Tuite MJ. Non-femoroacetabular impingement. *Semin Musculoskelet Radiol.* 2013;17(3):279–285. doi: 10.1055/s-0033-1348094 [doi].
4. Alhaneedi GA, Abdullah AS, Ghouri SI, Abuodeh Y, Al Dosari MM. Avulsion fracture of anterior inferior iliac spine complicated by hypertrophic malunion causing femoroacetabular impingement: Case report. *Int J Surg Case Rep.* 2015;11:117–120.
5. Ross JR, Larson CM, Adeoye O, Kelly BT, Bedi A. Residual deformity is the most common reason for revision hip arthroscopy: A three-dimensional CT study. *Clin Orthop Relat Res.* 2015;473(4):1388–1395.
6. Amar E, Druckmann I, Flusser G, Safran MR, Salai M, Rath E. The anterior inferior iliac spine: Size, position, and location. An anthropometric and sex survey. *Arthroscopy.* 2013;29(5):874–881.
7. Tibor LM, Leunig M. The pathoanatomy and arthroscopic management of femoroacetabular impingement. *Bone Joint Res.* 2012;1(10):245–257.
8. Hetsroni I, Poultsides L, Bedi A, Larson CM, Kelly BT. Anterior inferior iliac spine morphology correlates with hip range of motion: A classification system and dynamic model. *Clin Orthop Relat Res.* 2013;471(8):2497–2503.
9. Mimura T, Kawasaki T, Itakura S, et al. Prevalence of radiological femoroacetabular impingement in Japanese hip joints: Detailed investigation with computed tomography. *J Orthop Sci.* 2015.

Medical Student Research Project

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Seizure-Associated Anterior Shoulder Instability: Review of the Literature and Operative Case Series

DENNIS VAYSBURG, BS; JOHN JENNINGS, MD; ERIC KROPF, MD

Department of Orthopaedic Surgery, Lewis Katz School of Medicine at Temple University, Philadelphia, PA

Introduction

Shoulder dislocations may result from seizures due to violent, uncoordinated muscle contractions, or secondary to associated trauma, such as a fall from standing. Damage to both the humeral head and glenoid are common in these situations and predispose the patient to instability and future dislocations.[1–4] While posterior dislocations are commonly associated with seizures, anterior dislocations occur with nearly equal frequency and are associated with a higher rate of recurrence (47% vs 12%), even after surgical intervention.[4]

Patients with seizure-associated anterior dislocations have been found to have greater average bone loss in the anterior glenoid (40%, as opposed to 10% in those with non-seizure-associated cases).[3] Furthermore, patients with seizure disorders are constantly at an increased risk for these often violent injuries even after initial management of their injury. While some event recurrence is unavoidable, reports of medical noncompliance are common in this patient population. The combination of large bony injuries and a recurrent trauma to the shoulder presents a significant dilemma for surgeons managing these patients.

Standard soft tissue repairs for anterior shoulder instability, such as the Bankart and Putti-Platt procedures, have a high rate of failure when performed alone due to extensive bone defects.[5] Open reconstruction with femoral head bone allografts has been shown to have success in preventing recurrence,[2] as has extending the glenoid articular surface by means of an iliac crest-derived bone buttress.[5] The Latarjet procedure has also be used effectively, particularly in well-controlled cases of epilepsy where recurrent dislocation occurs during activities of daily living.[6] Both the bone block and Latarjet procedures leave the patient with good stability, motion, and function, with the greatest limitation involving external rotation.[2, 5]

The goal of this study is to review the literature for patients with seizure-provoked shoulder dislocations with recurrent instability, and to present a series of patients to exemplify strategies for management.

Materials and Methods

The literature review was conducted by cross-searching both anterior shoulder dislocation and instability with both seizure and epilepsy in the NCBI database. Results were narrowed to those that were in English; we also excluded articles that did not include anterior instability or that had anterior dislocations that were not associated with seizure. Patients described in the literature were categorized based on what type of procedure was performed and if the shoulder re-dislocated postoperatively. Further information, including the cause of the seizures, presence of Bankart or Hill Sachs lesions, and range of shoulder motion after the procedure, was also used if available.

In addition, the case series includes three patients from Temple University Hospital in Philadelphia, PA who presented with anterior shoulder instability resulting from seizure. IRB approval was obtained prior to accessing patient records.

Case Reports

Case 1

Patient CH is an 18-year-old male with a history of epilepsy and a single prior anterior dislocation which occurred in the setting of a seizure now presenting to the emergency department with left shoulder pain and deformity without neurovascular deficits. Imaging at that time demonstrated an anterior dislocation with an isolated Hill-Sachs lesion and a concentric reduction was obtained under conscious sedation. One month later, this patient again dislocated the shoulder while jumping into a river and Xrays confirmed another anterior shoulder dislocation with both a Hill-Sachs and a bony Bankart lesion. The shoulder was reduced in the emergency department. On follow-up, advanced imaging (Figure 1) revealed a complete loss of the anterior and inferior glenoid labrum, a large Hill-Sachs lesion, and the shoulder was indicated for surgery. A diagnostic arthroscopy, debridement, and anterior capsule labral repair/Bankart repair with an open capsular shift was performed and the patient was placed in a sling for six weeks.

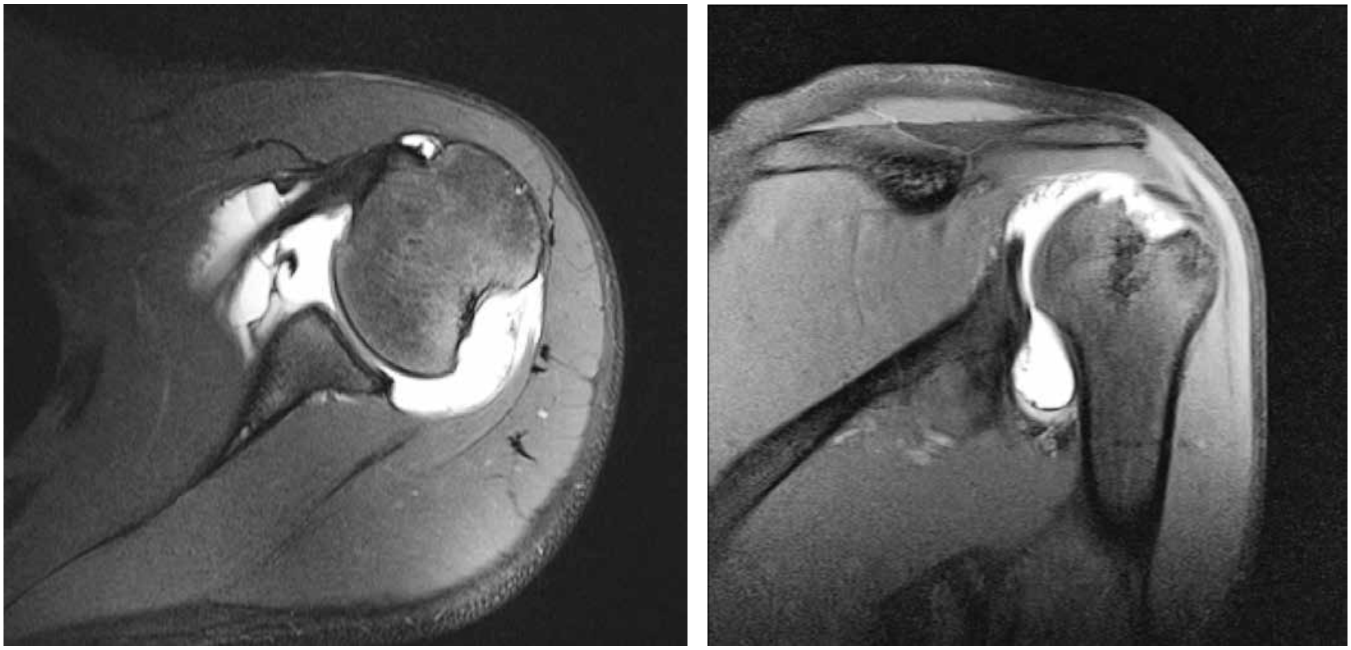


Figure 1. Magnetic Resonance Imaging of a loss of the anterior and inferior glenoid labrum and a Hill-Sachs lesion in the left shoulder.

Over the following 19 months, the patient presented to the emergency department four times with seizures due to reported noncompliance with his medication, twice with concurrent anterior shoulder dislocations. A CT study of the shoulder conducted one month later revealed a large, chronic, Hill-Sachs deformity with at least two small bone fragments measuring up to 5 mm within the defect and a Bankart lesion encompassing greater than 25% of the glenoid articular surface with multiple small bone fragments within the soft tissue and joint space anterior to the glenoid (Figure 2). The patient underwent a Latarjet procedure four months later. The patient presented to the emergency department one month later with a seizure but no dislocation. Imaging studies conducted one month and two months postoperatively (Figure 3) indicate no new fractures or instability.

Case 2

Patient LB is a 25-year-old female with a history of seizures and multiple anterior left shoulder dislocations despite nonoperative treatment. MRI of the left shoulder (Figure 4) demonstrated an anterior labral tear, superior migration of the humeral head, and a Hill-Sachs lesion. One month later, the patient underwent bone grafting of the Hill-Sachs lesion and a Bankart repair. Two years postoperatively, she returned due to a seizure-induced left anterior shoulder dislocation and radiographs which revealed a large Hill-Sachs lesion. This was not problematic until a year later when she returned for bilateral shoulder dislocations after a seizure, followed by a subsequent dislocation the next year. Arthrography of the left shoulder confirmed the Hill-Sachs lesion and glenohumeral instability.

Over the course of the following four years, LB returned to the emergency department with two right shoulder anterior dislocations and two bilateral anterior dislocations, all of which were managed with closed reductions. An arthrogram of the left shoulder during this period indicated subluxation, an attenuated anterior labrum, and absence of the anterior inferior glenohumoral ligament, while radiographs after the last right shoulder dislocation revealed a greater tuberosity fracture (Figure 5). Open reduction and internal fixation of the right greater tuberosity was performed with concomitant Bankart repair of the labrum and bursectomy. In the months following the procedure, the patient presented once with a seizure associated anterior left shoulder dislocation which was reduced under sedation. An Xray of the left shoulder indicated an increased irregularity of the superior surface of the humoral head likely due to trauma and chronic dislocation but no evidence of joint effusion was found (Figure 6). Xrays of the right shoulder conducted three months postoperatively showed healing with some residual minimal deformity but otherwise congruent joint spaces.

Case 3

Patient HM is a 38-year-old epileptic male who underwent a left shoulder arthroscopy with debridement, a Bankart repair, and bone grafting of the Hill-Sachs lesion. He had a two-year precedent history of seizure-related anterior left shoulder dislocations and preoperative imaging (Figure 6) demonstrated both Bankart and large Hill-Sachs lesions. Nineteen months later, the patient presented to the department again with a seizure-related left anterior shoulder dislocation which was managed with a closed reduction. Radiographs indicated that the Hill-Sachs lesion had recurred.



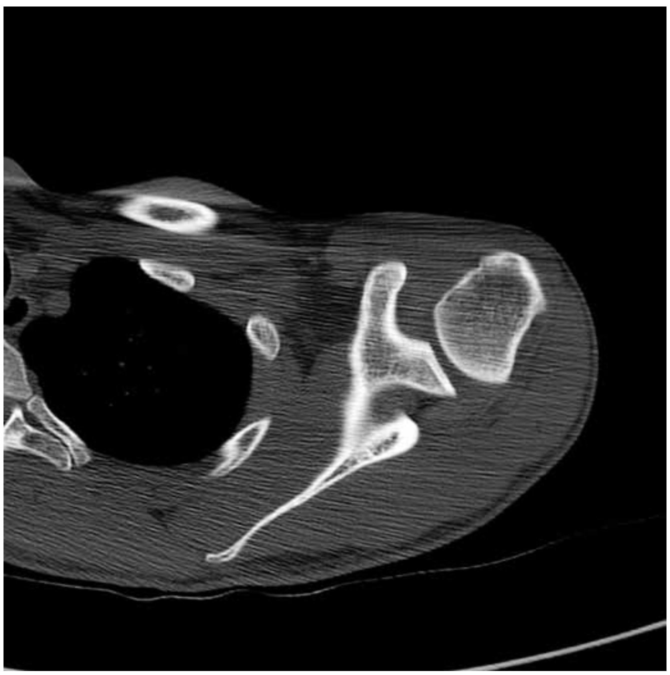
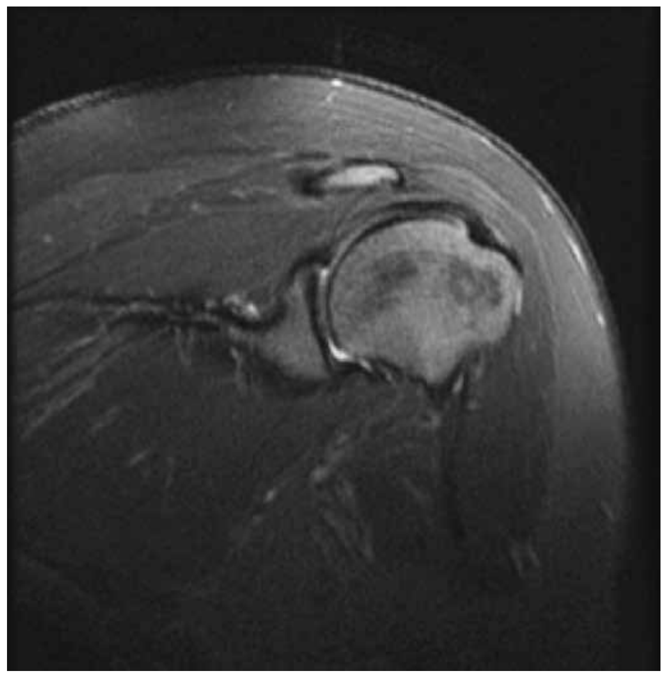




Figure 2. Left shoulder Hill-Sachs lesion with two small bone fragments as well as a Bankart lesion.

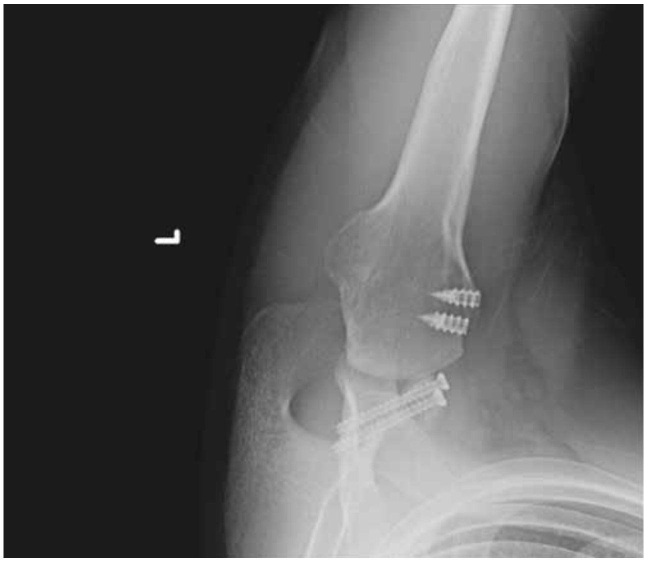
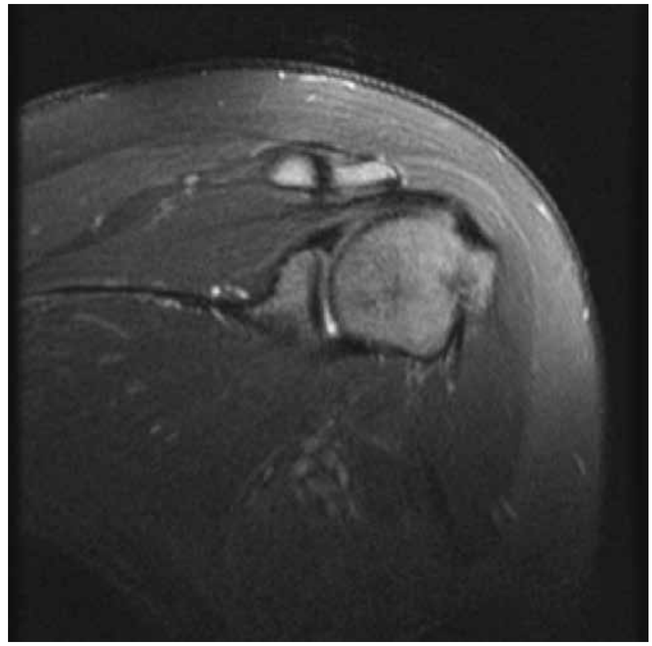
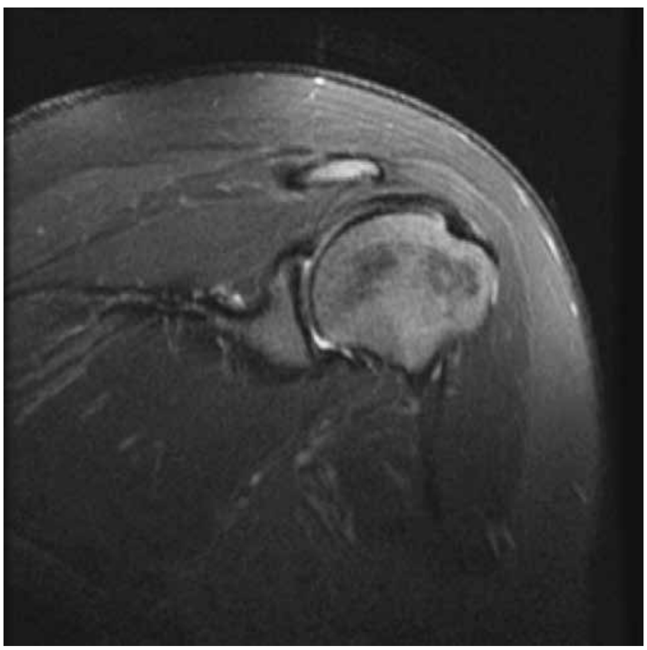


Figure 3. Imaging two months postoperatively showing no new fractures.





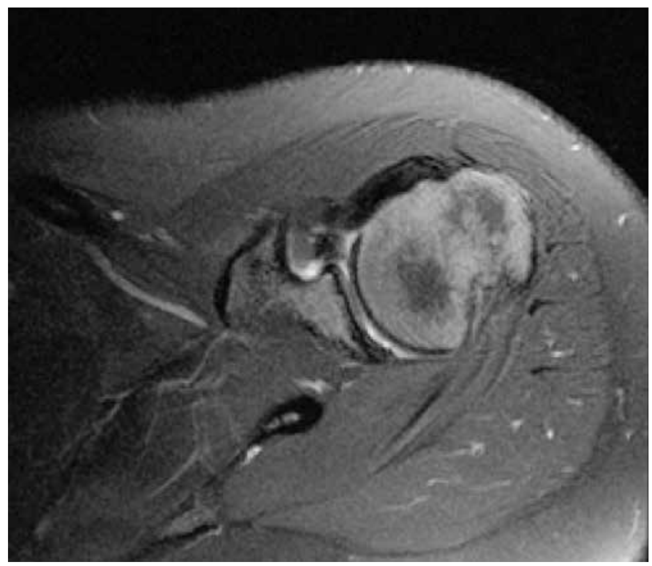


Figure 4. Magnetic Resonance Imaging showing an anterior labral tear, superior migration of the humeral head, and a Hill-Sachs lesion.

In the following year, he suffered two more anterior left shoulder dislocations, one while sleeping and one during seizure. Both were managed with closed reductions. An arthrogram (Figure 7) and CT (Figure 8) revealed large Bankart and Hill-Sachs lesions, a SLAP tear, small partial-thickness articular surface tears of the posterior supraspinatus and anterior infraspinatus tendons at the insertion, and an intra-articular loose body at the subscapularis recess (Figure 7). Over the next four years, the patient experienced one dislocation, not associated with seizure, which was managed with closed reduction. An MRI of the shoulder at age 46 revealed that the Bankart lesion was mostly healed, a slightly smaller size of the Hill-Sachs deformity, a complete tear of the superior and posteriosuperior labrum with displaced labrum extending into the superior glenohumeral joint, and slightly increased tearing of the supraspinatus tendon compared to the previous study (Figure 9). A CT performed two years later revealed a new, healing, corocoid process fracture. Two months after the CT, an arthroscopic revision of the anterior labral repair along with an open osteochondral allograft reconstruction of the humeral head/mega-OATS procedure was performed. One postoperative radiograph identified no lesions or fractures.

Figure 5. Radiograph showing a right greater tuberosity fracture.

Figure 6. Imaging showing left Bankart and Hill-Sachs lesions.

Discussion

In this case series, three patients with seizure-related recurrent anterior shoulder dislocations are described (four total shoulders, as LB had bilateral dislocations), each failing conservative treatment and requiring surgery. All three patients dislocated after their initial Bankart repairs (and Hill-Sachs repairs for LB and HM). A second procedure was necessary in two cases (Latarjet for CH and humoral head allograft and labral revision repair for HM), while LB underwent a Bankart repair on the other shoulder, which has not dislocated since. After the second surgery, no further dislocations were reported for CH or HM.

When a shoulder dislocation is identified, closed reduction should be attempted and may provide definitive treatment, particularly in first time dislocators.[3, 7–18] Medication noncompliance and violent, traumatic seizures with large bony defects significantly complicate management of these injuries in patients with a history of epilepsy and surgical intervention is frequently needed.[4] Even then, some procedures failed to provide a permanent solution, and the patients required subsequent surgeries.[4, 7, 11]

The Bankart and Putti-Platt procedures, two commonly performed soft tissue repairs which address glenoid and labral defects, result in frequent recurrence of dislocation when performed on a patient with a bony defect.[5] Bony procedures such as femoral head allografts, extension of the glenoid articular surface using an iliac crest-derived bone buttress, and the Latarjet procedure have been shown to have success in preventing recurrence.[2, 5, 6]

Bremner et al. described a patient who suffered a seizure due to an excessive dose of tramadol hydrochloride and nortriptyline with bilateral anterior shoulder dislocations and accompanying Hill-Sachs lesions. Both shoulders underwent a closed reduction; one regained full range of motion, but the other dislocated again and required an open reduction with a femoral head allograft.[7] Cottias et al. documented a patient with bilateral anterior dislocations and both cora-

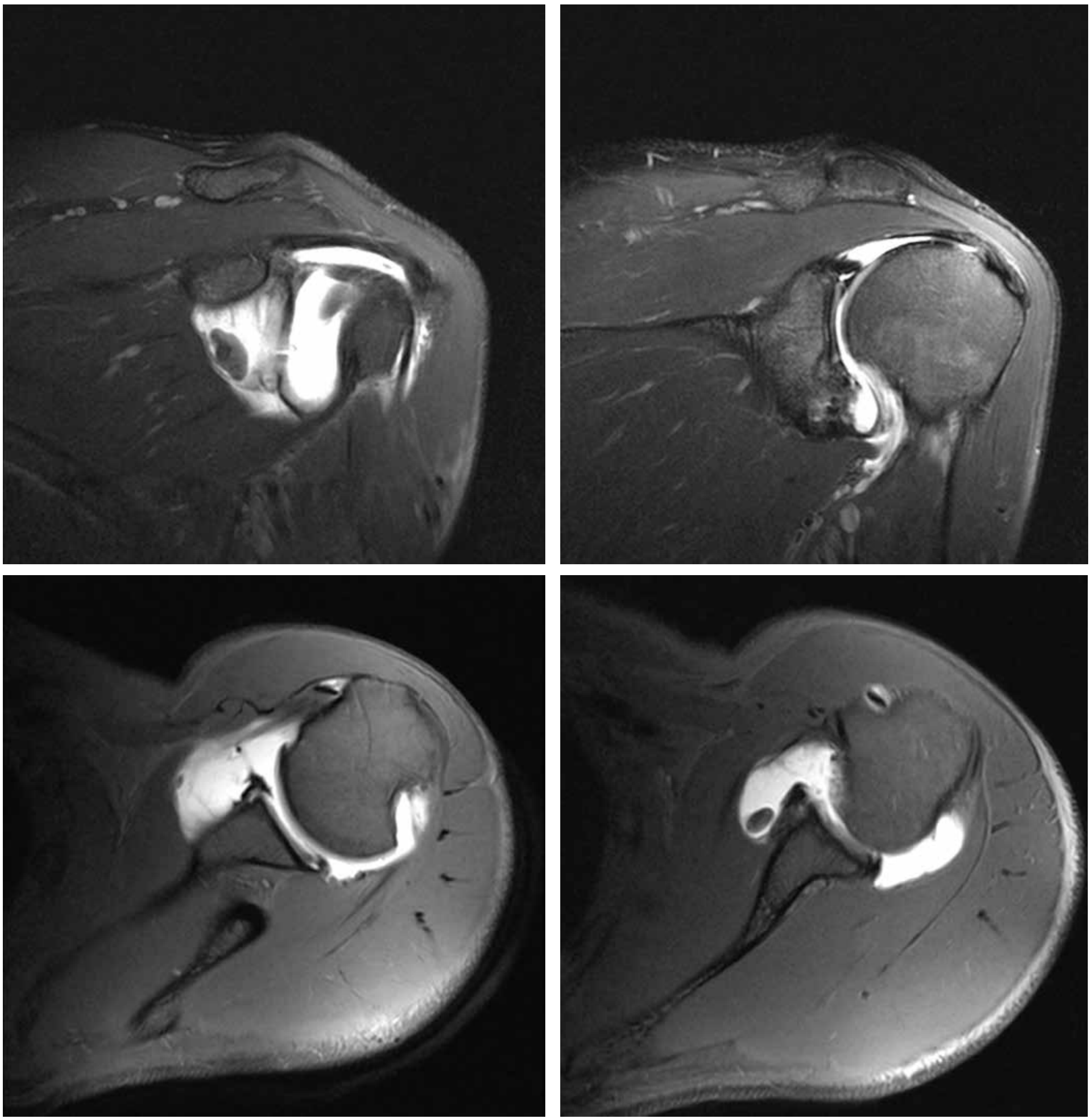


Figure 7. Left shoulder large Bankart and Hill-Sachs lesions, a SLAP tear, small partial-thickness articular surface tears of the posterior supraspinatus and anterior infraspinatus tendons at the insertion, and an intra-articular loose body at the subscapularis recess.

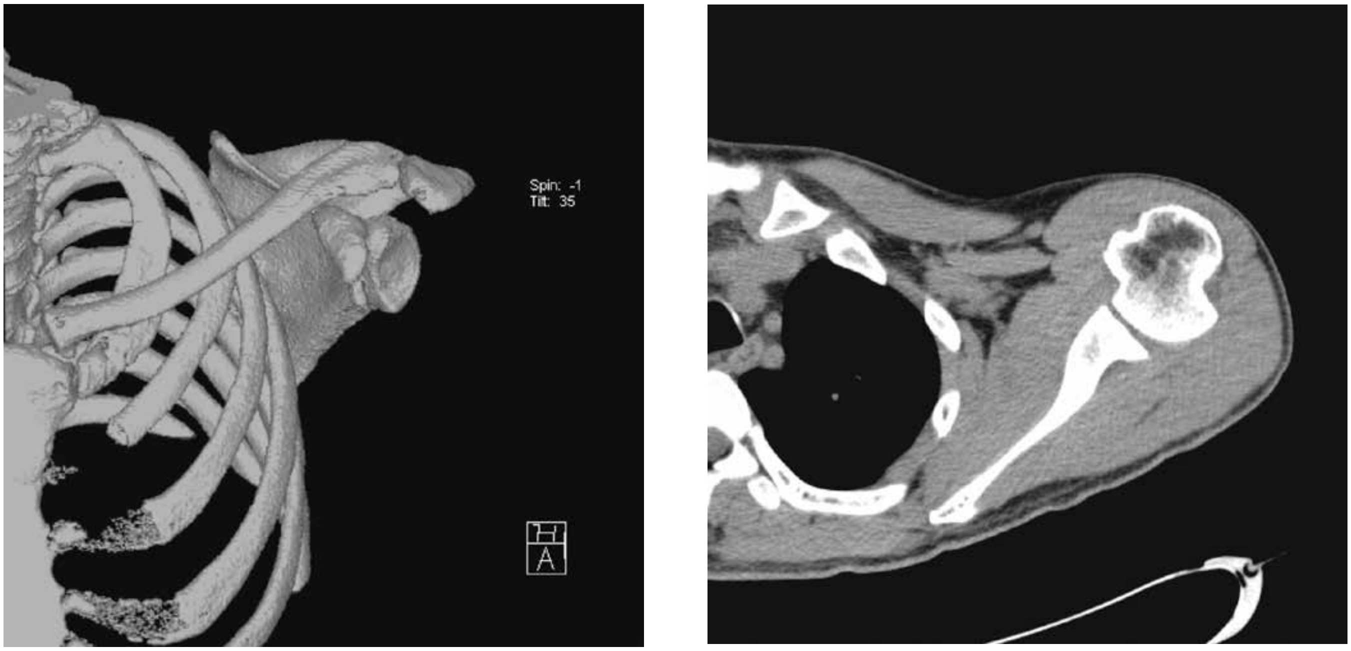


Figure 8. Left large Hill-Sachs and Bankart lesions.

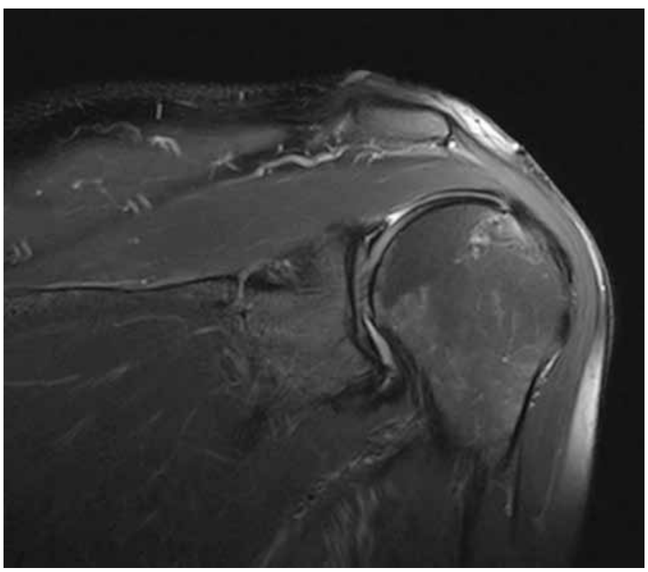


Figure 9. Imaging showing tearing of the supraspinatus tendon.

coid and greater tuberosity fractures after a hypoglycemic seizure. One shoulder regained full range of motion after a closed reduction, while the other required fixation of the tuberosity with cancellous screws and later, a Latarjet procedure, before becoming stable. The patient retained full range of motion in both shoulders at a two-year follow-up.[8] Aufderleide et al. described an anterior dislocation after a seizure suffered during alcohol withdrawal that underwent a closed reduction,[9] while Rawat et al. decribes the closed reduction of an anterior dislocation suffered from an eclampsia-related seizure.[10] Taneja,[11] O'Connor,[12] and Monoharan[13] all reported closed reductions of bilateral anterior dislocations occurring after first-time seizures of unknown cause, all of which resulted in full range of motion and strength.

Anterior instability in epileptic patients was also managed successfully by closed reduction in some cases. Lasanianos et al. described a patient with bilateral anterior dislocations and Hill-Sachs lesions, as well as one greater tuberosity fracture, following an epileptic seizure. Both shoulders underwent closed reductions and greater tuberosity fracture was internally fixed. Both shoulders had full range of motion at a four-month follow-up.[14] Mofidi et al. reported another bilateral anterior dislocation (one recurrent, one new) after an epileptic seizure that underwent a closed reduction.[15] Rethnam et al. mentioned a patient with an epileptic seizure-associated dislocation that was managed with a closed reduction. It was noted that the patient had neither a Hill-Sachs nor a Bankart lesion.[16] Buhler et al. documented four closed reductions of epileptic patients' shoulders. Two of them were the first procedure performed on the shoulder, one of whom had a Hill-Sachs and the other a Bankart lesion, while the other two followed unsuccessful Eden-Lange-Hybinette procedures, one on a shoulder with both Hill-Sachs and Bankart lesions and one on a shoulder with neither. None of the four shoulders required subsequent procedures after the closed reductions.[4]

Not all closed repairs proved to be entirely successful. Ribbans described an epileptic patient with bilateral anterior instability managed by closed reduction. One shoulder regained nearly full range of motion, while the other remained stiff with abduction limited to 60° and external rotation to 5°.[17] Weng et al. performed a reconstruction of large bony glenoid lesions with femoral head allografts and capsular shifts on four epileptic patients who had previously undergone closed reductions and redislocated. One of the four dislocated again after the procedure, and was successfully managed with another closed reduction. These patients had Rowe scores averaging 21 preoperatively and 81 postoperatively.[2]

All three patients included in the case series had undergone at least one closed reduction as the first line of treatment for their dislocation. As described in the literature, the shoulders subsequently redislocated and required management with open reductions (LB had both shoulders unsuccessfully managed with closed reduction). In each case, Bankart repairs were the first surgery performed.

Soft tissue repairs showed mixed results when used to manage anterior shoulder instability. The techniques used commonly in the literature included the Bankart repair, Capsular shift, Putti-Platt, and Remplissage. Buhler et al. detailed soft tissue repairs performed on eight shoulders. Three of the shoulders (one with a Hill-Sachs lesion, one with a bony Bankart lesion, and one with both) were stable after a single Bankart repair, and one (with both Hill-Sachs and Bankart lesions) that had previously been managed with derotation osteotomy was also successfully managed by the Bankart repair.[4] Sonel et al. also reported Bankart repairs performed, with Remplissage, on two shoulders with Hill-Sachs lesions. These repairs succeeded in stabilizing the shoulders, but they were left with limitations, particularly in extension (both 20°), internal rotation (25° and 20°), and external rotation (30° and 35°).[18] Weng et al. described a Bankart repair performed on a shoulder with a Hill Sachs lesion that required a further Femoral Head Allograft to achieve successful stabilization.[2] Buhler et al. also reported three unsuccessful Putti-Platt procedures, all performed on shoulders with both Hill-Sachs and Bankart lesions. The three shoulders required subsequent bony repairs (derotation osteotomy, bone block, and Eden-Lange-Hybinette) before stability was achieved. They also described an unsuccessful Inferior Capsular Shift that required a subsequent bone block and Bankart repair. Of these cases, the Bankart repair was successful in 80% of cases (85.7% if counting Bankart and Remplissage performed together), while the Putti-Platt was not successful in any case (this may be because the Putti-Platt does not address the bony lesions).[2, 4, 18]

CH underwent a diagnostic arthroscopy, debridement, and anterior capsule labral repair/Bankart repair with an open capsular shift after closed reductions failed, but within 19 months, the shoulder had redislocated twice. LB's left shoulder was managed with a Bankart repair and bone-grafting of the Hill-Sachs lesion, but dislocated two years after the surgery and has dislocated three times since then. LB's right shoulder was managed with a Bankart repair, bursectromy, and fixation of a fractured tuberosity, and has not dislocated since. HM underwent a debridement, Bankart repair, and Hill-Sachs graft after six unsuccessful closed reductions, but dislocated the shoulder during a seizure 18 months postoperatively. The Bankart repair was offered to these patients as the first operative treatment prior to attempting a bony repair, but was only successful in the instance of LB's right shoulder, which is in accordance with the success rate described in the literature. CH and HM underwent a second, bony procedure.

Common bony repairs included femoral head autografts and allografts, bone buttressing, Latarjet and Bristow procedures, and the Eden-Lange-Hybinette procedure. Bone buttressing and femoral head autografts/allografts involve anterior extension of the glenoid by securing the autograft or allograft to the deficient anterior rim. Eden-Lange-Hybinette is another bone block used to augment the anterior glenoid rim. The Latarjet and Bristow procedures involve the transfer of the coracoid process through the subscapularis and attachment to the anterior rim of the glenoid. The Latarjet involves transfer of a larger portion of the coracoid which results in the formation of a sling by the conjoint tendon. MEGA-OATS involves the transfer of a cylindrical osteochondral plug into a damaged area. Derotation osteotomy was also used in some cases, and some bony repairs were accompanied by soft tissue procedures. Buhler et al. reported four unsuccessful Eden-Lange-Hybinette procedures (three performed on patients with both Hill-Sachs and Bankart lesions, one with neither). Two of these shoulders required subsequent repositioning, one an Allograft and Bristow, and one an Arthrodesis before stability was achieved. They also described a successfully performed derotation osteotomy, a Bristow, and two allografts on shoulders that had not been previously operated on, as well as a derotation osteotomy, a bone block, and a bone block with a Bankart procedure perfomed on shoulders that had previously been treated unsuccessfully with soft tissue repairs.[4]

Raiss et al. reported mixed results with the Latarjet procedure, which was performed on 14 shoulders, all of which had both Hill-Sachs and Bankart repairs. Patients had an average postoperative Rowe score of 76; average flexion decreased from 165° to 160°, and external rotation from 54° to 43°. Eight patients continued to have seizures, and six of the shoulders dislocated (43%). Five of these were managed with bone buttresses, and of these, two were also treated with a Putti-Platt procedure and one with a capsular shift. Two dislocated again but were successfully managed with another bone buttress. Raiss et al. thus recommend the Latajet for well-controlled epileptics who experience minimal seizures and instead dislocate while doing physical activity throughout their daily lives.[6] Allografts were found to be used most in the literature for treatment of recurrent instability. Hutchinson et al. described 15 shoulders treated with bone buttress autografts from either the iliac crest or femoral head. Of the 15 shoulders, three had previously been treated with Bankart repairs, three with Bristow, and three with Putti-Platt. Thirty-two months postoperatively, none of the patients experienced dislocation, but they had some limitation in external rotation. Hutchinson attributes the success of the bone buttress over the Eden-Lange-Hybinette to the larger size of the graft and subsequent greater extension of the glenoid curvature.[5] Weng et al. reported five femoral head allografts with capsular shifts performed on epileptic patients, four of whom had previously been treated with closed reductions, and one with a Bankart repair. One of these patients experienced a further dislocation that required closed reduction, and one had a self-reduced sublaxation. Rowe scores increased from a preoperative average of 24 to a postoperative average of 84.[2] Bremner et al. described a successful femoral head autograft performed with a rotator cuff repair on a patient who had previously undergone a closed reduction and who regained full range of motion postoperatively, while Nathan et al. reported a successful humeral head allograft.[1, 7] Lastly, Mehta et al. described a humeral head plasty performed on a massive Hill-Sachs lesion locked onto the anterior glenoid. This procedure was paired with capsular release and a Bankart repair and resulted in a stable shoulder six months postoperatively but that had clinically asymptomatic avascular necrosis. Based on the literature, various allografts used to extend the glenoid cavity have a high success rate (87.1%) when compared to the other two procedures mentioned most frequently: the Latarjet (57%) and Eden-Lange-Hybinette (0%).[1, 2, 4–7]

Neither of the patients who underwent bony procedures have experienced a dislocation since their second surgery. HM underwent a labral revision repair and mega-OATS allograft reconstruction of the humoral head, while CH underwent a Latarjet procedure. HM's shoulder reported no significant changes seven months postoperatively, while CH has not dislocated in the 13 months since their surgery, despite their large Hill-Sachs deformity being left unaddressed.

The Latarjet is a particularly useful procedure as it provides both bony stability to the glenoid as well as creating a sling from the conjoin tendon that acts on the subscapularis when the arm is abducted and externally rotated to guard against anterior and inferior dislocations. This explains the Latarjet's effectiveness in patients with anterior dislocations unassociated with seizure, and why it is an approach that should be used, in addition to management of seizure, for these patients.

Management of the three patients has demonstrated that closed reduction is not an effective treatment, as all four shoulders redislocated both with and without seizure. The literature shows success with closed reduction limited to patients with single episodes of seizure or absence of glenohumoral defects. These types of dislocations warrant surgical planning and the decision of whether to use a soft tissue or bony procedure. Patients that do not have large bony lesions in the glenoid or humoral head can be managed with a soft tissue repair such as the Bankart. This was the case with LB's right shoulder which did not have a Hill-Sachs lesion and was successfully managed by the Bankart procedure. In the case of patients with bony lesions frequently produced by high-energy injury or recurring dislocation, a more aggressive approach with bony repair is likely necessary; all three such shoulders redislocated after the first Bankart repair. The Latarjet and labral revision/mega-OATS were successful for CH and HM, respectively, suggesting that Bankart may be bypassed in patients with similar lesions. Another necessary aspect of management for all of these patients is the optimization with their primary care physician and neurologist to prevent further seizures, as these were associated with many of the dislocations. Strict monitoring of the patients and medication compliance can reduce the number of seizures and subsequent stress on the repaired shoulder.

References

1. Nathan ST, Parikh SN. Osteoarticular allograft reconstruction for hill-sachs lesion in an adolescent. *Orthopedics.* 2012;35(5):e744–7.
2. Weng PW, Shen HC, Lee HH, Wu SS, Lee CH. Open reconstruction of large bony glenoid erosion with allogeneic bone graft for recurrent anterior shoulder dislocation. *Am J Sports Med.* 2009;37(9): 1792–1797.
3. Guity MR, Akhlaghpour S, Yousefian R. Determination of prevalence of glenoid bony lesions after recurrent anterior shoulder dislocation using the 3-D CT scan. *Med J Islam Repub Iran.* 2014;28:20.
4. Buhler M, Gerber C. Shoulder instability related to epileptic seizures. *J Shoulder Elbow Surg.* 2002;11(4):339–344.
5. Hutchinson JW, Neumann L, Wallace WA. Bone buttress operation for recurrent anterior shoulder dislocation in epilepsy. *J Bone Joint Surg* Br. 1995;77(6):928–932.
6. Raiss P, Lin A, Mizuno N, Melis B, Walch G. Results of the latarjet procedure for recurrent anterior dislocation of the shoulder in patients with epilepsy. *J Bone Joint Surg Br.* 2012;94(9):1260–1264.
7. Bremner LF, Dewing CB, McDonald LS, Provencher MT. Simultaneous bilateral anterior shoulder fracture dislocation following a seizure: A case report. *Mil Med.* 2013;178(3):e400–3.
8. Cottias P, le Bellec Y, Jeanrot C, Imbert P, Huten D, Masmejean EH. Fractured coracoid with anterior shoulder dislocation and greater tuberosity fracture — report of a bilateral case. *Acta Orthop Scand.* 2000; 71(1):95–97.
9. Aufderheide TP, Frascone RJ, Cicero JJ. Simultaneous bilateral anterior and posterior shoulder dislocations. *Am J Emerg Med.* 1985;3(4): 331–333.
10. Rawat S, Meena S, Gangari SK, Lohia LK. Anterior dislocation of shoulder in eclampsia: A case report. *Chin J Traumatol.* 2012;15(4): 249–250.
11. Taneja AK, Pecci Neto L, Skaf A. Bilateral anterior glenohumeral dislocation and coracoid processes fracture after seizure: Acute MRI findings of this rare association. *Clin Imaging.* 2013;37(6):1131–1134.
12. O'Connor-Read L, Bloch B, Brownlow H. A missed orthopaedic injury following a seizure: A case report. *J Med Case Rep.* 2007;1:20.
13. Manoharan G, Singh R, Ahmed B, Kathuria V. Acute spontaneous atraumatic bilateral anterior dislocation of the shoulder joint with hill-sachs lesions: First reported case and review of literature. *BMJ Case Rep.* 2014;2014:10.1136/bcr-2013-202847.
14. Lasanianos N, Mouzopoulos G. An undiagnosed bilateral anterior shoulder dislocation after a seizure: A case report. *Cases J.* 2008;1(1): 342-1626-1-342.
15. Mofidi M, Kianmehr N, Farsi D, Yazdanpanah R, Majidinezhad S, Asadi P. An unusual case of bilateral anterior shoulder and mandible dislocations. *Am J Emerg Med.* 2010;28(6):745.e1–745.e2.
16. Rethnam U, Ulfin S, Sinha A. Post seizure anterior dislocation of shoulder — beware of recurrence. *Seizure.* 2006;15(5):348–349.
17. Ribbans WJ. Bilateral anterior dislocation of the shoulder following a grand-mal convulsion. *Br J Clin Pract.* 1989;43(5):181–182.
18. Sanel S, Sencan S, Ocguder A, Solakoglu C. Bilateral, locked, recurrent anterior shoulder dislocation: Case report. *Eklem Hastalik Cerrahisi.* 2015;26(1):52–55.

Case Report

Arthroscopic Ankle Arthrodesis Using a TTC Retrograde Nail: Case Report and Technique Discussion

Eric Gokcen, MD

Department of Orthopaedic Surgery, Lewis Katz School of Medicine at Temple University, Philadelphia PA

Abstract

Arthroscopic ankle arthrodesis has been shown to provide quicker and more reliable healing, but has typically been reserved for minimal deformity ankle arthritis.[8–14] The following case report demonstrates an expanded indication for arthroscopic ankle arthrodesis in patients with deformity and associated comorbidities that would put them at significant risk for complications with open procedures. By doing the procedure arthroscopically, the risk of wound complications is significantly reduced, yet using a TTC nail provides significantly increased stability across the fusion site compared to percutaneous screw fixation.

Case Report

The patient is a 67-year-old male with diabetes, end stage renal disease (ESRD) on dialysis, and peripheral neuropathy who initially presented with chronic, progressively worsening left ankle pain. His examination revealed an ankle effusion with no erythema and skin intact with no ulcers. The ankle had a painful limited range of motion and was in valgus alignment. No instability was noted. He had decreased sensation in the foot, with good palpable pulses. X-rays of the left ankle (Figures 1A–C) revealed end-staged osteoarthritis of the tibiotalar joint with valgus alignment.

Because of the patient's comorbidities, extensive nonoperative management was utilized, including bracing, aspiration (normal synovial fluid, negative for infection or crystals) and steroid injection. He had only a month of relief after the steroid injection, which was repeated several times. He was unable to take any Nsaids due to his ESRD. Despite prolonged nonoperative management, the patient continued to have debilitating pain, requiring him to ambulate with a walker.

Surgical options of ankle arthrodesis were then discussed, including the possibility of infection, nonunion, and even amputation. The patient was willing to take those risks to alleviate his pain. Due to his high risk of soft tissue complications from his comorbidities, a decision was made to proceed with an arthroscopic ankle arthrodesis. In addition, there was concern that percutaneous screw fixation would not provide adequate long-term stability of the fusion site which would be anticipated with a diabetic patient with peripheral neuropathy and ESRD. Therefore, a decision was made to utilize a retrograde hindfoot nail for stabilization. In addition, arthroscopic allograft bone grafting of the fusion site would be included to maximize the healing potential.

Technique

The patient was positioned supine with a thigh tourniquet and using a Ferkel thigh holder. Skin traction was applied and the ankle routinely arthroscoped utilizing standard anteromedial and anterolateral portals. As expected, there was extensive osteoarthritis with bone on bone apposition in the lateral aspect of the ankle joint. Any remaining cartilage was removed with a shaver, and the surface of the bone was then taken down to bleeding bone with an arthroscopic burr. Trinity Elite bone graft was then passed through a trocar and evenly spread throughout the joint with a Freer elevator.

Skin traction was removed and the ankle was provisionally held in appropriate alignment utilizing K-wires. Intraoperative fluoroscopy was performed to confirm the position of the ankle. Care was taken to ensure correction of the valgus deformity. A Synthes Hindfoot nail was implanted retrograde through a plantar incision, using fluoroscopy for correct placement. To maximize fixation, a spiral blade was utilized in the calcaneus, with locking screws in the talus and tibia after applying manual compression. Intraoperative fluoroscopy was used to confirm good position of the ankle and the implant. The small wounds were then closed routinely and the patient was placed into a sugar tong splint.

The patient was kept nonweightbearing and followed up in the clinic two weeks postoperatively for a wound check. All the wounds had healed nicely. The patient had less swelling then preoperatively and had minimal pain. He was placed into a short leg cast and instructed to remain nonweightbearing. He returned at the six-week postop visit for cast removal and x-rays (Figures 2A–C) which revealed maintenance of alignment with hardware in good position and early fusion. He was placed into a cam boot, remaining nonweightbearing, and scheduled to follow up with more x-rays in another month. At three months, he initiated weight bearing as tolerated, and by six months, he could ambulate full weight bearing with no pain, with mild residual swelling around the ankle. All wounds had healed well. X-rays revealed good progression of the fusion at three months, and stable at six

Figure 1A–C. Preoperative ankle x-rays.

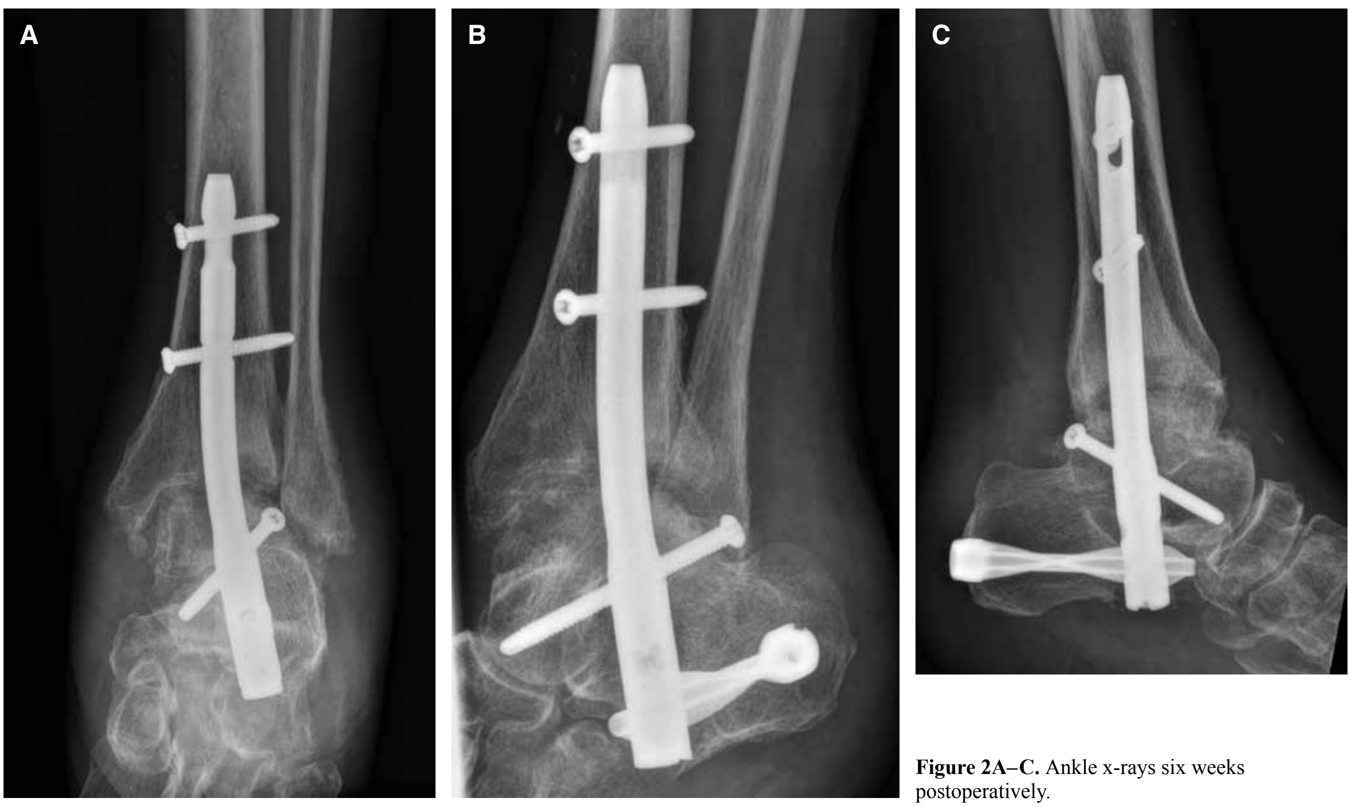


Figure 2A–C. Ankle x-rays six weeks postoperatively.

months (Figure 3). There were no hardware complications nor loss of alignment.

Discussion

Ankle arthrodesis is the gold standard for treating advanced ankle arthritis that has failed nonoperative treatment.[1–4] More recent literature has supported the use of plate or intramedullary fixation to improve construct stability for patients that are higher risk for delayed or nonunion.[5–7] However, implantation of those devices has typically required more extensive exposure which in many high risk patients, increases the risk of postoperative soft tissue complications such as wound infection and dehiscence.

Arthroscopic ankle arthrodesis has been demonstrated to lead to faster and higher fusion rates at a lower overall cost, but has been limited to patients without significant defor-

Figure 3A–C. Ankle x-rays six months postoperatively.

mity.[8–14] Fixation has typically been with percutaneous screws which is effective for the standard patient. However, for high-risk patients, this fixation construct may not provide adequate fixation for the longer healing times required. As previously noted, plate fixation significantly improves construct stability; however, arthroscopic approaches are not amenable to plate fixation, since an open incision is required for implantation. Alternatively, retrograde nailing requires relatively small incisions that are located distant to the ankle fusion site, and are thus less likely to result in wound complications. Only one published series in the literature is from Sekyia et al.,[15] which was a case series in 2011 of nine ankles that underwent arthroscopic ankle arthrodesis with retrograde nail fixation. Eight of the ankles went on to union and there were no soft tissue complications. Rico et al.[16] reported on the two-year follow up of two patients that underwent arthroscopic TTC with a retrograde nail. They obtained fusion of both cases with good improvement in their AOFAS scores and no complications.

One question that presents with retrograde nailing for ankle arthrodesis is whether the subtalar joint needs to be fused at the same setting. Does placing the nail across an intact subtalar joint have any adverse effects? Lowe et al.[17] did a cadaveric study of retrograde ankle nailing and determined that only 6% of the talar posterior facet and 4% of posterior facet of calcaneus was damaged. There was no damage to the middle facet. In a clinical setting, Mulhern[18] performed a multicenter medical record review comparing TTC arthrodesis with and without subtalar arthrodesis and found no difference in outcomes at midterm follow up. There was, however, significantly increased subtalar joint deterioration on x-ray. With limited data to define the parameters for subtalar arthrodesis, it may be reasonable to consider adding a subtalar arthrodesis in the more active and healthier patients, but avoid the additional fusion site risk of nonunion and surgical morbidity in the less active, higher risk patients who have a normal subtalar joint. Since the overarching concept of doing an arthroscopic ankle arthrodesis with a retrograde nail is to minimize soft tissue compromise and provide better stabilization in the high-risk patient, then in these circumstances, avoiding the subtalar joint is a reasonable consideration.

Conclusion

Arthroscopic ankle arthrodesis with retrograde nail stabilization is a good option for high-risk patients. The arthroscopic approach minimizes the soft tissue morbidity associated with open procedures and provides faster and more reliable fusion rates. The addition of a retrograde nail for stabilization improves the stability of the construct to allow for the prolonged healing time that is anticipated in high-risk patients, but adds only minimal morbidity to the soft tissues during surgery. In addition, high-risk patients with a normal subtalar joint appear to tolerate nailing without the need for concomitant fusion of the subtalar joint. High-risk patients requiring ankle arthrodesis may benefit from arthroscopic ankle arthrodesis with stabilization utilizing a retrograde hindfoot nail.

References

1. Hendrickx RP, Stufkens SA, de Bruijn EE, et al. Medium- to long-term outcome of ankle arthrodesis. *Foot Ankle Int.* 2011 Oct;32(10):940–7.
2. Fuchs S, Sandmann C, Skwara A, Chylarecki C. Quality of life 20 years after arthrodesis of the ankle. A study of adjacent joints. *J Bone Joint Surg Br.* 2003;85(7):994–8.
3. Mazur JM, Schwartz E, Simon SR. Ankle arthrodesis. Long-term follow-up with gait analysis. *J Bone Joint Surg Am.* 1979 Oct;61(7): 964–975.
4. Thomas R, Daniela TR, Parker K. Gait Analysis and Functional Outcomes Following Ankle Arthrodesis for Isolated Ankle Arthritis. *J Bone Joint Surg Am.* 2006 Mar;88(3):526–535.
5. Tarkin IS, Mormino MA, Clare MP et al. Anterior Plate Supplementation Increases Ankle Arthrodesis Construct Rigidity. *Foot Ankle Int.* 2007;28(2):219–223.
6. Mitchell PM, Douleh DG, Thompson B. Comparison of Ankle Fusion Rates With and Without Anterior Plate Augmentation. *Foot Ankle Int.* 2016 Dec 5 [epub ahead of print].
7. Franceschi F, Franceschetti E, Torre G, et al. Tibiotalocalcaneal arthrodesis using an intramedullary nail: a systematic review. *Knee Surg Sports Traumatol Arthrosc.* 2016;24:1316.
8. Townshend D, Di Silvestro M, Krause F, et al. Arthroscopic versus open ankle arthrodesis: a multicenter comparative case series. *J Bone Joint Surg Am.* 2013 Jan 16;95(2):98–102.
9. O'Brien TS, Hart TS, Shereff MJ et al. Open Versus Arthroscopic Ankle Arthrodesis: A Comparative Study. *Foot Ankle Int.* 1999 Jun; 20(6):368–374.
10. Gougoulias NE, Agathangelidis FG, Parsons SW. Arthroscopic Ankle Arthrodesis. *Foot Ankle Int.* 2007 Jun;28(6):695–706.
11. Ferkel RD, Hewitt M. Long-Term Results of Arthroscopic Ankle Arthrodesis. *Foot Ankle Int.* 2005 Apr;26(4):275–280.
12. Myerson MS Quill G. Ankle arthrodesis. A comparison of an arthroscopic and an open method of treatment. *Clin Orthop Relat Res.* 1991;(268):84–95.
13. Zvijac JE, Lemak L, Schurhoff MR, et al: Analysis of arthroscopically assisted ankle arthrodesis. *Arthroscopy.* 18:70–75, 2002.
14. Peterson et al. Arthroscopic Versus Open Ankle Arthrodesis: A Retrospective Cost Analysis. *J Foot Ankle Surg.* 2010;49:242–7.
15. Sekiya H, et al. Arthroscopic Tibiotalocalcaneal Arthrodesis with Intramedullary Nail with Fins: A Case Series. *J Foot Ankle Surg.* 2011 Jun; 50(5):589–592.
16. Vilà y Rico J, et al. Arthroscopic Tibiotalocalcaneal Arthrodesis with Locked Retrograde Compression Nail. *J Foot Ankle Surg.* 2013;52(4): 523–528.
17. Lowe JA, Routh LK, Leary JT, Buzhardt PC. Effect of Retrograde Reaming for Tibiotalocalcaneal Arthrodesis on Subtalar Joint Destruction: A Cadaveric Study. *Foot Ankle Surg.* 2016 Jan-Feb;55(1):72–5.
18. Mulhern JL. Is Subtalar Joint Cartilage Resection Necessary for Tibiotalocalcaneal Arthrodesis via Intramedullary Nail? A Multicenter Evaluation. *J Foot Ankle Surg.* 2016;55(3):572–577.

Case Report

Delayed Treatment of a Neonatal Type-I Monteggia Fracture-Dislocation

William R. Smith, MD; Scott Kozin, MD; Dan Zlotolow, MD

Department of Orthopaedic Surgery, Lewis Katz School of Medicine at Temple University, Philadelphia PA

Abstract

Delayed diagnosis of a Monteggia fracture-dislocation changes a straightforward, treatable injury into a complex problem. Acute neonatal injuries may be missed due to the inability to visualize the unossified skeleton on x-ray, interpreted later as "congenital" dislocations. We report the case of a 14 month old with a neonatal Monteggia type-I fracture dislocation secondary to birth trauma, with anterior radial head dislocation and plastic deformation of the ulna. Uniplanar external fixation was used to restore ulnar length and correct angulation, with subsequent radiocapitellar joint closed reduction. Joint congruity was maintained at two-year follow-up, with articular remodeling demonstrated on serial arthrogram.

Introduction

Delayed diagnosis of a Monteggia fracture-dislocation changes a straightforward, treatable injury into a complex and often insurmountable problem. Untreated cases can be complicated by pain and functional limitations, including pain with activity, progressive valgus deformity of the elbow, and limitations of forearm rotation.[1–3] There is currently no consensus on the appropriate treatment algorithm with respect to surgical indications, timing, or technique. Some authors have recommended an individualized approach to each patient.[4] There is consensus that restoring satisfactory function becomes more difficult over time as the local anatomy changes in response to the injury. The radial head and capitellum become progressively deformed, remodeling of the original fracture angulation results in a straighter, but shorter bone, and the medial collateral ligament becomes incompetent. As a result, over time the surgical options become more limited and complex, discouraging reconstruction after 3–5 years from injury.[5–7] We report the case of a 14-month-old male with a previously undiagnosed Monteggia type-I fracture dislocation secondary to birth trauma, with anterior radial head dislocation and plastic deformation of the ulna, who developed difficulty with elbow range of motion and forearm rotation.

Case Report

A 14-month-old boy presented for consultation with decreased range of motion of the right elbow and forearm, initially recognized by the family approximately three weeks following a traumatic birth. Delivery was complicated by failure to progress after crowning, with subsequent emergent conversion to Cesarean section. Prior investigations by his pediatrician and the referring orthopaedist revealed anterior radial head subluxation and ulnar bowing, suggestive of a chronic Monteggia fracture-dislocation. A brief trial of physical therapy had been instituted without appreciable improvement. Examination revealed passive elbow motion from full extension to 90 degrees of flexion (0–90 degrees), 30 degrees of supination, and 60 degrees of pronation. Repeat radiographs confirmed anterior subluxation of the radial head and suggested prior plastic deformity of the distal 1/3rd of the ulna (Figure 1). A presumptive diagnosis was made of a Monteggia type-I fracture-dislocation with plastic deformation of the ulna secondary to birth trauma, with delayed diagnosis and subsequent radiocapitellar joint deformation. Confirmation was sought with an arthrogram, since the radial head was yet to ossify.

Figure 1. Right elbow AP x-ray at the time of initial presentation demonstrating anterior subluxation of the radial head and evidence of prior plastic deformity of the distal 1/3rd of the ulna (3-27-2014).

The arthrogram demonstrated a convex radial head, consistent with the chronicity of the injury, but also a convex, round capitellum, suggesting that the radiocapitellar joint had been congruous at one time. The radial head had migrated proximally, with overlap between the radial head and capitellum. The ulnotrochlear joint was well reduced (Figure 2). The decision was made to restore ulnar length and angulation using an external fixator, without directly addressing the radiocapitellar joint. The fixator (Orthofix Mini Rail, The Colony, TX) was applied through a direct ulnar incision. A sub periosteal dissection of the ulna was performed at the osteotomy site, maintaining the periosteum in continuity. The ulna was cut using a reciprocating saw, with irrigation to limit thermal necrosis. Apex posterior angulation of the ulna was created and maintained with the articulated fixator device (Figures 3–4). Lengthening was started seven days postoperatively, and continued for 24 days until adequate ulnar length had been achieved (approximately 24 mm). Repeat arthrogram in the operating room confirmed a congruent radiocapitellar joint reduction that was stable through full passive range of motion of the elbow and forearm (Figure 5). The fixator was then secured in position and a long arm cast was applied. The cast and external fixator were removed in the operating room four weeks later. A protective, thermoplastic flexion splint was fabricated by the occupational therapy department and worn for an additional four weeks following external fixator removal.

Figure 2. Right elbow AP view of arthrogram demonstrating a convex radial head, which has migrated proximally, overlapping with a convex, round capitellum (4-30-2013).

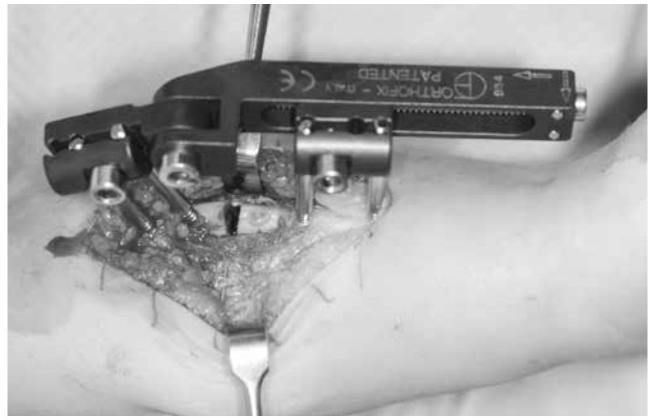


Figure 3. Clinical photograph intraoperatively of the ulnar osteotomy site following uniplanar external fixator placement.

Figure 4. Right elbow lateral view of intraoperative fluoroscopy demonstrating the articulated external fixator placement with apex posterior angulation of the ulna (4-30-2013).

At three-month follow-up, examination the range of motion had markedly improved, with a 50-degree increase in supination (80 degrees total), nearly equal to the contralateral forearm (85 degrees). Pronation was maintained equivalent to the contralateral side, and passive elbow motion improved modestly to 0–100 degrees. Radiographs confirmed a healed osteotomy site, with the radius pointing to the capitellum on all views (Figure 6). These results were maintained at the most recent two-year follow-up (Figures 7–8). A repeat arthrogram demonstrated marked radial head remodeling and a congruent radiocapitellar articulation (Figure 9).

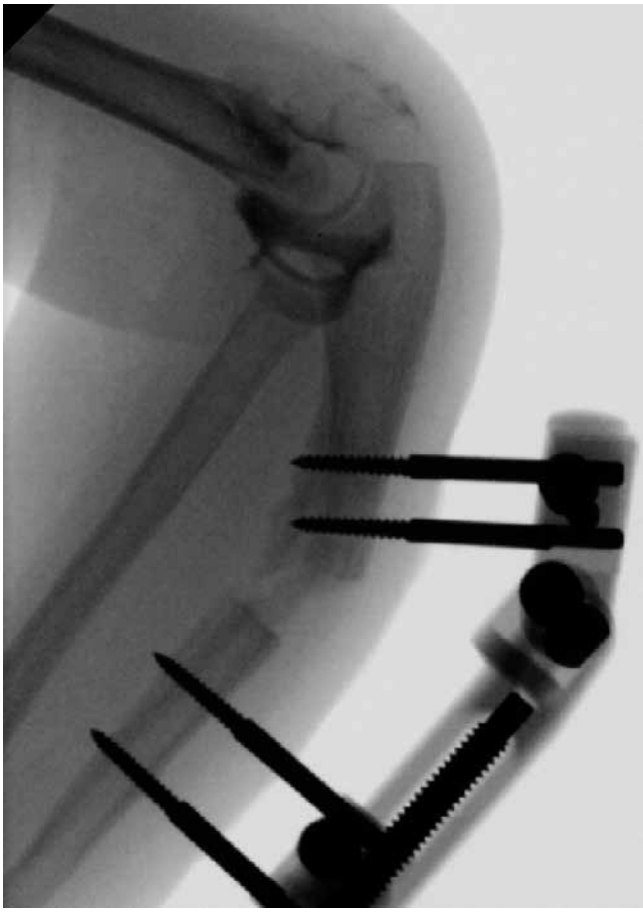


Figure 5. Right elbow lateral view of intraoperative fluoroscopy demonstrating approximately 24 mm of distraction at the osteotomy site with interval callus formation and maintenance of the apex posterior angulation (5-24-2013).

Discussion

Monteggia fracture-dislocations in children are uncommon, comprising 1.5–3% of all pediatric elbow injuries.[8] Following the original description by Giovanni Monteggia in 1814, Bado described a classification system based on radiographic patterns and mechanisms.[8] Bado type I lesions are generally accepted as the most common in the pediatric population (70%). A variant of the type I lesion was also described by Bado, with plastic deformation of the ulna and an associated radial head dislocation (rather than the standard anteriorly angulated ulnar diaphyseal fracture), which is thought to be less common.[8–10] Plastic deformation of the ulna is often missed, likely resulting in an under-reporting of the incidence. Untreated dislocations can result in pain, deformity, and loss of motion that persist into adulthood.[11] Emphasis has been placed on early recognition and treatment, with excellent results reported with non-operative and operative methods in the acute setting.[12, 13]

A neonatal Monteggia fracture is an undescribed entity. In this case, it is certainly possible that the birth trauma did not cause the radial head dislocation, but rather the condition existed in utero. Had the loss of motion not been appreciated by the family until later in life, subsequent radiographs may have appeared like a congenital dislocation. In this case, whether due to a true Monteggia fracture-dislocation or a congenital dislocation, we were able to secure a stable, aligned radiocapitellar joint that has maintained reduction at two years of follow up. The radial head changed from convex to concave, indicative of remodeling and concentric joint loading. The benefits include an improvement in motion and restoration of the critical radial column of the elbow. This should protect the child from the long-term valgus instability for which there is currently no solution.

Figure 6. Right elbow lateral x-ray demonstrating a healed osteotomy site, with the radius pointing to the capitellum on all views.

Although we cannot be certain, we believe the curvature of the ulna and the convexity of the capitellum suggest that in this case there was an injury rather than a congenital difference. Indeterminate factors include the amount of remodeling that might have occurred over time,[17] and therefore the available time interval we have to recognize these injuries. We do not hypothesize that all "congenital" dislocations are Monteggia fracture-dislocations, rather that some may be. Dislocations identified within the first few years of life merit at least an arthrogram for evaluation of radial head and capitellum development. A well-developed radial head and capitellum may be more amenable to attempted reduction. Delayed diagnosis in "congenital" dislocations may lead to anatomic complexity that discourages attempted joint reduction.[14, 20]

This case is notable not only because of the timing and diagnosis of the injury, but also because we performed an ulnar osteotomy and lengthening via uniplanar external fixation, with indirect reduction of the radiocapitellar joint. There is currently no consensus on the treatment of missed Monteggia fractures.[14–20] The most commonly reported options include an ulnar osteotomy to correct angulation and either acute or gradual ulnar lengthening or radial shorten-

Figure 7. Clinical photograph demonstrating range of motion at two-year follow up. Supination of 80 degrees on the right (operative) side, a 50-degree improvement, and nearly equal to the contralateral forearm (85 degrees), full pronation, and elbow range of motion from 0 degrees (full extension) to 100 degrees of flexion.

Figure 8. Right Forearm AP x-ray in supination demonstrating a healed osteotomy site, with the radius pointing to the capitellum on all views (2-9-2016).

ing.[1, 15, 16–18] Prior series' utilizing ulnar osteotomy for radial head reduction have reported good short-term (three year) and long-term (eight year) results with respect to range of motion, restoring near full forearm pronation (average 85°, range 70°–90°) and retaining only a small 10-degree deficit in supination.[17, 20] Correlations between radiographic out-

Figure 9. Right elbow AP view of the repeat arthrogram revealing marked radial head remodeling, with restoration of convexity and joint congruency at the completion of treatment (2-9-2016).

comes and delay to ulnar osteotomy have been reported, with poorer results and increased risk of redislocation after 40 months. Radial head deformation is recognized as a potential reason for the residual loss of motion due to psuedosubluxation or joint incongruity,[17, 20] with progressive deformity the longer treatment is delayed.[19]

Due to the overlap of the radial head and capitellum, we opted for lengthening of the ulna prior to addressing the radiocapitellar joint directly. As has been previously described, an overcorrection of the extension posture of the ulna was added to point the radial head towards the capitellum.[17] The arthrogram was critical both for decision-making and implementation of the plan intraoperatively. After nearly four weeks, we were able to affect a closed radiocapitellar joint reduction in the operating room. Again, the arthrogram was indispensable for confirming that we had the required length and that the desired radial head position had been achieved. A third visit to the operating room was necessary for fixator removal. Repeat arthrograms revealed the ability of the radial head to remodel, with restoration of convexity and joint congruency at the completion of treatment (Figure 9). The combination of a stable reduction and remodeled joint congruity led to excellent results with respect to pain relief and range of motion, with our patient achieving full pronation and lacking only 5–10 degrees of supination in reference to the contralateral forearm, which is comparable to prior reports.[17–20]

In conclusion, Monteggia lesions are ideally managed in the acute setting, with successful outcomes following closed reduction.[8, 9] However, good long-term radiographic and clinical results have been reported up to 40 months after injury via ulnar osteotomy and lengthening.[20] Our neonatal case demonstrates the successful use of the principles of ulnar osteotomy and gradual lengthening to achieve a stable, closed reduction with subsequent joint remodeling, with decreased pain and improved forearm and elbow motion clinically.

References

1. Best TN, Orth FA. Management of old unreduced Monteggia fracture-dislocations of the elbow in children. *J Pediatr Orthop.* 1994;14: 193–9.
2. Oner FC, Diepstraten AF. Treatment of chronic post-traumatic dislocation of the radial head in children. *J Bone Joint Surg Br.* 1993;75: 577–81.
3. Bhaskar A. Missed Monteggia fracture in children: Is annular ligament reconstruction always required? *Indian J Orthop.* 2009 Oct-Dec; 43(4): 389–395.
4. Papandrea R, Waters PM. Post-traumatic reconstruction of the elbow in the pediatric patient. *Clin Orthop Relat Res.* 2000;370:115–26.
5. Stoll TM, Willis RB, Paterson DC. Treatment of missed Monteggia fracture in the child. *J Bone Joint Surg Br.* 1992;74:436–440.
6. Kim HT, Park BG, Suh ST, Yoo CI. Chronic radial head dislocation in children, Part I: Pathological changes preventing stable reduction and surgical correction. *J Pediatr Orthop.* 2002;22:583–90. [PubMed]
7. Tan JW, Mu MZ, Liao GJ, Li JM. Pathology of annular ligament in pediatric Monteggia fractures. *Injury.* 2008;39:451–5.
8. Bado JL. The Monteggia lesion. *Clin Orthop Relat Res.* 1967;50: 71–86.
9. Olney BW, Menelaus MB. Monteggia and variant lesions in childhood. *J Pediatr Orthop.* 1989 Mar-Apr;9(2):219–23.
10. Garza JF. Monteggia fracture-dislocation in children. In: Beaty JH, Kasser JR, editors.: *Rockwood and Wilkin's Fractures in Children.* 6. Philadelphia: Lippincott Williams & Wilkins; 2006, pp. 491–528.
11. Lloyd-Roberts GC, Bucknill TM. Anterior dislocation of the radial head in children: etiology, natural history and management. *J Bone Joint Surg Br.* 1977;59-B:402–407.
12. Letts M, Locht R, Wiens J. Monteggia fracture-dislocations in children. *J Bone Joint Surg Br.* 1985;67:724–727
13. Wiley JJ, Galey JP. Monteggia injuries in children. *J Bone Joint Surg Br.* 1985;67:728–731.
14. Nakamura K, Hirachi K, Uchiyama S, et al. Long-term clinical and radiographic outcomes after open reduction for missed Monteggia fracture-dislocations in children. *J Bone Joint Surg Am.* 2009;91(6): 1394–1404.
15. Wang MN, Chang WN. Chronic posttraumatic anterior dislocation of the radial head in children: thirteen cases treated by open reduction, ulnar osteotomy, and annular ligament reconstruction through a Boyd incision. *J Orthop Trauma.* 2006;20:1–5.
16. Kim HT, Park BG, Suh JT, Yoo CI. Chronic radial head dislocation in children, Part 2: results of open treatment and factors affecting final outcome. *J Pediatr Orthop.* 2002;22:591–597.
17. Lädermann A, Ceroni D, Lefèvre Y, Rosa V, Coulon G, Kaelin A. Surgical treatment of missed Monteggia lesions in children. *J Child Orthop.* 2007;1:237–242.
18. Bouyala JM, Bollini G, Jacquemier M, Chrestian P, Tallet JM, Tisserand P, Mouttet A. The treatment of old dislocations of the radial head in children by osteotomy of the upper end of the ulna. Apropos of 15 cases. *Rev Chir Orthop Reparatrice Appar Mot.* 1988;74:173–182.
19. Kim HT, Conjares JN, Suh JT, Yoo CI. Chronic radial head dislocation in children, Part 1: pathologic changes preventing stable reduction and surgical correction. *J Pediatr Orthop.* 2002;22:583–590.
20. Rahbek O, et al. Long-Term Outcome after Ulnar Osteotomy for Missed Monteggia Fracture-dislocation in Children. *J Child Orthop.* 2011;5(6):449–457.

Senior Abstract

Senior Bio Questionnaire

- Full Name: Dustin A. Greenhill
- Birthdate: 6/23/1981
- Hometown: West Palm Beach, FL
- Undergraduate University: United States Military Academy (West Point)
- Undergraduate Degrees: Mathematics and Civil Engineering
- Medical School: Temple University School of Medicine
- Fellowship: Pediatric Orthopaedics and Scoliosis, Texas Scottish Rite Hospital for Children
- Significant Other: Daniela Greenhill
- Children: Marielle Greenhill
- Hobbies: Mountain biking, snowboarding
- Interesting Fact: My dad changed our family name from Lopez to Greenhill after emigrating from Cuba

Does Weight-Bearing Assignment After Intramedullary Nail Placement Alter Healing of Tibial Shaft Fractures?

Dustin A. Greenhill, MD

Introduction

There is no consensus regarding postoperative weight-bearing (WB) assignment after treatment of tibial shaft fractures with an intramedullary nail. This study aims to determine if the postoperative WB assignment after tibia intramedullary nail placement alters healing.

Methods

Closed AO type 42A fractures treated with a reamed statically-locked intramedullary nail over a 10-year period were retrospectively reviewed from injury at two-, three-, six-, nine- and 12-month intervals until union or revision. Patients were categorized according to postoperative weight-bearing assignment: weight-bearing-as-tolerated (WBAT) or non-weight-bearing (NWB). Patients with additional diagnoses that confound routine fracture healing were excluded. Postoperative radiographic union scores for tibial fractures (RUST), coronal/sagittal angulations, and length were compared between different weight-bearing groups. Union was defined as a RUST $\geq$10 at a painless fracture site.

Results

A total of 83 patients achieved union (32 WBAT, 51 NWB). Both WB groups had similar preoperative demographics. Average age was 37 $\pm$ 13 years and follow-up averaged 1.3 $\pm$ 0.2 years. There were no significant differences in average time to radiographic union between NWB versus WBAT groups (5.5 vs. 6.1 months, respectively; $P = 0.208$) nor radiographic healing at two-, three-, and six-month intervals ($P = 0.631$). There were two nonunions and one fracture shortened in the NWB group. There were no reoperations for symptomatic or broken hardware in either cohort.

Conclusion

Immediate WBAT after statically-locked intramedullary nail placement in simple tibial shaft fractures does not alter the time until or course of radiographic union.

Senior Abstract

Senior Bio Questionnaire

- Full Name: James Robert Lachman
- Birthdate: 7/6/1984
- Hometown: Bryn Mawr, PA
- Undergraduate University: Bucknell University
- Undergraduate Degrees: Anthropology and Spanish
- Medical School: Temple University SOM
- Fellowship: Duke, Foot and Ankle Surgery
- Significant Other: Michelle Lachman
- Children: Nora Lachman
- Hobbies: Golf, homebrewing
- Interesting Facts: I won "Best Vocals" in a monumental upset over Arianna at our department karaoke night

Going Rogue with Perioperative Antibiotics in Ankle Fracture Surgery: Who Are We Protecting?

James R. Lachman, MD

Introduction

Surgeon preference has been replaced in favor of an approach using evidence-based medicine for most things in Orthopaedics. The use of perioperative antibiosis in ankle fracture surgery is standardize for inpatients (24 hours of antibiotics post-operatively) but variable for outpatient surgery. Some surgeons prefer to prescribe 24 hours of oral (PO) antibiotics while others give no antibiotics at all post-operatively. In this study, inpatients receiving 24 hours of intra-venous antibiotics were compared to those patients receiving 24 hours of PO antibiotics and those receiving no post-operative antibiotics.

Methods

1,442 patients with ankle fractures requiring open reduction internal fixation were retrospectively reviewed in this multi-centered study. Demographic data including age, sex, BMI, and race were collected. Clinical data including diabetes status, smoking status, hepatitis C virus (HCV) or human immunodeficiency virus (HIV) status, draining wound, infection requiring additional antibiotics (abx), and infection requiring return to operating room (RTOR) were compared across the groups.

Results

See data table for complete results. These data suggest no differences in incidence of draining wound, cellulitis, or return to OR for infection between the three groups. No differences were noted amongst the groups for any risk factors for infection including BMI, previous infection, smoking status, HCV/HIV status, or diabetes.

Discussion

The use of antibiotics post-operatively, whether intravenous or oral, did not decrease the incidence of clinically significant or clinically insignificant post-operative infection. Based on the findings in this study, there is no justification for prescribing PO antibiotics to patients undergoing outpatient open reduction and internal fixation of ankle fractures. Furthermore, inpatients undergoing the same procedure did not show any advantage to post-operative antibiosis and may also not benefit from this practice.

	Inpatient Group (IV Antibiotics 24 Hours)	Outpatient Group 1 (PO Antibiotics 24 Hours)	Outpatient Group 2 (No Antibiotics)	Totals
Number (ankles)	439	483	520	1,442
Diabetes	61 (13.8%)	71 (14.7%)	68 (13.1%)	200 (13.9%)
Smoker	131 (29.8%)	121 (25%)	143 (27.5%)	395 (27.4%)
HCV/HIV	6 (1.4%)	4 (0.8%)	9 (1.7%)	19 (1.3%)
Draining wound	24 (5.4%)	29 (6.0%)	25 (4.8%)	78 (5.4%)
Infection requiring additional abx	19 (4.3%)	23 (4.8%)	29 (5.6%)	71 (4.9%)
Infection requiring RTOR	4 (0.9%)	3 (0.6%)	4 (0.7%)	11 (0.7%)

*None of these differences are statistically significant.

Senior Abstract

Senior Bio Questionnaire

- Full Name: Anastassia Newbury
- Birthdate: 6/16/1984
- Hometown: Omaha, NE
- Undergraduate University: University of Iowa, University of Nebraska at Omaha
- Undergraduate Degree: Biology
- Medical School: University of Nebraska College of Medicine
- Fellowship: NYU Hospital for Joint Diseases, Hand and Upper Extremity
- Significant Other: Steven Newbury
- Children: Charlie Nina Newbury
- Hobbies: Pursuit of foodie experiences and the ultimate cocktail, reading many leather-bound books on British history, and finding new ways to boost the economy
- Interesting Fact: Only resident to change their first and last name after starting residency

Saving Hearts, Killing Fingers: The incidence of Digital Ischemia in an ICU Patient Population

Anastassia Newbury, MD

Purpose

Digital necrosis of the upper extremity is a rare yet severe condition that generally leads to amputation of the fingers and/or hand. Necrosis is primarily caused by diminished or total loss of blood supply to body tissues, which can result from a variety of factors. Upper extremity digital necrosis is an increasingly prevalent problem in hospitalized patients. There are several known risk factors in special patient populations, such as scleroderma and other connective tissue disorders. However, little is known about risk factors in a population of critically-ill patients requiring blood pressure support. The purpose of this study was to identify risk factors for upper extremity digital necrosis in critically-ill patients receiving vasopressor support.

Methods

A retrospective chart review was conducted to gather a cohort of patients with upper extremity ischemia, stratify the extent of the comorbidities, using the APACHE II intensive care mortality predictor, and identify the type, number and total dosage of vasopressors given. This data was then compared to a control group of intensive care patients who received pressure support, but did not develop upper extremity ischemia.

Results

The ischemia group was found to have higher predicted mortality than did the non-ischemic group. An elevated serum sodium, low GCS, presence of organ insufficiency, elevated APACHE II score, presence of hypertension, and increasing total number of comorbidities were found to be independent risk factors for the development of ischemia. Total number of vasopressors, total days of vasopressor therapy and total vasopressor doses had a moderate correlation with development of digital ischemia and a moderate negative correlation with days to development of ischemia. The odds ratio predictive of ischemia was highest for number of vasopressors (OR = 7.4 ($p = 0.0007$; 95% CI 2.7–20.2)), followed by number of vasopressors days (OR = 2.1 ($p = 0.0006$; 95% CI 1.4–3.2)), and lowest for APACHE II score (OR = 1.1 ($p = 0.03$; 95% CI 1.01–1.1)). No correlation was found between burden of disease or duration of vasopressor therapy with level of ischemia.

Conclusions

Patients on more than two vasopressors, those who receive treatment for multiple days and those with a high APACHE II score were more like to develop digital ischemia.

Senior Abstract

Senior Bio Questionnaire

- Full Name: Arianna Trionfo
- Birthdate: 12/18/1983
- Hometown: Glassboro, NJ
- Undergraduate University: Loyola College of Maryland
- Undergraduate Degrees: Biology and Psychology
- Medical School: UMDNJ – Robert Wood Johnson Medical School
- Fellowship: The Children's Hospital of Philadelphia, Pediatrics
- Significant Other: Gary Lamsback
- Children: Audrey Jennifer Lamsback
- Hobbies: Interior design, travel, couponing
- Interesting Fact: I lived in Newcastle, England for a year and traveled to 12 countries

The Incidence of Postoperative Loss of Midline Function and Associated Variables in Children with Brachial Plexus Birth Palsy

ARIANNA TRIONFO, MD

Purpose

To quantify the rate of loss of midline function (LOM) in patients with brachial plexus birth palsy (BPBP) who previously underwent surgery about the shoulder, as well as to identify variables associated with postoperative LOM.

Methods

Records of patients with BPBP who were treated with surgery about the shoulder during a 10-year period were retrospectively reviewed. Levels of palsy, serial physical examinations, and all upper extremity procedures were recorded. LOM was defined as modified Mallet (MMS) or Active Movement Scale (AMS) internal rotation score less than three. Exclusion criteria were as follows: <1-year follow-up after most recent procedure, insufficient documentation, or preexisting loss of midline function. Odd ratios were computed to identify variables associated with the development of LOM.

Results

Thirty-four (20.9%) of 162 included patients developed LOM. Predictive variables associated with LOM included: global palsy, microsurgical nerve grafting, MMS abduction <4, AMS wrist flexion <5, AMS wrist extension <5, and AMS finger flexion <5. Among these, patients with global palsy were most likely to lose midline function. Age, closed shoulder reduction with casting in external rotation, shoulder tendon transfers, surgical glenohumeral reduction, and humeral osteotomies were not predictive of LOM.

Conclusions

Approximately one in every five patients with BPBP will develop LOM after undergoing treatment aimed to improve shoulder abduction and external rotation. Patients with global palsy, a history of microsurgery, or a physical exam consistent with persistent upper and middle trunk involvement are at the highest risk for developing subsequent LOM.

Resident Research Day

April 16, 2016

The Temple University Department of Orthopaedic Surgery held its annual Resident Research Day on April 16, 2016. This event showcases current Temple orthopaedic surgery residents' ongoing and published research endeavors. Our keynote speaker and guest judge was Daniel Horwitz, MD, Chief of Orthopaedic Trauma at Geisinger Health System. Dr. Horwitz presented an informative lecture entitled "The Simple and Not So Simple Ankle Fracture."

Jim Lachman (PGY-4) presented his first place paper, "Interosseous Fusion Techniques in the Foot: Does It Really Hurt Less?" Dr. Lachman performed reviews of radiographic and clinical data to determine the outcomes of four major foot and ankle arthrodesis techniques. He concluded that implant choice whether in the midfoot, hindfoot, or ankle does in fact have an effect on pain reported at follow-up.

Mark Solarz's (PGY-5) paper titled "Underinsured Patients Experience Delays in Treatment and Higher Rates of Irreparable Meniscal Injury Following Anterior Cruciate Ligament Repair" placed second at this year's resident research day. It revealed that underinsured populations experienced multiple delays throughout the treatment of their ACL injury. Meniscal tear progression and increased meniscectomy rates were also associated with these delays.

Katharine Harper (PGY-3) shared third place with Dustin Greenhill (PGY-4) for her paper on "Radiation Exposure of the Pelvis Following Total Hip Arthoplasty." Dr Harper's paper concluded that the increased radiation exposure to abdominopelvic organs was likely secondary to increased scatter and difficulty modifying radiation doses. Dr. Greenhill assessed three brachial palsy evaluation systems in his paper, "Relationships Between Three Classification Systems in Brachial Plexus Birth Palsy." One conclusion made was in support of the individual use of the modified mallet score when managing children with brachial palsy due to its lack of correlation with AMS and Toronto scores.

Dayna Phillips, MD

Special Event

Temple-Shriners Alumni Day 2016

A little rain never hurt anyone; however, a lot can ruin a round of golf. This year, the annual Temple-Shriners alumni day took place at the beautiful Normandy Farm Hotel and Conference Center in Blue Bell on Friday, May 6, 2016. Unfortunately, this was one of the rainiest days in recent memory, but that would not stop the residents, attendings, and alumni from participating in an excellent event nonetheless.

The keynote speaker this year was Dr. Matthew Ramsey of the Rothman Institute. As one of the world's experts in shoulder and elbow surgery, he highlighted the indications and outcomes for total elbow replacement. He was followed by Dr. Kristofer Matullo (Class of 2008), who discussed topics and cases involving surgery of the wrist and hand. The morning academic session was concluded by highlighting the advances in research within the department and discussing the importance of the Lachman Fund and how instrumental it has been in allowing residents to pursue their research interests.

Many of the residents and alumni did not let the rain completely ruin the afternoon as they enjoyed each other's company (and some Shirley Temples) at a local watering hole. Hopefully, the 2017 Alumni Day will offer some better weather with the same great attendance.

Justin M. Kistler, MD

Special Event

8th Annual Philadelphia Orthopaedic Trauma Symposium

June 10–11, 2016

Temple University's Medical Education and Research Building served as the location for the 8th annual Philadelphia Orthopaedic Trauma Symposium. Temple's very own Dr. Saqib Rehman and Dr. Matthew Craig (Jefferson Health–Abington Memorial Hospital) were chairmen and head organizers for this event. In addition to their efforts, the course faculty included 27 orthopaedic surgeons from Philadelphia and surrounding hospitals who contributed with lectures and skills labs. Participation from residents, students, nurses, physician assistants, and educators also assisted in the success of this event.

The keynote lecture titled "Femoral Neck Fractures in the Young Adult: What Makes Sense" was given by Dr. Cory Collinge, Professor of Orthopaedic Surgery at Vanderbilt University. Dr. Collinge stressed the importance of performing an adequate assessment of these fractures in order to develop an equally adequate preoperative plan, reduction, and fixation. Participants were then able to apply these concepts in the skills lab that followed.

In addition to femoral neck fractures, this year's symposium focused on educating participants in the acute management of extremity fractures and operative skills for periarticular fractures. Current controversies and previously-debated issues were discussed during the "lower extremity trauma debates." During this segment of the program, distinguished surgeons presented their stance on the treatment of specific fracture types with certain treatment options. One debate topic focused on the "Fixation of Intertrochanteric Femur Fractures: Sliding Hip Screw Versus Intramedullary Nail." Despite these heated debates, no long-term friendships were lost, but life-long knowledge was gained.

Dayna Phillips, MD

Special Event

Ponderosa Bowl 2016

Sunday, December 11, 2016 was the 6th installment of the annual Ponderosa Bowl on the hallowed grounds of the normally frozen tundra of Dr. Thoder's backyard. The football gods pardoned the participants once again this year, as the weather was cooperative. The players did have to dodge a few dogs, as always, but they were certainly welcome in the flow of the game.

The Cherry Team was represented by Dr. Colin "Mac" Vroome, Dr. James Bennett, and Dr. Alex Johnson (of Randolph Macon football fame). The White Team was represented by Dr. Jeff Wera, Dr. Courtney Quinn, and a great friend of the department, Dr. Michael Narvaez from Einstein Orthopaedics. Dr. Justin Kistler, given the lack of speed and strong arm, was the stand-in "steady-QB" for the game (although there were rumblings that it was because winning was a guarantee as the full time quarterback).

The game was highlighted by some deep passes and impressive catches by Jeff Wera that would have even impressed Odell Beckham, Jr. The first half was a tight battle with back and forth scoring. The game was tightly, but fairly, officiated by the always vigilant official, Dr. Thoder. The White Team kicked their offense into high gear during the second half with three unanswered touchdowns allowing them to easily pull away from the inferior Cherry Team. Thankfully, there were no serious injuries during the game, probably owed to the fact that Dr. Jim Lachman sat this one out.

In keeping with tradition, the game was followed by food, drinks, cigars, darts, and NFL Red Zone on three televisions in the cozy confines of the famous Ponderosa basement. Dr. Thoder's hospitality and company continues to be the highlight of this event year after year.

Justin M. Kistler, MD

Faculty

Temple University Department of Orthopaedic Surgery and Sports Medicine

Chairman

Eric J. Kropf, MD

Professors

Joseph Thoder, MD, *The John W. Lachman Professor*
William DeLong, MD
Pekka Mooar, MD
Ray Moyer, MD, *The Howard H. Steel Professor*
Joseph Torg, MD
F. Todd Wetzel, MD, *Vice Chairman*

Associate Professors

Eric Gokcen, MD
Matthew Lorei, MD
Saqib Rehman, MD
J. Milo Sewards, MD
Bruce Vanett, MD

Assistant Professors

Hesham Abdelfattah, MD
Leslie Barnes, MD
Christopher Haydel, MD
Cory Keller, DO
Min Lu, MD
Michelle Noreski, DO
Zeeshan Sardar, MD
Ryan Schreiter, DO

Adjunct Faculty — Philadelphia Shriners Hospital

Scott Kozin, MD, *Chief of Staff*
Philip Alburger, MD
Corinna Franklin, MD
Steven Hwang, MD
Sarah Nossov, MD
Amer Samdani, MD, *Chief of Surgery*
Joshua Pahys, MD
Harold van Bosse, MD
Albert Weiss, MD
Daniel Zlotolow, MD

Adjunct Faculty — Jefferson Health–Abington Memorial Hospital

Andrew Star, MD, *Chief of Orthopaedics*
Shyam Brahmabhatt, MD
David Craft, MD
Matthew Craig, MD
Michael Gratch, MD
Victor Hsu, MD
Moody Kwok, MD
Guy Lee, MD
Rachel Shakked, MD
T. Robert Takei, MD
Jeffrey Vakil, MD

Adjunct Faculty — St. Christopher's Hospital for Children

Peter Pizzutillo, MD, *Chief of Surgery*
Alison Gattuso, DO
Megan Gresh, MD
Michael Kwon, MD
Martin Herman, MD, *Chief of Orthopaedics*
Joseph Rosenblatt, DO
Shannon Safier, MD

Division of Adult Reconstruction

Matthew Lorei, MD
Division Chief

Min Lu, MD

Michael MacGregor, MSPAS, PAC

Pekka Mooar, MD

General

Our division heads the musculoskeletal care of the older adult with hip and knee conditions. Our surgical focus is on hip and knee replacement: including partial knee replacement, primary total joint replacement, revision replacement and complex reconstruction. One of our primary missions is to educate residents in the art and science of hip and knee replacement surgery and advance reconstruction. Within the past year, we have successfully transitioned to a comprehensive electronic order set. This has helped to streamline postop care of the joint replacement patient and eliminate medical errors, unnecessary work and duplication of services. We are still working out some of the bugs but the process seems to be working smoothly overall. We continue to make efforts to reduce our length of stay and have trimmed it to an ALOS of 2.4 days (this compares to 3.2 just two years ago). We have also transitioned from primarily post acute care transfer to a SNF to predominantly discharge home despite the shorter LOS. We continue to work on reducing our readmission rate. Dr. Mooar is currently involved in the Novacart trial comparing MACI cartilage transplantation vs. microfracture of femoral condylar articular cartilage defects. Dr. Mooar also helped to craft the 2016 AAOS AUC for the management of Carpal Tunnel Syndrome, serving as a voting panel moderator. In August of 2016, we welcomed Min Lu, MD to the Orthopaedic Department as well as the Division of Arthroplasty. Dr. Lu is originally from Brooklyn, NY and is a triple graduate of University of Chicago, having earned his undergraduate and medical degrees there as well as competing his orthopaedic training at that same institution. More recently, he completed a fellowship in adult joint reconstruction surgery at the University of California San Francisco.

Presentations

1. Lu M, Sing D, Kuo A, Hansen E. Preoperative Anemia Independently Predicts 30 Day Complications After Aseptic and Septic Revision Total Joint Arthroplasty. Scientific Poster. *American Association of Hip and Knee Surgeons Annual Meeting,* Dallas, TX, November 2016.

Division Report

Division of Division of Foot and Ankle Surgery

Eric Gokcen, MD
Division Chief

The Division of Orthopaedic Foot and Ankle Surgery provides comprehensive care for the foot and ankle patient, including deformity correction, sports medicine, joint reconstruction, and trauma care. In addition, teaching of orthopaedic residents, medical students, and podiatry students is performed with both didactic and clinical education.

The division is undergoing recent changes with the arrival of Eric Gokcen, MD as the Division Head following Joseph Eremus, MD stepping down from the faculty after a long and distinguished career at Temple University. In light of these recent changes, the division is in the process of developing new clinical initiatives and research activities. Teaching and journal presentations were done at a local sports medicine journal club attended by sports medicine healthcare providers from throughout the Philadelphia area. Podium teaching at a Philadelphia city-wide OITE review was provided in October 2016. Dr. Gokcen presented Grand Rounds on January 4th on the topic of Global Orthopaedics. Through an AOFAS visiting professor scholarship, the division hosted Scott Ellis, MD, the Division Chair of Foot and Ankle Surgery at the Hospital for Special Surgery for a journal club session on foot and ankle pathologies on February 17th followed by a Grand Rounds presentation on February 18th on "Adult Flatfoot." In the meantime, didactic teaching sessions with the residents and students on various foot and ankle pathologies continues.

New Faculty

Eric C. Gokcen, MD — Dr. Gokcen, a graduate of the Sidney Kimmel School of Medicine of Thomas Jefferson University, comes to us from Loma Linda University where he was the Division Head of Foot and Ankle Surgery in the Orthopaedic Surgery Department. Prior to that appointment, he spent several years in Africa, providing orthopaedic care and developing residency training programs. His previous experience was in private orthopaedic practice in the Bucks County/Mercer County area.

Division Report

Division of Hand Surgery

Joseph Thoder, MD
Division Chief

Hesham Abdelfattah, MD

Bruce Vanett, MD

General

The division of Hand Surgery at Temple is growing. We have added a new faculty member. He is Hesham Abdelfattah, MD. Hesham hails from west Texas, a graduate of Texas Tech, completed his orthopaedic residency at West Virginia University, and is fellowship trained in hand surgery from Thomas Jefferson University as well as a shoulder and elbow fellowship at the University of Pennsylvania. He has special interests in upper extremity trauma, as well as elbow and wrist arthroplasty. He has hit the ground running in his first few months here with a busy clinic and OR schedule. He has a dedication to caring for the community, educating residents, and producing meaningful research in our field.

Over the past 2+ decades, Temple Orthopaedics has produced a significant number of graduates who have pursued fellowships and careers in hand surgery, many of whom are now leaders in the field. Representation of our clinical accomplishments in terms of contributions to the field of hand surgery can be found in the list of podium presentations, scientific exhibits and publications listed in this and prior issues of our journal. Hesham will be a welcome addition to the program, contributing to our clinical, educational and research efforts. He will no doubt be a leader in the field going forward.

Division Report

Division of Orthopaedic Trauma

Saqib Rehman, MD, MBA
Division Chief

Christopher Haydel, MD

Clinical Care

The Division of Orthopaedic Trauma is focused on the care of patients with fractures, multiple trauma, and related injuries. We strive for excellence in patient care, education, research, and service. Our recent patient care initiatives have included the implementation of our Geriatric Fracture Program, a comprehensive effort to improve the quality of care for patients with hip fractures at Temple University Hospital. This follows the successful implementation of best practice/clinical efficiency pathways for open fractures and for femoral shaft fractures. Working collaboratively on interdisciplinary teams has helped standardize care, minimize errors, improve efficiency, and ultimately improve patient care. Through continuous performance improvement reviews and innovation, we hope to continue improving for our patients at Temple.

Education

The 8th Annual Philadelphia Orthopaedic Trauma Symposium was hosted by Temple again, with well over 100 participants gathered for a day and a half of CME lecture, case discussion, technique labs, and learning. Due to the positive response from participants, we plan on having it again here in June 2017 with a theme of "What's New in Orthopaedic Trauma."

Resident and student didactic educational efforts have increased in the past year, with a major effort in creating and delivering online educational content. With the creation and ongoing efforts of our Orthoclips.com website, utilization of Blackboard online learning tools, and flipped classroom methods, the Division of Orthopaedic Trauma is emphasizing an active learning model in medical education. The addition of our YouTube channel with over 1,500 subscribers and viewers in 198 countries has allowed us to reach a truly global audience.

The ortho trauma faculty continues to teach at national courses and meetings including annual meetings of the American Academy of Orthopaedic Surgeons (AAOS), Orthopaedic Trauma Association (OTA) and Foundation for Orthopaedic Trauma (FOT) as well as AOTrauma. In addition, we have taught at local and regional courses, given grand rounds lectures at other teaching programs, and taught in a combined AAOS/AAHS, OTA webinar this past year.

Service

We have been actively serving many of these above societies, chair the Humanitarian Committees of the OTA and of the FOT, serve on the FOT Executive Board and serve as manuscript reviewers for multiple scientific journals *(JOT, CORR, JTrauma, Orthopedics).* Back home at Temple, the ortho trauma faculty actively serve and chair numerous committees and project teams at the university, hospital, and departmental levels.

Clinical Trials

The Division of Orthopaedic Trauma, as Principal Investigators, is actively enrolling patients in the following clinical trials:

- Major Extremity Trauma Research Consortium (METRC) — VANCO trial
- METRC — STREAM trial
- Regional vs. General Anesthesia for Promoting Independence after Hip Fracture Surgery (REGAIN)

Scientific Publications (Pubmed)

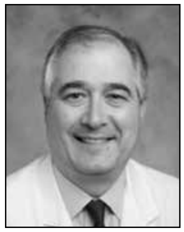
1. Jennings JD, Hahn A, Rehman S, Haydel C. Management of Adult Elbow Fracture Dislocations. *Orthop Clin North Am.* 2016 Jan;47(1):97–113.
2. Greenhill D, Haydel C, Rehman S. Management of the Morel-Lavallee lesion. *Orthop Clin North Am.* 2016 Jan;47(1):115–25.
3. Rehman S. Going out with a bang. *Orthop Clin North Am*. 2016 Jan;47(1):xxi.
4. Solarz MK, Thoder JJ, Rehman S. Management of major traumatic upper extremity amputations. *Orthop Clin North Am.* 2016 Jan;47(1):127–3.

5. Harper K, Rehman S. Orthopaedic disaster management in the 2015 Amtrak derailment. *J Trauma Acute Care Surg.* 2016 Jun;80(6):1032–8.
6. Lachman J, Rehman S. Tibial plateau Schatzker V/VI treated in ex fix/circular frame. In Tejwani NC editor, *Fractures of the Tibia, A Clinical Companion.* Springer, 2016.
7. Lachman JR, Rehman S. Chapter 3 — Bone Healing. In Hoppenfeld S, Murthy VL. *Treatment and Rehabilitation of Fractures.* 2nd Edition. Lippincott and Williams, 2016.
8. Gangavalli A, Malige A, Terre G, Rehman S, Nwachuku C. Opioid misuse in orthopaedic post-operative patients. *Journal of Orthopaedic Trauma,* 2016 PAP doi: 10.1097/BOT.0000000000000741.
9. Greenhill DA, Poorman M, Pinkowski C, Ramsey FV, Haydel C. Does weight-bearing assignment after intramedullary nail placement alter healing of tibial shaft fractures? *Orthop Traumatol Surg Res.* 2017 Jan 23. pii: S1877-0568(16)30178–5.
10. Kistler J, Solarz MK, Rehman S. Obturator artery injury resulting in massive hemorrhage from a low energy pubic ramus fracture: a case report. *Orthopedics,* 2017 Jan;5:1–3.

Scientific Presentations (Podium, Poster)

1. Jennings, JD, Haydel C, Rehman S. Management of Adult Elbow Fracture Dislocations. *American Academy of Orthopaedic Surgeons, Annual Meeting,* Orlando, FL, March 2016 (Scientific Exhibit).
2. Eccles J, Harper K, Quinn C, Ramsey F, Rehman S. Factors Affecting Timing of IV Antibiotic Administration for Patients with Open Fractures. *Pennsylvania Orthopaedic Society Spring Meeting,* Boca Raton, FL, April 2016 (Poster).
3. Harper, Quinn C, Iorio J, Rehman S. Percutaneous Sacroiliac Screw Fixation of the Posterior Pelvic Ring. *Pennsylvania Orthopaedic Society Spring Meeting,* Boca Raton, FL, April 2016 (Poster).
4. Harper K, Rehman S. Orthopaedic Disaster Management in the 2015 Amtrak Derailment. *Pennsylvania Orthopaedic Society Spring Meeting,* Boca Raton, FL, April 2016 (Poster).
5. Amer KM, Rehman S, Haydel C. Quantitative Analysis of the Efficacy and Safety of Tranexamic Acid in Orthopaedic Fracture Surgery. *Pennsylvania Orthopaedic Society Fall Meeting,* Pittsburgh, PA, October 2016 (Poster).
6. Lachman JR, Haydel C, Eremus J. Intraosseous Arthrodesis Techniques in the Foot and Ankle: Does It Really Hurt Less? *American Orthopaedic Foot & Ankle Society Annual Meeting,* Toronto, ON, July 2016 (Poster).
7. Greenhill DA, Poorman M, Pinkowski C, Ramsey FV, Haydel C. Does Weight Bearing Assignment After Intramedullary Nail Placement Alter Healing of Tibial Shaft Fractures? *Eastern Orthopaedic Association Annual Meeting,* New Orleans, LA, October 2016 (Podium).
8. Amer K, Rehman S, Haydel C. Efficacy and Safety of Tranexamic Acid in Orthopaedic Fracture Surgery: A Meta Analysis and Systematic Review. *Eastern Orthopaedic Association Annual Meeting,* New Orleans, LA, October 2016 (Podium).
9. Amer K, Rehman S, Haydel C. Efficacy and Safety of Tranexamic Acid in Orthopaedic Fracture Surgery: A Meta Analysis and Systematic Review. *American Academy of Orthopaedic Surgery Annual Meeting,* San Diego, CA, March 2017 (Podium).

Division of Spine Surgery



F. Todd Wetzel, MD
Division Chief

Zeeshan Sardar, MD, CM, FRCSC, MSc, B.Eng

This has been a year of growth for the spine service with recruitment of Dr. Zeeshan Sardar from the premier adult deformity spine fellowship in the nation, if not the world. Dr. Sardar's practice is building steadily, with some equipment issues for the large deformity cases yet to be resolved. Dr. Wetzel is the 33rd President of NASS through October 2017 and continues to maintain various editorial and academic responsibilities for several organizations. Some specific activities of the section are detailed below.

Academic

1. Peng Y, Kang Q, . . . Wetzel FT, Haydon RC, He TC. Transcriptional Signature of Bone Morphogenic Proteins-Mediated Osteogenic Signaling. *Spine (in press).*
2. Wetzel FT. New Technologies in Spinal Cord Stimulation. *Deutscher Wirbelsaulenkongress,* Hannover, Germany, December 3, 2016.

Educational

1. Bimonthly Spine Conference, with the Department Neurosurgery. Plans to incorporate PMR Department from next month.
2. Spine series lectures, Physician Assistant Curriculum, 2017.
3. Spine lecture series, Orthopaedic Residency Program.
4. Saw bones lab for pedicle screw instrumentation of the spine, Orthopaedic Residency Program.
5. Sardar ZM. Spine Deformity in the Adult Patient Population. Invited presentation at the *6th Annual Regional Neurosciences Conference and State of the Art Stroke Summit,* Atlantic City, NJ.
6. Sardar ZM. Adult Spine Deformity. *Grand Rounds presentation at Cooper University Bone and Joint Institute,* April 2017.
7. Wetzel FT. 28 Years Before the Mast — Reflections on Spine Care. *Young Spine Surgeons Forum, North American Spine Society, 31st Annual Meeting,* Boston, MA, October 26, 2016.
8. Wetzel FT. The Path to Leadership. *Committee Orientation Program, North American Spine Society, 31st Annual Meeting,* Boston, MA, October 27, 2016.
9. Wetzel FT. Integrating Spinal Cord Stimulation into a Surgical Practice. Current Concepts and Critical Evidence Based Appraisal of Spinal Cord Stimulation. *North American Spine Society, 31st Annual Meeting,* Boston, MA, October 28, 2016.
10. Diulus C, Wetzel FT. Stigmatized by Obesity: New Studies Offer Intriguing Insight. *SpineLine.* July/August 2016:33–35.
11. Wetzel FT. What Sort of Person Does a Job Like This? *SpineLine.* September/October 2016:8–10 (From the Desk of the First Vice President).
12. Wetzel FT. Precisely. *SpineLine.* November/December 2016:8–10 (From the Desk of the President).
13. Wetzel FT. Really Very Useless. *SpineLine.* January/February 2017, in press (From the Desk of the President).

External Activities

Sardar ZM: Reviewer, *The Spine Journal*; Reviewer, *Global Spine Journal;* Member, *AOSpine;* Membership pending board review, *Scoliosis Research Society*

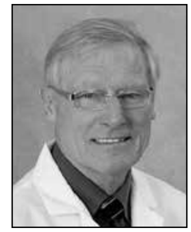
Wetzel FT: Board of Associate Editors, *The Spine Journal;* Board of Associate Editors, *Spine;* Guest Editor in Chief, focus issue, Spinal Cord Stimulation, *Spine;* Reviewer, *Clinical Orthopaedics and Related Research;* Reviewer, *Journal of Bone Joint Surgery;* Reviewer, *Pain;* 33rd President, the North American Spine Society; Chair, Editor-in-Chief Search Committee, *The Spine Journal;* NASS liaison, Patient Centered Outcomes Research Institute (PCORI), Washington DC; Spine Section and Program Committee, the American Academy of Orthopaedic Surgeons; Adult Examiner, Recertification and Part II Examinations, the American Board of Orthopaedic Surgeons

Division of Sports Medicine and Shoulder Surgery

Eric J. Kropf, MD
Division Chief

Leslie Barnes, MD

Cory Keller, DO

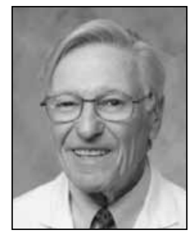


Ray Moyer, MD

Michelle Noreski, DO

Ryan Schreiter, DO

J. Milo Sewards, MD



Joseph Torg, MD

Clinical Care

The Division of Sports Medicine and Shoulder Surgery is a comprehensive, multidisciplinary group committed to providing the highest level of care to active and athletic patients of all ages. The Sports Medicine team has gone through an exciting phase of restructuring and expansive growth over the past three years, now comprised of three surgeons and four non-surgical providers. The team continues to perform advanced and cutting edge arthroscopic and minimally invasive surgery of the shoulder, elbow, hip and knee. Through diversification and the addition of talented non-surgical providers, the team also performs in-office ultrasound-guided procedures and offers stem cell and biologic therapies for acute sports-related injuries and early arthritis in active young patients. Collectively, the sports medicine team can develop individualized patient-focused treatment plans to maximize outcomes and meet the demands of the individual. The Sports Team sees over 20,000 patient visits a year and performs 1,100+ procedures annually. A key area of growth in 2016 has been through continued development of our Shoulder Reconstruction/Arthroplasty program. Dr. Leslie Barnes joined the team in 2015 to meet the needs of our patients with advanced rotator cuff disease and shoulder arthritis.

Education

This diverse group of providers has much to offer to our students and residents. Currently, our providers teach in the classroom, clinics, training rooms, athletic sidelines and operating rooms. We have dedicated time with Temple University medical students and Kinesiology/undergraduate and graduate athletic training students. While orthopaedic residents remain our primary focus, the sports division also works with medicine, family medicine and PM&R residents as well as area primary care sports medicine fellows.

The “Temple Sports Medicine Journal Club” meets on a bimonthly basis with a target audience of regional physical therapists, athletic trainers and sports medicine physicians and trainees.

The sports medicine faculty continues to teach at national courses and meetings including annual meetings of the American Academy of Orthopaedic Surgeons (AAOS), Arthroscopy Association of North America (AANA), the American Medical Society for Sports Medicine (AMSSM) and the American Orthopaedic Society for Sports Medicine (AOSSM).

Service/Outreach Programs

The Division of Sports Medicine provides comprehensive medical coverage for Temple University’s 600 varsity athletes. Our physicians can be seen in training rooms or on the sidelines of football, basketball and soccer games on a regular basis. We continue to deploy athletic trainers throughout the Philadelphia public and catholic leagues serving as team physicians to St. Joseph’s Preparatory, LaSalle College Preparatory, Father Judge High School, Archbishop Wood HS and Archbishop Ryan HS. Members of the team have also developed affiliate relationships with Arcadia University

Athletics and Drexel University's primary care sports medicine program.

Scientific Publications (PubMed)

1. Ly JA, Coleman EM, Cohen GS, Kropf EJ. Unrecognized osteoid osteoma of the proximal femur with associated CAM impingement. *J Hip Preserv Surg.* 2016;3(3): 236–237; DOI:10.1093/jhps/hnw002.
2. Ly JA, Coleman EM, Kropf EJ. Arthroscopic Double Row Suture Anchor Repair of Acute Posterior Bony Bankart Lesion. *Arthrosc Tech.* 2016;5(4):e839–843; doi: 10.1016/j.eats.2016.04.004.
3. Quinn CA, Ly JA, Narvaez MV, Kropf EJ. Management of Recurrent Posterior Shoulder Instability in a Young Contact Athlete Using a Posterior Bone Block Technique with Distal Tibia Osteochondral Allograft. *Techniques in Shoulder & Elbow Surgery* (accepted 2016, in publication processing).
4. Fink Barnes LA, Kim HM, Caldwell JM, Buza J, Ahmad CS, Bigliani LU, Levine WN. Satisfaction, function and repair integrity after arthroscopic versus mini-open rotator cuff repair. *Bone Joint J.* 2017 Feb;99-B(2):245–249.

Book Chapters

1. Fink Barnes LA, Parsons BO, Flatow EL. Glenohumeral Instability. Rockwood and Matsen: *The Shoulder,* 5th Edition, 2016.
2. Fink Barnes LA, Jim C. Hsu, Leesa M. Galatz. Mini-Incision Fixation of Proximal Humeral Four-Part Fractures. In *Minimally Invasive Surgery in Orthopedics* (pp 1–10), 2016.
3. Fink Barnes LA, Parsons BO, Flatow EL. Mini-Incision Bankart Repair. In *Minimally Invasive Surgery in Orthopedics*, 2016.
4. Donovan D, Fink Barnes LA, Parsons BO, Hausman MR. Minimally Invasive Approaches for Lateral Epicondylitis. In *Minimally Invasive Surgery in Orthopedics,* 2016.
5. Fink Barnes LA, Flatow EL. Overview of Shoulder Approaches. In *Minimally Invasive Surgery in Orthopedics,* 2016.
6. Kropf EJ, Colon JW, Torg JS. Knee Laxity: The Torg School. In Karlsson, Kuroda, Musahl Zaffagnini Eds. *Rotatory Instability of the Knee: An Evidence Based Approach.* Springer 2016.

Scientific Presentations (Podium, Poster, Invited Lecture)

1. Pandelidis A, Ly JA, Reilly M, Ramsey FV, Kropf EJ. Using MRI to Define Anatomy of Anterior Inferior Iliac Spine. *Eastern Orthopaedic Association Annual Meeting 2016,* New Orleans, LA, October 22, 2016 (podium).
2. Reilly M, Pandelidis A, Ly JA, Ramsey FV, Kropf EJ. Utility of MRI to Define Anatomical Features of the Anterior Inferior Iliac Spine. *11th Biennial ISAKOS Congress,* Shanghai China, June 4–8, 2017 (poster).
3. Kropf EJ. Combined Hip and Core Muscle Injury: Evaluation and Management of Nonarthritic Groin Pain. *Orthopaedic Surgery Grand Rounds, Georgetown University School of Medicine,* Washington, DC, March 22, 2016.
4. Kropf EJ. Hip Pain in the Contact and Overhead Athlete. *Inaugural INOVA Capital City Sports Medicine Summit,* Washington, DC, May 6, 2016.
5. Kropf EJ. Combined Hip and Core Muscle Injury. *Panther Alumni Symposium, AOSSM Annual Meeting 2016,* Colorado Springs, CO, July 8, 2016.
6. Kropf EJ. Combined Hip and Core Muscle Injury: Surgical Options. *Delaware Orthopaedic Symposium Christiana Hospital,* Newark DE, October 29, 2016.
7. Kropf EJ. Cartilage Preservation Techniques for the Knee. *ATI 2016 East Coast Sports Medicine Summit,* Philadelphia, PA, November 12, 2016.
8. Kropf EJ. Early Career Development: Challenge and Opportunity in Academic Practice. *Pennsylvania Orthopaedic Society Spring 2017 Scientific Meeting,* Erie, PA, May 11, 2017.
9. Fink Barnes LA, Luchetti TJ, Buza J, Jobin CM, Ahmad CS. Athletes with Shoulder Instability: A Prospective Study of Player Attitudes on Operative vs Non-operative Treatment. *American Academy of Orthopaedic Surgeons Annual Meeting,* February 29–March 6, 2016, Orlando, FL.
10. Barnes LA. Rotator Cuff Repair — Routine to Complicated. *Panel at the 150th NYOH Alumni Meeting,* New York, NY, May 2016.
11. Sewards JM. Lead, Follow, or Get Out of the Way: Leadership Development in Residency. Presented at *Grand Rounds, Department of Orthopaedics, Miller School of Medicine at the University of Miami,* January 2017, Miami, FL.
12. Brusalis CM, Jarvis-Selinger S, Rosenblatt J, Herman MJ, Mulcahey MK, Sewards JM, Mehta S. Near-peer Teaching in Orthopaedic Surgery: Happening with Little Oversight. *2017 ACGME Annual Education Conference,* March 2017, Orlando, FL (poster).
13. Jennings JJ, Kistler J, Sewards JM, Thoder JJ. Lateral Epicondylitis: Controversies and Management. *2017 Annual Meeting of the American Academy of Orthopaedic Surgeons,* San Diego, CA (scientific exhibit).
14. Keller CJ. Shoulder Mechanics and Pathology. *Chestnut Hill Family Medicine Grand Rounds,* October 2016.
15. Keller CJ. Sudden Cardiac Death in Athletes. *LKSOM Family Medicine Review Course,* November, 2016.
16. Keller CJ. Nutritional Supplements in Sports. *LKSOM Family Medicine Review Course,* November, 2016.
17. Keller CJ. The Throwing Shoulder. *Lewis Katz School of Medicine, Temple University PM&R Grand Rounds,* November, 2016.
18. Keller CJ. Shoulder Assessment. LKSOM Family Medicine Review Course, March, 2017.
19. Keller CJ. The Aging Athlete. *Reading Hospital Family Medicine Grand Rounds,* March, 2017.

Temple University Hospital
Department of Orthopaedic Surgery and Sports Medicine
House Staff 2016–2017

Arianna Trionfo, MD

Hometown: Glassboro, NJ

Undergraduate: Loyola College in Maryland

Medical School: UMDNJ – Robert Wood Johnson

Fellowship: Pediatrics, Children's Hospital of Philadelphia

James Lachman, MD

Hometown: Bryn Mawr, PA

Undergraduate: Bucknell University

Medical School: Temple University School of Medicine

Fellowship: Foot and ankle, Duke University

Anastassia Newbury, MD

Hometown: Omaha, NE

Undergraduate: University of Iowa

Medical School: University of Nebraska College of Medicine

Fellowship: Hand/upper extremity, NYU Hospital for Joint Disease

Dustin Greenhill, MD

Hometown: West Palm Beach, FL

Undergraduate: U.S. Military Academy (West Point)

Medical School: Temple University School of Medicine

Fellowship: Pediatrics, Texas Scottish Rite Hospital for Children

Katherine Harper, MD

Hometown: London, Ontario, Canada

Undergraduate: McMaster University

Medical School: Royal College of Surgeons in Ireland School of Medicine

Interest: Adult reconstruction

John Jennings, MD

Hometown: Allentown, PA

Undergraduate: Pennsylvania State University

Medical School: Temple University School of Medicine

Interests: Hand/upper extremity

James Bennett, MD

Hometown: Charlotte, VT

Undergraduate: Colby College

Medical School: St. George's University School of Medicine

Interest: Pediatric spine

William Smith, MD

Hometown: Havertown, PA

Undergraduate: Pennsylvania State University

Medical School: Jefferson Medical College

Interests: Hand/upper extremity

Temple University Hospital
Department of Orthopaedic Surgery and Sports Medicine
House Staff 2016–2017 *(cont.)*

Justin Kistler, MD

Hometown: Horsham, PA

Undergraduate: University of Pittsburgh

Medical School: Temple University School of Medicine

Interests: Hand/upper extremity

Courtney Quinn, MD

Hometown: Potomac, MD

Undergraduate: University of Southern California

Medical School: Georgetown University School of Medicine

Interest: Sports, hand/upper extremity

Megan Reilly, MD

Hometown: Longwood, FL

Undergraduate: University of Florida

Medical School: Georgetown University School of Medicine

Interests: Foot and ankle

Peter Eyvazzadeh, MD

Hometown: Bethlehem, PA

Undergraduate: Bucknell University

Medical School: Penn State University College of Medicine

Interest: Sports

Dayna Phillips, MD

Hometown: Rosenhayn, NJ

Undergraduate: University of the Sciences

Medical School: Rutgers – New Jersey Medical School

Interest: Undecided

Colin "Mac" Vroome, MD

Hometown: Havertown, PA

Undergraduate: Villanova

Medical School: Jefferson Medical College

Interests: Sports, hand/upper extremity

Jeffrey Wera, MD

Hometown: Villa Hills, KY

Undergraduate: The College of William & Mary

Medical School: University of Louisville School of Medicine

Interest: Undecided

Robert Ames, MD

Hometown: Dallas, TX

Undergraduate: Rutgers University

Medical School: Temple University School of Medicine

Interests: Spine, pediatrics

Temple University Hospital
Department of Orthopaedic Surgery and Sports Medicine
House Staff 2016–2017 *(cont.)*

Dana Cruz, MD

Hometown: New York, NY

Undergraduate: University of Southern California

Medical School: Albert Einstein College of Medicine

Interests: Hand/upper extremity, spine

Alexander Johnson, MD

Hometown: East Norriton, PA

Undergraduate: Randolph-Macon College

Medical School: Drexel University College of Medicine

Interest: Undecided

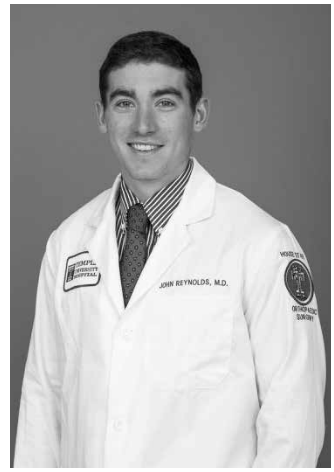
Nimit Lad, MD

Hometown: Winona, MN

Undergraduate: Duke University

Medical School: Duke University School of Medicine

Interest: Sports



Jack Reynolds, MD

Hometown: Malvern, PA

Undergraduate: Villanova University

Medical School: Jefferson Medical College

Interest: Undecided

Temple University Department of Orthopaedic Surgery and Sports Medicine: Research Update 2016–2017

Podium Presentations

Greenhill D, Smith W, Ramsey F, Kozin S, Zlotolow D. Conjoined Versus Isolated Shoulder Tendon Transfers in Brachial Plexus Birth Palsy. *European/North American Pediatric Orthopaedic Society Annual Meeting (EPOSNA),* Barcelona, Spain, May 2017.

Wetzel, FT. New Technologies in Spinal Cord Stimulation. *Deutscher Wirbelsaulenkongress,* Hannover, Germany, December 2016.

Greenhill D, Poorman M, Pinkowski C, Ramsey F, Haydel C. Does Weight Bearing Assignment After Intramedullary Nail Placement Alter Healing of Tibial Shaft Fractures? *Eastern Orthopaedic Association Annual Meeting,* New Orleans, LA, October 2016.

Amer KM, Rehman S, Haydel C. Quantitative Analysis of the Efficacy and Safety of Tranexamic Acid in Orthopaedic Fracture Surgery. *Pennsylvania Orthopaedic Society Fall Meeting,* Pittsburgh, PA, October 2016.

Haydel C. Efficacy and Safety of Tranexamic Acid in Orthopaedic Fracture Surgery: A Meta Analysis and Systematic Review. *Eastern Orthopaedic Association Annual Meeting,* New Orleans, LA, October 2016.

Jennings J. Wrist Septic Arthritis: Incidence, Risk Factors, and Predictors of Infection. *Eastern Orthopaedic Association,* New Orleans, LA, October 2016.

Wetzel FT. 28 Years Before the Mast: Reflections on Spine Care. *North American Spine Society 31st Annual Meeting,* Boston, MA, October 2016.

Wetzel FT. Integrating Spinal Cord Stimulation into a Surgical Practice: Current Concepts and Critical Evidenced Based Appraisal of Spinal Cord Stimulation. *North American Spine Society 31st Annual Meeting,* Boston, MA, October 2016.

Greenhill D. Van Bosse H. Does Open Reduction of Arthrogrypotic Hips Cause Stiffness? *POSNA Annual Meeting,* Indianapolis, IN, April 2016.

Jennings, J. Physicians' Attire Influences Patients' Perceptions in the Urban Outpatient Orthopaedic Surgery Setting. *Philadelphia Orthopaedic Society,* Boca Raton, FL, April 2016.

Greenhill D, Comstock D, Torg J, Navo P, Zhao H, Boden B. Inadequate Helmet Fit Increases Concussion Severity in American High School Football Players. *American Academy of Orthopaedic Surgeons Annual Meeting,* Orlando, FL, March 2016.

Trionfo A, Thoder JJ, Tosti R. Do Pre-Operative Antibiotics Reduce Bacterial Culture Growth from Hand Abscesses? *American Academy of Orthopaedic Surgeons Annual Meeting,* Orlando, FL, March 2016.

Trionfo A, Greenhill D, Solarz M, Ramsey F, Kozin S, Zlotolow D. Risk Factors for Loss of Midline Function in Patients with Brachial Plexus Birth Palsy. *Narakas Symposium XIX,* Barcelona, Spain, February 2016.

Greenhill D, Wissinger K, Trionfo A, Solarz M, Kozin S, Zlotolow D. External Rotation Predicts Outcomes After Glenohumeral Joint Reduction with Botulinum Toxin Type A in Brachial Plexus Birth Palsy. *POSNA Annual Meeting,* Indianapolis, IN, April 2016 and *Narakas Symposium XIX,* Barcelona, Spain, February 2016.

Greenhill D, Lukavsky R, Tomlinson-Hansen S, Kozin S, Zlotolow D. Relationships Between Three Classification Systems in Brachial Plexus Birth Palsy. *Narakas Symposium XIX,* Barcelona, Spain, February 2016.

Poster Presentations

Greenhill D, Abbasi P, Darvish K, Star A. Broach Handle Design Changes Force Distribution in the Femur During Total Hip Arthroplasty. *American Academy of Orthopaedic Surgeons Annual Meeting,* San Diego, CA, March 2017.

Jennings J, Kistler J, Thoder J, Sewards JM. Lateral Epicondylitis: Controversies and Management. *American Academy of Orthopaedic Surgeons Annual Meeting,* San Diego, CA, March 2017.

Jennings J, Thoder J. Management of Hand Gunshot Injuries. *American Academy of Orthopaedic Surgeons Annual Meeting,* San Diego, CA, March 2017.

Harper K, Quinn C, Rehman S, Rodriguez EK, Krause P, Born C. Mass Casualty in Orthopedics: From Planning to Management — Is Your Department Ready? *AAOS Annual Meeting,* San Diego, CA, March 2017.

Greenhill DA. Abbasi P. Darvish K. Star A. Broach Handle Design Changes Force Distribution in the Femur During Total Hip Arthroplasty. *American Academy of Orthopaedic Surgeons Annual Meeting,* San Diego, CA, March 2017.

Jennings J, Quinn C, Rehman S. Orthopaedic Surgery Financial Literacy: Assessing knowledge in Debt, Investment, and Retirement Savings. *American Academy of Orthopaedic Surgeons Annual Meeting,* San Diego, CA, March 2017.

Lu M, Sing D, Kuo A, Hansen E. Preoperative Anemia Independently Predicts 30-Day Complications After Aseptic and Septic Revision Total Joint Arthroplasty. *American Association of Hip and Knee Surgeons Annual Meeting,* Dallas, TX, November 2016.

Shaw J, Miller S, Plourde A, Gray C, Lu M, Shaw D, Hansen E. Intraoperative Methylene Blue Staining Allows for Visualization of Microbial Biofilm-Associated Tissue in Periprosthetic Joint Infection. *American Association of Hip and Knee Surgeons Annual Meeting,* Dallas, TX, November 2016.

DeHaan A, Lu M, Hansen E, Ries M. Proximalization of the Tibial Tubercle Osteotomy: A Solution for Patella Infera During Revision Total Knee Arthroplasty. *American Association of Hip and Knee Surgeons Annual Meeting,* Dallas, TX, November 2016.

Harper K, Eccles J, Quinn C, Ramsey F, Rehman S. Administration of IV Antibiotics in Patients with Open Fractures Is Dependent on Emergency Room Triaging. *OTA Annual Meeting,* National Harbor, MD, October 2016.

Amer KM, Rehman S, Haydel C. Quantitative Analysis of the Efficacy and Safety of Tranexamic Acid in Orthopaedic Fracture Surgery. *Pennsylvania Orthopaedic Society Fall Meeting,* Pittsburgh, PA, October 2016.

Greenhill D, Smith W, Ramsey F, Kozin S, Zlotolow D. Conjoined Versus Isolated Shoulder Tendon Transfers in Brachial Plexus Birth Palsy. *American Society for Surgery of the Hand Annual Meeting,* Austin, TX, September 2016.

Lachman J, Eremus J, Haydel C. Intra-Osseous Arthrodesis Techniques in the Foot and Ankle: Does It Really Hurt Less? *AOFAS Annual Meeting,* Toronto, Canada, July 2016.

Li S, Ali S, Harper K, Liang Q, Serratore D. Characteristics of In-Vivo MOSFET Dosimeters for Diagnostic X-Ray Low-Dose Measurement. *American Association of Physicists in Medicine (AAPM) Annual Meeting,* Washington, DC, July 2016.

Iorio J, Harper K, Quinn C, Rehman S. Percutaneous Sacroiliac Screw Fixation of the Posterior Pelvic Ring. *Pennsylvania Orthopaedic Society Spring Meeting,* Boca Raton, FL, April 2016.

Harper K, Eccles J, Quinn C, Ramsey F, Rehman S. Administration of IV Antibiotics in Patients with Open Fractures Is Dependent on Emergency Room Triaging. *Pennsylvania Orthopaedic Society Spring Meeting,* Boca Raton, FL, April 2016.

Reilly M, Greenhill D, Kripke L, Ramsey F, Haydel C. Outcomes After Suprapatellar Versus Infrapatellar Tibial Intramedullary Nailing. *Pennsylvania Orthopaedic Society Spring Meeting,* Boca Raton, FL, April 2016.

Greenhill D, Poorman M, Pinkowski C, Ramsey F, Haydel C. Does Weight Bearing Assignment After Intramedullary Nail Placement Alter Healing of Tibial Shaft Fractures? *Pennsylvania Orthopaedic Society Spring Meeting,* Boca Raton, FL, April 2016.

Greenhill D, Lukavsky R, Tomlinson-Hansen S, Kozin S, Zlotolow D. Relationships Between Three Classification Systems in Brachial Plexus Birth Palsy. *POSNA Annual Meeting,* Indianapolis, IN, April 2016.

Harper K, Quinn C, Iorio J, Rehman S. Percutaneous Sacroiliac Screw Fixation of the Posterior Pelvic Ring. *Pennsylvania Orthopaedic Society Spring Meeting,* Boca Raton, FL, April 2016.

Harper K, Rehman S. Orthopaedic Disaster Management in the 2015 Amtrak Derailment. *Pennsylvania Orthopaedic Society Spring Meeting,* Boca Raton, FL, April 2016.

Eccles J, Harper K, Quinn C, Ramsey F, Rehman S. Factors Affecting Timing of IV Antibiotic Administration for Patients with Open Fractures. *Pennsylvania Orthopaedic Society Spring Meeting,* Boca Raton, FL, April 2016.

Trionfo A, Makowski AL, Latta L, Ouelette EA. Characterizing Ulnocarpal Instability in the General Population. *Orthopaedic Research Society Annual Meeting,* Orlando, FL, March 2016.

Fink Barnes LA, Luchetti TJ, Buza J, Jobin CM, Ahmad CS. Athletes with Shoulder Instability: A Prospective Study of Player Attitudes on Operative vs Non-operative Treatment. *American Academy of Orthopaedic Surgeons Annual Meeting,* Orlando, FL, March 2016.

Jennings JD, Haydel C, Rehman S. Management of Adult Elbow Fracture Dislocations. *American Academy of Orthopaedic Surgeons Annual Meeting,* Orlando, FL, March 2016.

Jennings JJ. Ulnar Nerve Compression Isolated to the Motor Branch: A Case Series of Three Unique Etiologies. *American Association for Hand Surgery,* Scottsdale, AZ, January 2016.

Publications in Peer-Reviewed Journals

Harper K, Rehman S. Orthopaedic disaster management in the 2015 Amtrak derailment. *Journal of Trauma & Acute Care Surgery,* June 2016;80(6): 1032–38.

Li S, Ali S, Harper K, Liang Q, Serratore D. Characteristics of In-Vivo MOSFET Dosimeters for Diagnostic X-Ray Low-Dose Measurements. *Med. Phys.* 2016;43:3667.

Gaspar MP, Abdelfattah HM, Welch IW, Vosbikian MM, Kane PM, Rekant MS. Recurrent cubital tunnel syndrome treated with revision neurolysis and amniotic membrane nerve wrapping. *J Shoulder Elbow Surg.* 2016 Dec;25(12):2057–2065. PMID:27751716.

Gaspar MP, Kho JY, Kane PM, Abdelfattah HM, Culp RW. Orthogonal Plating with Corrective Osteotomy for Treatment of Distal Radius Fracture Malunion. *Jour Hand Surg Am.* 2017;42(1):e1–e10. PMID: 27751716.

Ames RJ, Samdani AF, Betz RR. Anterior scoliosis correction in immature patients with Idiopathic scoliosis. *Operative Techniques in Orthopaedics: Early Onset Scoliosis* (in press).

Samdani AF, Bastrom TP, Ames RJ, Miyanji F, Pahys JM, Marks MC, Lonner BS, Newton PO, Shufflebarger HL, Yaszay B, Flynn JM, Betz RR, Cahill PJ. Factors affecting the outcome in appearance of AIS surgery in terms of the minimal clinically important difference. Bennett JT, *Eur Spine J.* 2016 Dec 9. [Epub ahead of print]

Samdani AF, Bennett JT, Ames RJ, Asghar JK, Orlando G, Pahys JM, Yaszay B, Miyanji F, Lonner BS, Lehman RA Jr, Newton PO, Cahill PJ, Betz RR. Reversible Intraoperative Neurophysiologic Monitoring Alerts in Patients Undergoing Arthrodesis for Adolescent Idiopathic Scoliosis: What Are the Outcomes of Surgery? *J Bone Joint Surg Am.* 2016 Sep 7;98(17):1478–83.

Sisko Z, Lu M, Ghate R, Bashyal R, Srinivasan A, Puri L. The 72-hour Medicare Mandate After Total Joint Arthroplasty: Is this Medically Necessary? *Jour Arthroplasty.* 2016;31(5):947–951.

Lu M, Hansen E. Hydrogen Peroxide Wound Irrigation in Orthopaedic Surgery. *Journal of Bone and Joint Infection.* 2017;2(1):3–9.

Jennings JD, Ilyas AM. Septic Arthritis of the Wrist. *Journal of the American Academy of Orthopaedic Surgeons* (in press).

Jennings JD, Ciaravino SG, Ramsey FV, Haydel C. Physicians' Attire Influences Patients' Perceptions in the Urban Outpatient Orthopaedic Surgery Setting. *Clin Orthop Relat Res.* 2016;474:1908–1918.

Jennings JD, Hahn A, Rehman S, Haydel C: Management of Adult Elbow Fracture Dislocations. *Orthop Clin North Am.* 2016;47:97–113.

Solarz MK, Kistler JM, Rehman S. Obturator artery injury resulting in massive hemorrhage from a low energy pubic ramus fracture. *Orthopedics.* 2017 Jan;5:1–3.

Greenhill D, Abbasi P, Darvish K, Star A. Broach Handle Design Changes Force Distribution in the Femur During Total Hip. *Journal of Arthroplasty* (in press).

Jennings J, Greenhill D, Zlotolow D. Triplanar Humeral Osteotomy for Restoration of Midline Function in Patients with Brachial Plexus Birth Palsy. *Techniques in Hand & Upper Extremity Surgery* (in press).

Greenhill D, Poorman M, Pinkowski C, Ramsey F, Haydel C. Does Weight Bearing Assignment After Intramedullary Nail Placement Alter Healing of Tibial Shaft Fractures? *Orthopaedics & Traumatology: Surgery & Research* (in press).

Greenhill D, Comstock D, Torg J, Navo P, Zhao H, Boden B. Inadequate Helmet Fit Increases Concussion Severity in American High School Football Players. *Sports Health.* 2016 May;8(3):238–43.

Greenhill D, Wissinger K, Trionfo A, Solarz M, Kozin S, Zlotolow D. External Rotation Predicts Outcomes after Glenohumeral Joint Reduction with Botulinum Toxin Type A in Brachial Plexus Birth Palsy. *J Pediatr Orthop.* 2016 Feb 15 [Epub ahead of print].

Greenhill D, Haydel C, Rehman S. Management of the Morel-Lavallée Lesion. *Orthop Clin North Am.* 2016 Jan;47(1):115–25.

Jennings JD, Hahn A, Rehman S, Haydel C. Management of Adult Elbow Fracture dislocations. *Orthop Clin North Am.* 2016 Jan;47(1):97–113.

Greenhill D, Haydel C, Rehman S. Management of the Morel-Lavallee lesion. *Orthop Clin North Am.* 2016 Jan;47(1):115–25.

Rehman S. Going out with a bang. *Orthop Clin North Am.* Jan 2016; 47(1):xxi.

Solarz MK, Thoder JJ, Rehman S. Management of major traumatic upper extremity amputations. *Orthop Clin North Am.* Jan 2016;47(1):127–3.

Harper K, Rehman S. Orthopaedic disaster management in the 2015 Amtrak derailment. *J Trauma Acute Care Surg.* 2016 Jun;80(6):1032–8.

Gangavalli A, Malige A, Terre G, Rehman S, Nwachuku C. Opioid misuse in orthopaedic post-operative patients. *J Orthop Trauma.* 2016 Oct;26 [Epub ahead of print].

Lachman J, Eremus J, Haydel C. Intra-Osseous Arthrodesis Techniques in the Foot and Ankle; Does it Really Hurt Less? *Foot and Ankle Orthopaedics* [E-pub ahead of print].

Ibrahim, SA, Blum M, Lee GC, Mooar P, et al. Effect of a Decision Aid on Access to Total Knee Replacement for Black Patients with Osteoarthritis of the Knee: A Randomized Clinical Trial. *JAMA Surg.* 2017;152(1): e164225.

DePalma MJ, Slipman CW, Wetzel FT. The Mechanism of Action of Non-endoscopic Percutaneous Disc Decompression Treatment of Discogenic Lumbosacral Radiculopathy. *The Spine Journal* (in press).

DePalma MJ, Slipman CW, Wetzel FT. The Efficacy and Safety of Non-endoscopic Percutaneous Disc Decompression Treatment of Discogenic Lumbosacral Radiculopathy. *The Spine Journal* (in press).

Kang Q, Sun MH, Cheng H, Peng Y, Montag AG, Deyrup AT, Jiang W, An N, Luu H, Szatkowski JP, Vanichakarn P, Park JY, Gupta P, Wetzel FT, Haydon RC, He TC. Distinct Bone Forming Activity of the Bone Morphogenetic Proteins. *Journal of Biological Chemistry* (in press).

Jennings JD, Solarz MK, Haydel C. Application of Tranexamic Acid to Trauma and Orthopaedic Surgery. *Orthop Clin North Am.* 2016 Jan; 47(1):127–136. PMID: 26614928.

Solarz MK, Thoder JJ, Rehman S. Management of Traumatic Upper Extremity Amputations. *Orthop Clin North Am.* 2016 Jan;47(1):137–143. PMID: 26614927.

Trionfo A, Thoder JJ, Tosti R. The effects of preoperative antibiotics on culture growth in hand abscesses. *Hand.* 2016 Jun;11(2):216–20.

Samdani AF, Belin E, Bennett JT, Miyanji F, Pahys J, Shah SA, Newton PO, Betz RR, Cahill PJ, Sponseller PD. Major Perioperative Complications after Surgery for Cerebral Palsy: Assessment of Risk Factors. *Eur Spine J.* 2016 Mar;25(3):795–800.

Textbook Chapters

Ames RJ, Samdani AF. 50 Essential Articles Every Spine Surgeon Should Know: Effects of Bracing Adolescents with Idiopathic Scolisos (NEJM 2013). Vaccaro et al. In press.

Fink Barnes LA, Parsons BO, Flatow EL. Glenohumeral Instability. Rockwood and Matsen: *The Shoulder,* 5th Edition, 2016.

Fink Barnes LA, Flatow EL. Arthroscopic Repair of Massive Rotator Cuff Tears: Anatomic Considerations, Releases, and Mobilization Techniques. *AAOS Advanced Reconstruction: Shoulder 2, Arthroscopy, Arthroplasty, and Fracture Management,* 2016.

Fink Barnes LA, Jim C. Hsu, Leesa M. Galatz. Mini-Incision Fixation of Proximal Humeral Four-Part Fractures. In *Minimally Invasive Surgery in Orthopedics* (pp 1–10)*,* 2016.

Fink Barnes LA, Parsons BO, Flatow EL. Mini-Incision Bankart Repair. In *Minimally Invasive Surgery in Orthopedics,* 2016.

Donovan D, Fink Barnes LA, Parsons BO, Hausman MR. Minimally Invasive Approaches for Lateral Epicondylitis. In *Minimally Invasive Surgery in Orthopedics,* 2016.

Fink Barnes LA, Flatow EL. Overview of Shoulder Approaches. In *Minimally Invasive Surgery in Orthopedics,* 2016.

Lachman J, Rehman S. Tibial plateau Schatzker V/VI treated in ex fix/circular frame. In Tejwani NC ed.: *Fractures of the Tibia, A Clinical Companion.* Springer, 2016.

Lachman JR, Rehman S. Chapter 3 — Bone Healing. In Hoppenfeld S, Murthy VL: *Treatment and Rehabilitation of Fractures.* 2nd Edition. Lippincott and Williams, 2016.

Joseph J. Thoder
Orthopaedic Excellence Award

"In recognition of Dr. Thoder's steadfast dedication to the Temple Orthopaedic Surgery Residency. Through his mentorship, we pursue academic and clinical excellence, while learning the importance of heritage, teamwork, and family. This award, presented by the chief residents, honors the orthopaedic resident who best exemplifies the standards of scholarly achievement and personal excellence set forth by Dr. Thoder."

Given as a graduation gift by the class of 2010, Drs. Abi Foroohar, Allan Tham, Ifran Ahmed, and John Parron fund a yearly award given to the resident that demonstrates qualities commensurate with Dr. Thoder's vision of a Temple Orthopaedic Surgeon. Selected from the graduating chief resident class, the recipient is presented with a cash prize and a plaque.

This year, **Courtney Quinn** (Class of 2019) was selected by Rupam Das, Kasey Komperda, Colin Mansfield, and Mark Solarz (Class of 2016).

Previous Winners:
2015 — Katharine Harper, MD
2014 — Arianna Trionfo, MD
2013 — Rupam Das, MD
2012 — Matthew Kleiner, MD
2011 — Richard Han, MD
2010 — John Fowler, MD

Courtney Quinn, MD

Snapshots from 2016–2017

It doesn't actually require six hands to do hand surgery.

Marianne kickin' it with Temple Legends.

"Simply reduce this fragment and then fill this void and then put a plate here and then some screws in here and you're done."

Last case during a long trauma OR day . . .

No shortage of presenters at the Eastern Orthopaedic Association annual meeting. L-R: John Jennings (PGY4), Dustin Greenhill (PGY5), Meghan Reilly (PGY3)

Temple representation at the 2016 AOA Meeting. L-R: Saqib Rehman, Milo Sewards, Christopher Haydel, Arianna Trionfo (PGY-5), Jim Lachman (PGY-5)

Snapshots from 2016–2017

Someone should tell Dayna Phillips (PGY2) that this isn't a real person.

Dr. Moyer confirming the stability of PGY1 Jack Reynold's knee after miles of hospital speed-walking and noncontact agility maneuvers through the ER during his intern rotation.

Justin lost the battle with the puddle while Dr. Haydel heckled.

The trauma clinic no-show rate on Halloween was perplexing and without reason.

Snapshots from 2016–2017


Residents supporting Mark Solarz at the 2016 POS Resident Bowl!


Tactical surgery in OR 5 on Veteran's Day.


Teaching rounds


Believe it or not, Will Smith (PGY4) and John Jennings (PGY4) really did attend the EOA conference.


"Don't worry guys, I'm totally on top of these vent settings."


Greenhill breakfast of champions

Snapshots from 2016–2017

Congratulations to Gary and Arianna (Trionfo) Lamsback on the birth of their daughter Audrey Jennifer on 11/9/16!

Congratulations to Steve and Anastassia Newbury on the birth of their daughter Charlie Nina on 4/5/16!

Nimid Lad (PGY1) putting in his first pedicle screw ever . . . and breaching the medial wall.

Residents looking dapper in their Grand Rounds attire. And Dr. Sewards housing a sandwich.

Snapshots from 2016–2017

Cameron Haydel was the anchor for the Battlefrog team — not even winded!

Jack Reynolds (PGY1) shirtless. Again.

Snapshots from 2016–2017

Dr. Freddie Fu Grand Rounds

Instructions to Authors

Editorial Philosophy

The purpose of the *Temple University Journal of Orthopaedic Surgery & Sports Medicine (TUJOSM)* is to publish clinical and basic science research performed by all departments of Temple University that relate to orthopaedic surgery and sports medicine. As such, *TUJOSM* will consider for publication any original clinical or basic science research, review article, case report, and technical or clinical tips. All clinical studies, including retrospective reviews, require IRB approval.

Editorial Review Process

All submissions will be sent to select members of our peer review board for formal review.

Manuscript Requirements

Manuscripts are not to exceed 15 double spaced type-written pages and/or 5,000 words (minus figures/tables/pictures). The manuscript should contain the following elements: Title page, Abstract, Body, References, and Tables/Legends. Pages should be numbered consecutively starting from the title page.

(1) Title Page — The first page, should contain the article's title, authors and degrees, institutional affiliations, conflict of interest statement, and contact information of the corresponding author (name, address, fax, and email address).

(2) Abstract — The second page, should be a one-paragraph abstract less than 200 words concisely stating the objective, methods, results, and conclusion of the article.

(3) Body — Should be divided into, if applicable, Introduction, Materials & Methods, Results, Discussion, and Acknowledgements. Tables and figures (in JPEG format) with their headings/captions should be listed consecutively on separate pages at the end of the body, not continuous within the text.

(4) References — Should be listed following the format utilized by *JBJS.* For example: Smith, JH, Doe, JD. Fixation of unstable intertrochanteric femur fractures. *J Bone Joint Surg Am.* 2002;84:3553–58.

Submissions

All submissions are now digital. Please submit the manuscript in a Microsoft Word document to templejournal@gmail.com.

Disclaimer: **This journal contains manuscripts that are considered interpersonal communications and extended abstracts and not formalized papers unless otherwise noted.**

TEMPLE ORTHOPAEDICS & SPORTS MEDICINE CONVENIENTLY LOCATED IN 6 LOCATIONS.

Temple Orthopaedics & Sports Medicine is one of the region's premier programs for the treatment of musculoskeletal disorders.

With six offices located in Philadelphia, Pennsylvania, and its suburbs, Temple's board certified Orthopeadic specialsts are now closer to your patients. For your added convenience, radiology services are available at all our locations.

Each site offers some of the most respected orthopaedic surgeons and rehabilitation specialists in the region, all using the most advanced treatments and orthopaedic surgery techniques. From seniors coping with hip or knee paint to weekend warriors with bad strains to athletes suffering for sports injuries, your patients will receive state-of-the-art care without having to travel far.

Temple University Hospital
3401 N. Broad Street
5th Floor, Boyer Pavilion
Philadelphia, PA 19140
215-707-2111

Temple Health Ft. Washington
515 Pennsylvania Avenue
Fort Washington PA, 19034
215-641-0701

Temple Orthopaedics & Sports Medicine at Roosevelt Boulevard
11000 Roosevelt Boulevard
Philadelphia, PA 19116
215-698-5400

Temple Health Oaks
450 Cresson Boulevard
Suite 200
Oaks, PA 19456
610-630-2222

Temple Orthopaedics & Sports Medicine at Chestnut Hill Hospital
Medical Office Building
8815 Germantown Pike, Suite 14
Philadelphia, PA 19118
215-248-9400
215-248-9403

Temple Orthopaedics & Sports Medicine at The Navy Yard
Vincera Institute
1200 Consitution Avenue
Suite 110
Philadelphia, PA 19112
267-592-3200

Orthopaedics & Sports Medicine
TEMPLE HEALTH

ortho.templehealth.org

Department of Orthopaedic Surgery
Temple University School of Medicine
3401 N. Broad Street
Philadelphia, PA 19140

PRESORTED
BOUND PRINTED MATTER
U.S. POSTAGE PAID
PHILADELPHIA, PA
PERMIT NO. 1044