Temple University Journal of Orthopaedic Surgery & Sports Medicine

Joseph Eremus, MD

Volume 13 Spring 2018

A John Lachman Society Publication

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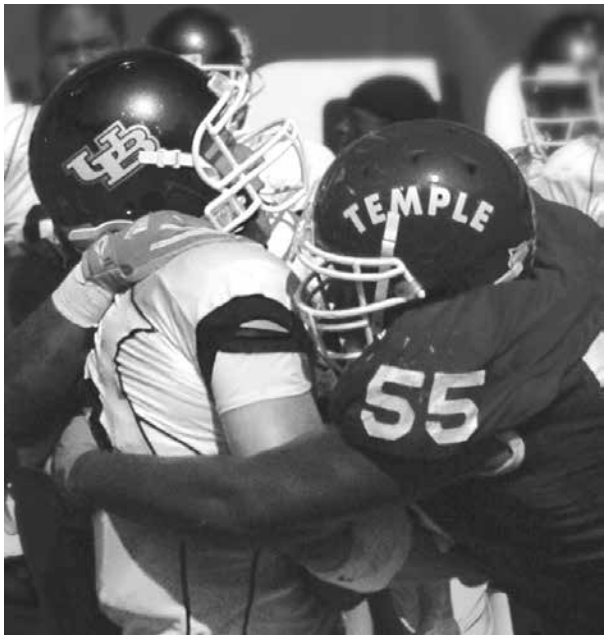
The Temple University Concussion and Athletic Neurotrauma Program

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:

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

Temple University Hospital

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Temple Orthopaedics & Sports Medicine

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All articles published in this journal are communications of current research taking place at Temple University and are therefore considered extended abstracts. As abstracts, they are not the property of the *Temple University Journal of Orthopaedic Surgery & Sports Medicine.*

Letter from the Chairman

2017–18 was another great year for Temple Orthopaedics and Sports Medicine. As always, it is with great pride that I introduce this year's *Journal* which highlights the accomplishments of our residents, students and faculty. I hope that you enjoy this year's edition and are academically stimulated by the work being performed within our department.

This year, we dedicate the *Journal* to the memory of Dr. Joseph Eremus, a very fitting honor. His passion for and dedication to Temple Orthopaedics was unparalleled. Joe came back to Temple shortly after I was hired. I was very fortunate to have had the opportunity to bend his ear for early career and life advice. I was also fortunate to sit and talk with him to hear his thoughts about Temple prior to his passing. His eyes lit up when he spoke of Temple Orthopaedics. He truly loved the work he was doing and the interactions he had with patients, students, residents and faculty. He referred to Temple Ortho as his "dream job" and was forever grateful to have had the opportunity to spend the end of his career here. Joe had seemingly endless energy. He touched countless lives and inspired us all during his time at Temple. I trust that the continued excellence of our program would bring him great pride.

Last year, in the "Chair's Corner," I reflected on the changes around us, both external pressures and internal restructuring within the department. In 2018, the landscape of orthopaedic care continues to evolve and, as always, Temple stands true to our mission — to provide the highest level of care to all patients regardless of situation or circumstance. In November, we held our first-ever department-wide orthopaedic retreat. Appropriately, this was held on the eve of Thanksgiving. At the same time when we all reflect on what it is for which we are grateful, we also revisited what it is that Temple Orthopaedics and Sports Medicine is all about. The passion and commitment to our patients and our mission was apparent in faculty, staff and residents alike. Personally, I left that meeting invigorated and excited for the work and challenges that lie ahead for us.

The rapid growth I discussed last year has slowed to a steady state. The Department of Orthopaedic Surgery and Sports Medicine is currently comprised of 21 providers (14 surgeons, five non-surgical providers, and two physician assistants) representing all specialties. We continue to provide academic specialist care at Temple Hospital, Northeast Philadelphia, Fort Washington, the Navy Yard and Chestnut Hill Hospital. Our recently recruited physicians are expanding rapidly making each of these locations busier than ever. With two more surgeons set to join our team in 2018, we will now have multiple and diverse physicians in every specialty area. The added value to our patients but also to resident education is apparent every day.

A few notable events and changes occurred this past year. Sadly, F. Todd Wetzel, MD has moved on to become the Chair of Orthopaedics at Bassett Health in Cooperstown, NY. His commitment to resident education, faculty development and ethical and compassionate patient care will be missed. Dr. Saqib Rehman was promoted to Vice Chair of Orthopaedic Surgery. Saqib's dedication to our department and the high standards he sets in terms of patient care and education made him the logical successor to Dr. Wetzel. Dr. J. Milo Sewards was honored this fall at the Temple/Navy football game for his commitment to the US Navy and Temple athletics. Our department and the friends of the Sewards family had an excellent showing at our first official Temple Orthopaedics tailgate. Sadly, just days later, Milo was deployed to active military service. We thank him for his service and wish him a safe and rapid return. Dr. Eric Gokcen brings a wealth of international orthopaedic experience. He quickly established an international elective opportunity travelling to Kenya with Meghan Reilly (PGY4) this past year. Plans are underway to return on a regular basis with a PGY4 resident and select attending staff.

Through the efforts of the Temple Orthopaedic alumni association, Dr. Joseph J. Thoder was honored with a portrait ceremony and the establishment of an annual upper extremity lecture series. It was a packed house for the portrait ceremony. The outpouring of friends, family and colleagues was impressive, but most amazing was seeing all the past residents who have been inspired and mentored by Dr. Thoder through the years. Dr. John Fowler was honored as the inaugural Joseph J. Thoder, MD lecturer expanding on his use of ultrasound in upper extremity compressive neuropathies. It was great to see John excelling at UPMC and continuing work that began when he was a resident here at Temple.

As our department grows, the excitement around orthopaedics is palpable at Temple. This year, we saw the largest group of students entering the orthopaedic match that I have seen in the past 10 years. We trust that they will shine and represent us well in their future endeavors.

As always, this *Journal* could not be made possible without the efforts of many. Justin Kistler (PGY4) has admirably filled the role as editor of the *Journal.* Drs. Joe Torg and Saqib Rehman continue to be the driving force behind much of this work. We must also acknowledge the tireless efforts of Joanne Donnelly, Justin Ly and the Office of Clinical Research.

It is with great pride that we present the academic accomplishments of our department faculty, residents and students. 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 13! Temple has a great tradition of excellent research efforts by our medical students, residents, and faculty. This year's *Journal* represents the continued tireless efforts of our department.

The Department of Orthopaedic Surgery and Sports Medicine 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 recent work from Asif Ilyas, MD who has a strong research interest in the ongoing opioid epidemic. Our Special Events section gives our readers a basic overview of the major events that have taken place this year. We have again included Division Reports to highlight some of the significant changes and accomplishments of our department's subspecialties.

This year's *Journal* has been dedicated to our beloved Joe Eremus, MD. Dr. Eremus embodied the essence of Temple Orthopaedics with a focus on resident education, the highest-quality patient care, and a love of life that was unmatched. As a member of one of the residency classes that had the great privilege of interacting with Dr. Eremus on a day-to-day basis, I can say that we miss him dearly but his presence has left a lasting impression on our department that we will forever cherish.

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

Justin Kistler, MD
Editor-in-Chief
Class of 2019

Residency Program Update

Our program director, Dr. J. Milo Sewards, is commissioned as Commander in the United States Navy and was called to duty to provide compassionate and patient-centered care overseas. In his absence, I have been called to duty to act as program director. With great honor and deference, I have the privilege to lead and serve a dedicated group of individuals that comprise a successful and highly coveted residency program.

The program is steadily growing and evolving. We have added new faculty members who further diversify our clinical and educational complement. Online educational tools and focused, interactive discussion sessions are replacing didactic lectures, reinforcing the principles of self-directed learning. With the addition of a complete surgical skills curriculum, our residents can participate in psychomotor training and master hand-eye coordination in a low-stress environment.

As this academic year comes to a close, there is a new beginning awaiting our four graduates. James Bennett has roots in Vermont, but will be heading to the Children's Hospital of Los Angeles to do a pediatric orthopaedic surgery fellowship with an emphasis in spine. Katharine Harper is from London, Ontario and will be heading to a warmer climate to do her fellowship at Houston Methodist in adult joint reconstruction surgery. John Jennings and William Smith both have local ties and will be doing hand and upper extremity fellowships. John is from Allentown and will be at the Rothman Institute here in Philadelphia. Will is from Havertown and is headed to the University of Pittsburgh Medical Center.

I am very proud of what we have achieved here at Temple and I am excited about our future endeavors. Throughout this *Journal,* you will see proof of our dedication to delivering excellent patient care, providing top-tier resident education, and producing clinical and basic science research that is worthy of publication.

Christopher Haydel, MD

Greetings from Overseas

Being away from the residency program has been difficult for many reasons. However, watching the evolution of teaching and the development of the residents from afar has its own rewards. Often, as we are involved in the day-to-day details of teaching and running various services, we miss the bigger picture of postgraduate medical education. I have had the privilege of being the observer as our surgical skills program has expanded and the individual services have developed journal clubs and didactic sessions. As Dr. Haydel has pointed out, the efforts put forth by our residents and their resulting achievements are a particular point of pride and enthusiasm.

On a personal note, going through the training necessary for a deployment to an active combat zone, then serving in that environment has taught me a number of lessons that I intend to bring back to the program and to our patients. Having been trained at Temple myself, I have a tremendous appreciation for what abilities that training grants, especially when faced with the limitations associated with orthopaedic care in an austere environment. Stanley McChrystal, a former commander of Special Operations in Iraq, wrote in "Team of Teams" about the critical need for adaptability and resilience in any complex environment, and he drives home his point by discussing a surgeon's response to trauma. While we focus on excellence in patient care, we can and should be thankful for Temple's contribution in resilience training.

I give my best to our departing chief residents, with my regrets that I am not there to personally see them off as they continue their respective journeys. I look forward to our paths crossing again in the future. I eagerly anticipate my return to Temple and our department. The residency program is certainly an improved version of what I left.

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 to promote and support the academic mission of the Department, primarily 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 (C3) of the Internal Revenue Code 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 and research 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 are not currently contributing to medical student and/or resident research projects or educational programs.

The second group consists of the Temple-Shriners' Alumni and the Thoder Portrait and lecture activity. It is my understanding that the Temple-Shriners' Alumni group is no longer actively soliciting funds for their activities, which primarily has involved social events. To be noted, however, they have supported senior residents taking the board review course. With the regard to the Thoder Portrait fund, this was initiated by the medical school.

It is the John Lachman Orthopaedic Research Fund of the John Lachman Society that, as already mentioned, 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 money at annual residents' research day presentations
5) Funds the *Temple University Journal of Orthopaedic Surgery & Sports Medicine*
6) Funds the accredited 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 Shriner's paper

At the annual meeting of the board of directors of the John Lachman Orthopaedic Research Fund, the following officers were re-elected for a one-year term: President: Dave Junkin, MD; Vice President: Eric Lebby, MD; Treasurer: Saqib Rehman, MD; Secretary: Joe Thoder, MD.

The summer medical student research program continues to be a most successful program. This past summer, eight sophomore medical students participated in the program. In addition to a number of the students producing manuscripts suitable for publication in the *Journal,* it is evident that a major value of this program is that those students have an opportunity to interface with the department in view of the

curriculum changes that no longer require students to rotate through orthopaedics. Clearly, this has become a major avenue of acquainting students to the residency program.

In view of the success of the Temple Orthopaedic Summer Research Program, this course has been approved by the curriculum committee and the dean as an elective in the first-year medical student curriculum to teach the students how to conduct a clinical research project based on the model we have developed in our department. The course will cover all aspects of clinical research. Topics that will be covered include: how to develop the research questions, literature review, including a primer on the use of PubMed or OVID or other search engines, use and disclosure of public health information, role of the IRB and responsibilities to protect the data, IRB submission guidelines, and mandatory ethics certification. Clearly, Temple Orthopaedics functions as a trendsetter in medical student education!

Once again, the John Lachman Society published and distributed the *Temple University Journal of Orthopaedic Surgery & Sports Medicine,* Volume 12. Eighteen hundred copies of the *Journal* have been distributed as follows: a) active faculty of the Temple University School of Medicine, b) orthopaedic surgeons who are alumni of Temple University School of Medicine, c) members of the John Lachman Society, d) department chairman and residency directors of all orthopaedic programs throughout the United States, and e) fellowship directors to all orthopaedic programs throughout the United States. Academic support for resident travel to meetings by the John Lachman Orthopaedic Research Fund during January 1, 2017 through December 21, 2017 involved 15 residents who have attended either formal courses or national meetings. The John Lachman Society web page can be entered at www.johnlachmansociety.org. The John Lachman Orthopaedic Research Fund is committed to $2,500-year expenditure for texts and other educational materials for resident teaching.

JOHN LACHMAN SOCIETY MEMBERSHIP — JANUARY 1, 2018

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(Continued on next page)

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*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. Moor, MD and Joseph S. Torg, MD and supported by the School of Medicine's Office of Clinical Research Administration, with Joanne Donnelly as the full-time research and program coordinator. We are also welcoming Bridget Slattery, a new full-time research coordinator who will be assisting the program and will be heading up two new trials later this year.

The program is now in its 14th year and continues to fulfill the vision of providing the Department of Orthopaedic Surgery 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 John Lachman Orthopaedic Research Fund. The summer research program will host 20 Temple medical students in 2018. 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, Ovid, and other search engines as well as RefWorks for managing citations. Gabrielle Ribblard, 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)

Principal Investigator: Saqib Rehman, MD, MBA; Sub-Investigator: Christopher Haydel, MD, ABOS

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

Principal Investigator: J. Milo Sewards, MD; Sub-Investigator: Pekka A. Mooar, MD; Sub-Investigator: Eric J. Kropf, MD

Open to enrollment — 10 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

Principal Investigator: Saqib Rehman, MD, MBA; Sub-Investigator: Christopher Haydel, MD, ABOS

Open to enrollment — 4 subjects enrolled

REGAIN
Regional vs General Anesthesia for Promoting Independence After Hip Fracture Surgery (Large Multi-Center Study)

Principal Investigator: Meera Gonzalez, MD, Anesthesia; Sub-Investigator: Christopher Haydel, MD, Orthopaedics

Open to enrollment — 23 subjects enrolled

Potential Industry-Sponsored Clinical Trials Drug or Device

Novartis
A Randomized, Placebo-Controlled, Patient and Investigator Blinded, Proof of Concept Study Investigating the Safety, Tolerability, and Preliminary Efficacy of Multiple Intra-Articular LNA043 Injections in Regenerating the Articular Cartilage of the Knee in Patients with Articular Cartilage Lesions

This phase 2 study will assess the efficacy, safety, and tolerability of multiple intra-articular (I.A.) injections of LNA043 over four weeks, in regenerating the articular surface in patients with cartilage lesions of the knee.

Principal Investigator: Pekka A. Mooar, MD; Sub-Investigator: Eric J. Kropf, MD;
Sub-Investigator: J. Milo Sewards, MD; Sub-Investigator: Min Lu, MD;
Sub-Investigator: Matthew Lorei, MD; Sub-Investigator: Michelle Noreski, DO;
Sub-Investigator: Corey Keller, DO; Sub-Investigator: Ryan Schreiter, DO

OrthoFix
A Prospective, Post-Market, Multi-Center, Open Label, Non-Randomized Clinical Study of the Efficacy Using Trinity ELITE® in Lumbar Fusion Surgery

This phase 4 study is a prospective, post-market, non-randomized open label clinical study with the primary objective of this clinical study is to measure the lumbar fusion rate in subjects at 24 months when lumbar arthrodesis is performed using Trinity ELITE®.

Principal Investigator: Zeeshan Sardar, MD, CM, FRCSC, MSc, B.Eng

Carmell Therapeutics
Phase 3 Bone Healing Accelerant Study for Treating Open Tibia Fractures

A phase 3 study that will evaluate the safety and efficacy of a bone healing accelerant in the treatment of open Gustilo-Anderson Grade IIIa/IIIb tibia-shaft fractures in subjects having their tibia fractures stabilized with intramedullary (IM) rodding.

Principal Investigator: Saqib Rehman, MD, MBA

Joanne M. Donnelly

Dedication

Joseph Eremus

Bruce Vanett, MD

Walt Whitman wrote, "Keep your face always toward the sunshine — and the shadows will fall behind you." That eternal optimism and upbeat attitude certainly describes the life of Joe Eremus. Even throughout the course of his illness, he was resolute in pushing forward with courage and grace. Joe's main focus always remained his family, his patients, his colleagues and his devoted residents. His character was forged in the small town of his birth, Boiling Springs, in rural central Pennsylvania. The values of honesty, integrity, and hard work were instilled in him by his parents. He was an avid student, a born leader, and was class president every year of high school. A superb wrestler, Joe was the first student from his small school to ever win a PIAA State High School Wrestling Championship in 1962. He also was a standout collegiate wrestler at Penn State. He went on to receive many academic honors at Penn State and was accepted to Penn Veterinary School after graduation. He found out that this was not his true calling, so he changed his career path midstream and decided to go to medical school. Before matriculating at Temple Med, fate stepped in. He found a job as a substitute physical education teacher at Marple Newtown High School in Broomall, PA. This was the best move of his life as he met Margo Perry, a beautiful, petite Spanish and English teacher there, and it was love at first sight. He married Margo in 1969 after his first year at Temple Med, and he continued that wonderful partnership for 48 years. He met Joe Torg along the way, who strongly encouraged him to go into Orthopedics, and the rest is history. He did his internship at Tulane Hospital in New Orleans and returned to Temple to train under the tutelage of the legendary Dr. John Lachman. After graduation, he went to Korea as a Major in the U.S. Army to fulfill his military commitment; he finished his tour at Fort Dix, New Jersey. He then joined Temple alumnus, Jim Kohl, in an orthopedic practice at Bryn Mawr Hospital where he stayed for 33 years. He had a keen interest in foot and ankle and garnered expertise in this particular field, one of the first orthopedists in the area to pursue this subspecialty because of its challenges and complexity. He later joined Dr. Hal Snedden and his group and continued in private practice. Always looking for new challenges, Joe contacted Joe Thoder to ask him if he was looking for a foot and ankle surgeon who was also interested in teaching. Dr. Thoder immediately said, "Of course — do you know someone?" In typical Joe Eremus fashion, his response was "yes, and it's me!!" With that being said, the deal was done. Joe enthusiastically returned to his beloved Temple, the "Mother Ship," in 2009 and joined Temple Orthopedics. As his wife recounts, Joe's years at Temple were the happiest and most fulfilling of his professional life.

Although there were many, one of Joe's greatest attributes was his humility. His enthusiasm at Temple was infectious, and he was beloved by all. We always knew when he was coming to Clinic by the shuffling of his feet and the sound of his ever-present toolbox. As the story goes, Joe used his wife's Chanel lipstick to mark the metatarsal heads to fit his Hapads. She was always wondering where she had lost her lipstick. To examine a foot, he would often demonstrate one of his favorite wrestling moves, a double leg dropdown on the floor. It didn't take much to make Joe happy; he loved his Stock's cakes — but only with milk — "yea baby!"

Most importantly, Joe clearly understood the value of family, always having his priorities in order. He made it a point not to miss his son John or his daughter Sarah's golf matches, swim meets, lacrosse or football games. Not exactly Fred Astaire on the dance floor, according to his wife, he thoroughly enjoyed going to the father-daughter dances. He reveled in playing with his four grandchildren and was overjoyed and so proud watching his children become such wonderful parents themselves. He loved playing golf at Aronimink Golf Club with his son John, who beat him on a regular basis. The Eremus' were active members of the Merion Cricket Club, and even hosted one of our department's Christmas parties there. Joe was an active member of the Men's Gardening Club of Philadelphia and enjoyed mowing his yard with his trusty gar-

den tractor. He had a fabulous garden which he meticulously maintained. Margo said that Joe's perfect storm was riding his tractor, having no rain, and listening to a Phillies game on a Sunday afternoon. He loved "his" Phillies; in fact, Joe and Tom Yucha, one of our other Temple Orthopedic graduates, became part owners of a Phillies farm team in Spartanburg, SC. According to Margo, she and Joe used to go to sit in the "owner's box," which was a picnic bench on the field, truly a Joe Eremus moment. He was deeply involved and active in St. David's Episcopal Church. He served on the vestry for years. He and his wife even chaired the church's 300th anniversary celebration.

Most of all, we remember Joe for his humanity. He was kind and giving to everyone he came in contact with. He inspired several of his residents to go into foot and ankle surgery. He was always ready to help out his colleagues. He dearly loved his family and his community. He was the kind of doctor that we all aspire to be — bright, humble, caring, and compassionate. Maya Angelou wrote "that people will forget what you said, people will forget what you did, but people will never forget how you made them feel." Joe Eremus made us all feel better about life and ourselves. A life well lived, a job well done; may you rest in peace my friend.

Commentary

The Distinguished Alumni Paper

Asif M. Ilyas, MD

Temple Ortho, Class of 2006; Program Director of Hand & Upper Extremity Surgery, Rothman Institute; Professor of Orthopaedic Surgery, Thomas Jefferson University

It is an honor to present this year's "Distinguished Alumni Paper." As the Resident Editor-in-Chief of the first volume of the *Temple University Journal of Orthopaedic Surgery & Sports Medicine,* published in 2006, it is even more meaningful to me.

This "Distinguished Alumni Paper" was published in the *Journal of Bone and Joint Surgery American* in 2016. First, I would like to acknowledge my co-authors for their diligence and participation in this study. Our findings have placed a spotlight on an important issue in both Orthopaedic Surgery as well as our society in general, opioids. Opioid dependency, abuse, and diversion has been on the rise over the past several years resulting in opioid-related overdose deaths becoming the leading cause of preventable deaths in Americans under 50 years of age, surpassing motor vehicle accidents. When we critically analyzed opioid consumption after upper extremity surgeries, we found that on average patients were being prescribed about 25 opioid pills and patients were only utilizing eight pills, meaning that patients only consumed a third of their opioids, leaving an additional two thirds available in the community for potential abuse and diversion. During the study period alone, which consisted of about 1,400 patients who consumed on average a third of their opioid prescription, the result was an additional 23,000 unused opioid pills distributed into the patients' homes and community. This "inadvertent over-prescribing" may be a potential contributor to the opioid epidemic and we challenge all orthopaedic surgeons to critically look at opioid consumption patterns of their patients after their specific surgeries so they can prescribe opioids in numbers more customized to the typical need of their patients and avoid over-prescribing.

Distinguished Alumni Paper

A Prospective Evaluation of Opioid Utilization After Upper-Extremity Surgical Procedures: Identifying Consumption Patterns and Determining Prescribing Guidelines

Nayoung Kim, BS; Jonas L. Matzon, MD; Jack Abboudi, MD; Christopher Jones, MD; William Kirkpatrick, MD; Charles F. Leinberry, MD; Frederic E. Liss, MD; Kevin F. Lutsky, MD; Mark L. Wang, MD, PhD; Mitchell Maltenfort, PhD; Asif M. Ilyas, MD

Investigation performed at the Rothman Institute at the Thomas Jefferson University, Philadelphia, Pennsylvania

Background: Although adequate management of postoperative pain with oral analgesics is an important aspect of surgical procedures, inadvertent overprescribing can lead to excess availability of opioids in the community for potential diversion. The purpose of our study was to prospectively evaluate opioid consumption following outpatient upper-extremity surgical procedures to determine opioid utilization patterns and to develop prescribing guidelines.

Methods: All patients undergoing outpatient upper-extremity surgical procedures over a consecutive 6-month period had the following prospective data collected: patient demographic characteristics, surgical details, anesthesia type, and opioid prescription and consumption patterns. Analysis of variance and post hoc comparisons were performed using t tests, with the p value for multiple pairwise tests adjusted by the Bonferroni correction.

Results: A total of 1,416 patients with a mean age of 56 years (range, 18 to 93 years) were included in the study. Surgeons prescribed a mean total of 24 pills, and patients reported consuming a mean total of 8.1 pills, resulting in a utilization rate of 34%. Patients undergoing soft-tissue procedures reported requiring fewer opioids (5.1 pills for 2.2 days) compared with fracture surgical procedures (13.0 pills for 4.5 days) or joint procedures (14.5 pills for 5.0 days) ($p < 0.001$). Patients who underwent wrist surgical procedures required a mean number of 7.5 pills for 3.1 days and those who underwent hand surgical procedures required a mean number of 7.7 pills for 2.9 days, compared with patients who underwent forearm or elbow surgical procedures (11.1 pills) and those who underwent upper arm or shoulder surgical procedures (22.0 pills) ($p < 0.01$). Procedure type, anatomic location, anesthesia type, age, and type of insurance were also all significantly associated with reported opioid consumption ($p < 0.001$).

Conclusions: In this large, prospective evaluation of postoperative opioid consumption, we found that patients are being prescribed approximately 3 times greater opioid medications than needed following upper-extremity surgical procedures. We have provided general prescribing guidelines, and we recommend that surgeons carefully examine their patients' opioid utilization and consider customizing their opioid prescriptions on the basis of anatomic location and procedure type to prescribe the optimal amount of opioids while avoiding dissemination of excess opioids.

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Although effective postoperative pain control is important, the U.S. Centers for Disease Control and Prevention (CDC) has reported that there is a growing epidemic of prescription painkiller abuse.[1] In 2007 alone, there were 27,658 accidental deaths related to prescription opioid overdose.[25] Furthermore, according to the American Society of Consultant Pharmacists, millions of pounds of "leftover" prescriptions go unused in patients' medicine cabinets each year in the United States.[3] Many factors contribute to this problem, including an increasingly aggressive culture of pain management, a lack of prescribing guidelines for physicians, inconsistent perioperative utilization of local anesthetics, and inadequate disposal instructions for patients.[4]

Orthopaedic surgical procedures pose a unique challenge and opportunity in safe pain management. Specifically, orthopaedic surgical procedures often result in greater postoperative pain than other surgical procedures because of the manipulation of musculoskeletal tissue.[5] Orthopaedic surgeons routinely prescribe opioids for postoperative pain management, yet little is known about the typical opioid requirements for various orthopaedic procedures. During a 2014 American Academy of Orthopaedic Surgeons (AAOS) symposium, it was recognized through an audience survey that most orthopaedic surgeons do not know how many pills to prescribe to their patients and/or how many pills their patients actually take.[6] This may result in inconsistent and often excessive opioid-prescribing patterns. A greater under-

standing of opioid consumption patterns can result in more optimal and safer prescribing habits by physicians and can decrease the risk for overprescribing and potential diversion or abuse.

The purpose of our study was to prospectively evaluate opioid consumption following outpatient upper-extremity surgical procedures. The goal was to determine opioid utilization patterns to help to develop prescribing guidelines.

Materials and Methods

After obtaining institutional review board approval, 9 hand surgery fellowship-trained, board-certified orthopaedic surgeons practicing in a single private academic group prospectively collected postoperative opioid consumption data for 6 consecutive months (in April 2014 to October 2014). Data were collected via a standardized intake form. The surgeons were not blinded, were asked to continue their normal prescribing patterns, and were aware that the patients would be asked about their opioid consumption postoperatively. Nicotine use information was not collected. On the day of the surgical procedure, the surgeon recorded the following variables on the intake form: the patient's age and sex, the procedure's anatomic location (hand or wrist, forearm or elbow, and upper arm or shoulder), the procedure type (soft-tissue surgical procedure, joint surgical procedure, or fracture surgical procedure), the anesthesia type (local, sedation, general, and/or regional), the opioid type prescribed, and the quantity of the opioid prescribed.

Patients were included if they had an outpatient surgical procedure of the hand, wrist, elbow, forearm, or shoulder. Patients undergoing inpatient procedures were excluded. At the first postoperative visit, the following data were solicited directly from the patient by a member of the research team and were added to the standardized intake form: the quantity of the prescribed opioid used, the total days of opioid use, the reason for discontinuation (the opioids no longer being necessary or the side effects associated with the opioids), and the side effects (if any). Finally, patients were asked if opioid disposal instructions were given to them at any point in time. A research team member collected the intake form, and the data were subsequently entered into a central database.

The opioids prescribed and studied in this study included Percocet (oxycodone and acetaminophen) or an oxycodone 5-mg equivalent, Vicodin (acetaminophen and hydrocodone) or a hydrocodone 5-mg equivalent, and Tylenol #3 (acetaminophen and codeine) with 30 mg of codeine. For the purposes of this study, each of these prescription opioid pills was treated as equivalent to the other.

The following surgical data were collected: the type of procedure and the type of anesthesia. The type of procedure was subcategorized as a soft-tissue procedure (i.e., carpal tunnel or trigger finger release), fracture procedure (i.e., any fracture reduction with internal fixation), or joint procedure (i.e., arthroscopy, arthrodesis, or arthroplasty). The types of anesthesia were divided into local anesthesia, local anesthesia with sedation, regional anesthesia with or without sedation, and general anesthesia. Finally, patient demographic characteristics, such as age, sex, and type of insurance, were also collected.

Statistical Analysis

The overall data were examined by descriptive statistics between the means. The mean number of pills used and the mean total number of days used were calculated on the basis of patient demographic characteristics (age, sex, and insurance type), procedure, anesthesia, injection, and volume of injection. The percentage of the total prescription used was calculated by dividing the number of pills taken by the total number of pills prescribed. Single-factor analysis of variance (ANOVA) was conducted to assess significance ($p < 0.05$) between the categorical variables and the continuous variables (number of pills and number of days). Post hoc comparisons were performed using t tests, with the p value for multiple pairwise tests adjusted by the Bonferroni correction.

Results

A total of 1,416 patients (639 male patients and 777 female patients) with a mean age of 56 years (range, 18 to 93 years) were included (Table I). Surgeons prescribed a mean total of 24 pills (median, 20 pills [range, 0 to 110 pills]) per surgical procedure. Overall, the mean postoperative reported opioid consumption was 8.1 pills (median, 4 pills [range, 0 to 90 pills]) for a mean time of 3.1 days, resulting in a utilization rate of 34%.

Overall Opioid Consumption Pattern

Overall, 28.3% of patients did not take any of their prescribed medications. An additional 56.1% of patients voluntarily discontinued the use of their prescription prior to its completion. In contrast, 11.0% of patients completed the entirety of their prescription, and 0.6% were still taking their medication at the time of their first postoperative visit. Finally, 4.0% did not wish to participate and did not respond.

Opioid Consumption by Age

The mean reported number of opioid pills consumed was highest (13.4 pills) among patients in the age group of 30 to 39 years ($p < 0.001$ according to ANOVA). Although the ANOVA and visual inspection of the graph make it clear that there is a real trend, pairwise tests between adjacent age groups (adjusted for 8 multiple comparisons) were only significant ($p = 0.03$) for the age groups of 60 to 69 years and 70 to 79 years. In fact, 47.3% of patients in the age groups of 30 to 39 years consumed their entire prescription. Subsequently, there was a decrease in opioid consumption in each successive age interval thereafter (from the ages of 40 to 89

Table I. Summary of Opioids Taken on the Basis of the Collected Variables

Category	No. of Patients	No. with Data on Pills	Mean No. of Pills Taken	No. with Data on Days	Mean No. of Days Pills Were Taken	Percentage of Pills Taken
Age group						
18 to 19 yr	20	20	12.7	20	5.0	57.3
20 to 29 yr	103	102	12.7	98	4.1	45.8
30 to 39 yr	120	120	13.4	111	4.9	47.3
40 to 49 yr	200	199	10.0	186	3.6	29.8
50 to 59 yr	335	329	8.4	302	3.2	27.7
60 to 69 yr	335	332	6.8	308	2.6	21.7
70 to 79 yr	215	212	4.6	198	2.1	19.9
80 to 89 yr	84	81	3.2	73	1.6	12.8
90 to 100 yr	4	4	12.8	4	4.8	43.3
Sex						
Female	777	769	7.9	712	2.9	25.8
Male	639	631	8.6	589	3.4	30.8
Insurance						
Private	910	900	8.1	840	4.7	27.9
Medicare	372	367	5.4	340	3.0	19.8
Automotive Association	10	10	13.1	10	4.6	45.3
Workers' Compensation	116	113	16.0	103	7.2	52
Self-pay or Medicaid	8	8	25.6	8	7.5	66
Procedure type						
Soft tissue	904	893	5.1	839	2.2	20.9
Fracture	260	257	13.0	243	4.5	39.4
Joint	252	242	14.5	252	5.0	46.4
Procedure location						
Hand	593	586	7.7	557	2.9	27
Wrist	658	651	7.5	600	3.1	27
Elbow or forearm	141	141	11.1	128	4.0	35
Upper arm or shoulder	24	23	22.0	14	6.0	56.6
Anesthesia*						
Local	286	285	4.5	250	2.0	16.3
Local with sedation	601	590	5.7	542	2.6	25
Regional	172	172	15.0	151	4.8	42.7
General	337	333	12.5	315	4.0	38.2

*Twenty patients did not undergo any anesthesia.

years), with the lowest amount consumed in the age group of 80 to 89 years. There was a paradoxical increase in opioid consumption in the age group of 90 to 100 years, although this was a small sample group of only 4 patients (Fig. 1).

Patients in the age range of 30 to 39 years had the highest reported mean opioid consumption for both soft-tissue procedures, at 11.6 pills, and joint procedures, at 19.2 pills. Patients in the age group of 18 to 19 years who received treatment for fracture fixation reported the highest mean consumption, at 18.9 pills.

On the basis of the anatomic location, patients in the age group of 18 to 19 years reported the highest mean opioid consumption for hand and wrist procedures (12.8 pills) and for elbow and forearm procedures (19.7 pills). Patients in the age group of 50 to 59 years showed the highest opioid consumption (32.5 pills) for upper arm and shoulder procedures. Lastly, patients in the age group of 20 to 29 years reported the highest mean opioid consumption (13.8 pills) for hand and wrist procedures.

Opioid Consumption by Sex

Male patients reported taking a mean number of 8.6 pills for 3.4 days, whereas female patients reported taking a mean number of 7.9 pills for 2.9 days postoperatively (Fig. 2). There was no significance in opioid consumption based on sex ($p = 0.20$).

Opioid Consumption by Insurance

Based on insurance type, patients who self-pay or have Medicaid reported consuming the greatest amount of opioids, at a mean number of 25.6 pills ($p < 0.001$ according to ANOVA) for 7.5 days. Patients with Workers' Compensation reported consuming the next greatest amount, with a mean consumption of 16 pills for 7.2 days. Patients with private insurance carriers consumed a mean number of 8.1 pills for 4.7 days, and Medicare patients, traditionally representing patients who are ≥65 years of age, reported having consumed the least amount, with a mean number of 5.4 pills for 3 days (Fig. 3). Post hoc comparisons between groups showed significant differences between patients with private insurance and those with Medicare ($p < 0.001$), between patients with private insurance and those with Workers' Compensation ($p < 0.001$), and between patients with Medicare and those with Workers' Compensation ($p < 0.001$).

Opioid Consumption by Procedure Type

Patients who underwent soft-tissue procedures reportedly consumed the least amount of opioids postoperatively, with

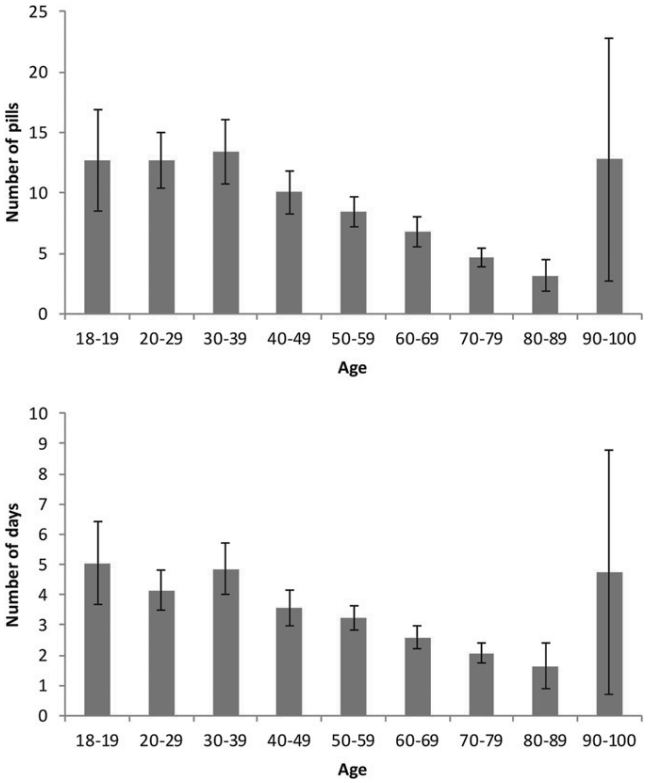

Figure 1. The mean number of pills and days by age. The error bars indicate the standard deviation.

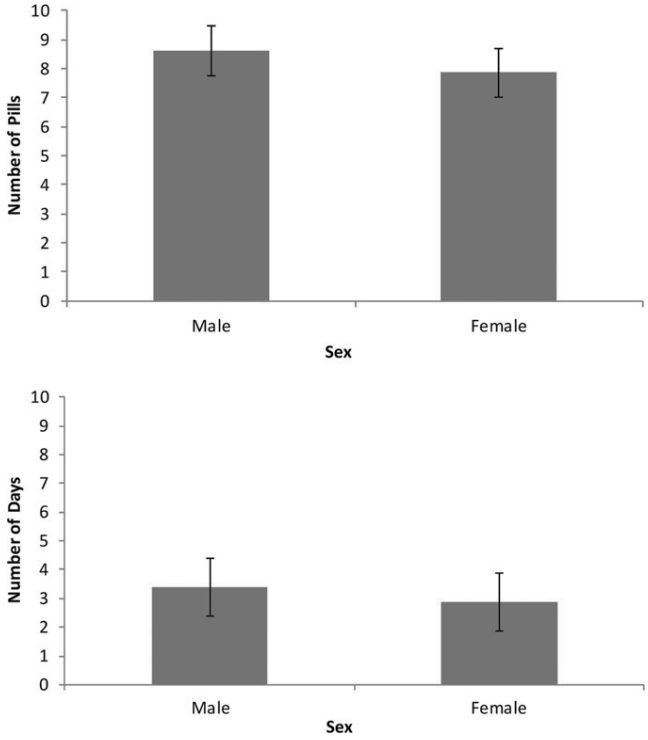

Figure 2. The mean number of pills and days by sex. The error bars indicate the standard deviation.

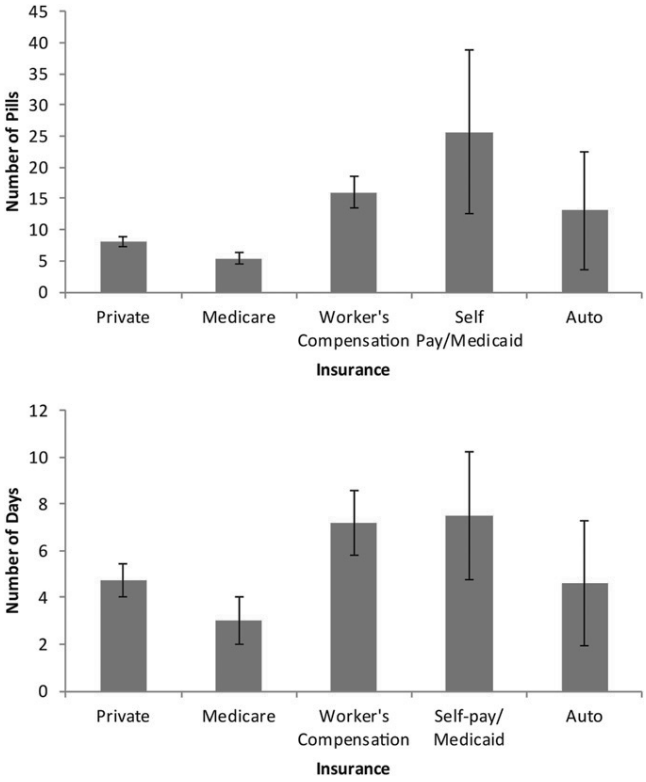

Figure 3. The mean number of pills and days by insurance type. The error bars indicate the standard deviation. Auto = Automotive Association.

a mean number of 5.1 pills ($p < 0.001$, ANOVA) for 2.2 days, compared with those who underwent fracture procedures (13.0 pills for 4.5 days) or joint procedures (14.5 pills for 5.0 days) (Fig. 4). When compared with adjacent groups, there were significant differences between patients who underwent soft-tissue procedures and those who underwent fracture procedures ($p < 0.001$) and between patients who underwent soft-tissue procedures and those who underwent joint procedures ($p < 0.001$). The most common surgical procedures performed in these categories are listed in Table II.

Opioid Consumption by Anatomic Site

Patients who had undergone hand and wrist surgical procedures reported the least opioid consumption, with those who had undergone hand surgical procedures having a mean number of 7.7 pills for 2.9 days and those who had undergone wrist surgical procedures having a mean number of 7.5 pills for 3.1 days ($p < 0.001$). However, post hoc pairwise comparisons adjusted for 3 multiple comparisons showed significance for procedures on the wrist compared with those on the elbow ($p = 0.008$). Patients who had undergone upper arm and shoulder surgical procedures had the greatest mean reported opioid consumption with 22.0 pills for 6.0 days. Patients who had undergone elbow and forearm surgical procedures had a reported mean opioid consumption of 11.1 pills for 4.0 days (Fig. 5). The most common surgical procedures in these categories are listed in Table III.

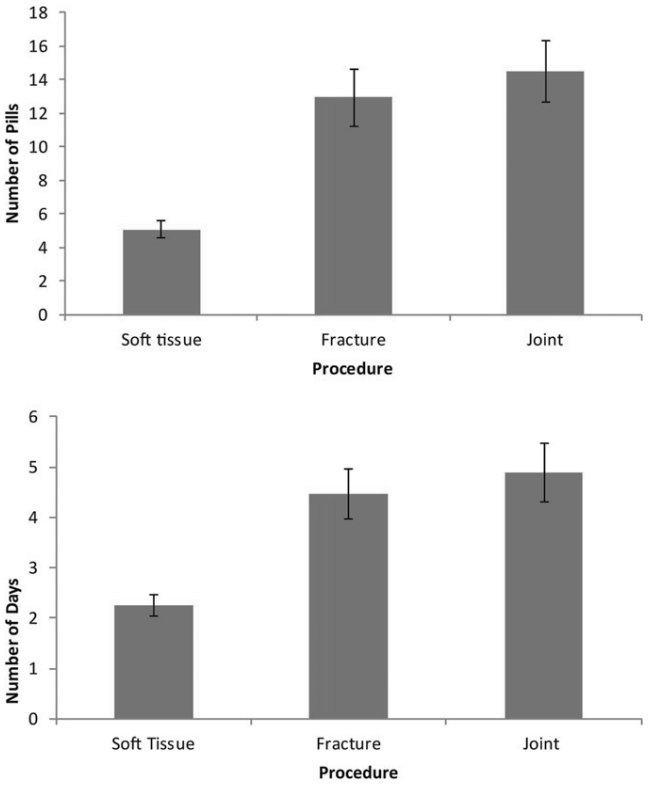

Figure 4. The mean number of pills and days by procedure. The error bars indicate the standard deviation.

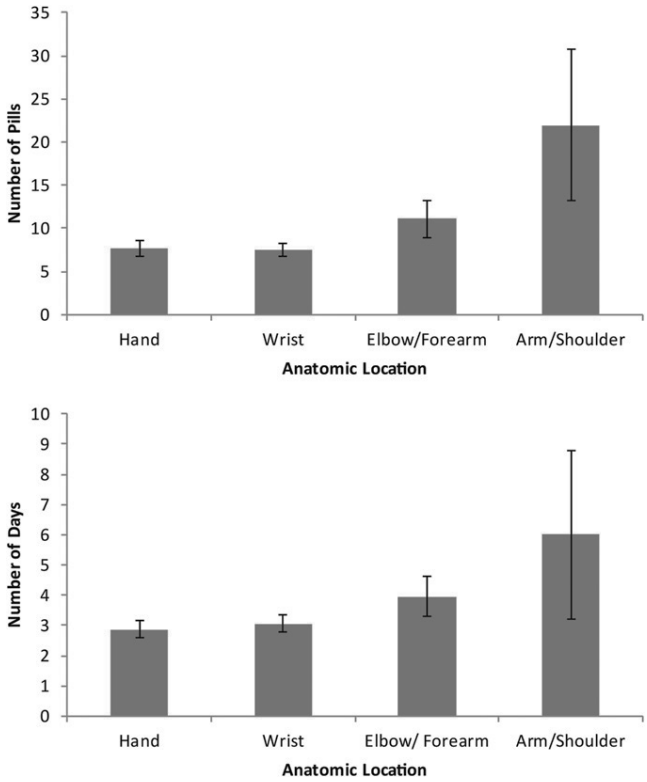

Figure 5. The mean number of pills and days by anatomic location. The error bars indicate the standard deviation.

Table II. Most Common Surgical Procedures by Procedure Type

Procedure	No. of Patients	Mean No. of Pills Taken
Soft tissue		
Carpal tunnel release	380	4.2
Trigger finger release	155	3.8
Mass excision	95	4.7
Fracture		
Distal radial open reduction internal fixation	114	13.7
Metacarpal open reduction internal fixation	46	9.6
Finger pinning	23	8.1
Joint		
Implant removal	39	12.3
Carpometacarpal arthroplasty	31	21.5
Tendon repair	28	14.5

Table III. Most Common Surgical Procedures by Anatomic Site

Procedure	No. of Patients	Mean No. of Pills Taken
Hand		
Trigger finger release	155	3.8
Mass excision	58	4.3
Metacarpal open reduction internal fixation	46	9.6
Wrist		
Carpal tunnel release	380	4.2
Distal radial open reduction internal fixation	114	13.7
De Quervain tenosynovitis	40	7.9
Elbow or forearm		
Cubital tunnel release	42	8.9
Lateral epicondyle debridement	23	13.5
Distal biceps repair	13	11.1
Shoulder or upper arm		
Acromioplasty rotator cuff	7	21.4
Humeral open reduction internal fixation	4	53.5
Distal clavicle resection	2	31.0

Opioid Consumption by Anesthesia Type

Patients who had undergone surgical procedures with only local anesthesia reportedly consumed the fewest opioids ($p < 0.001$), at a mean number of 4.5 pills for 2.0 days, compared with patients who had undergone surgical procedures with anesthesia with sedation (5.7 pills for 2.6 days), those who had undergone surgical procedures with general anesthesia (12.5 pills for 4.0 days), and those who had undergone surgical procedures with regional anesthesia (15.0 pills for 4.8 days) (Fig. 6). When a post hoc pairwise comparison was used to compare adjacent groups (6 groups), all groups were found to be significant ($p < 0.001$), except when patients who underwent local anesthesia were compared with those who underwent local anesthesia with sedation ($p = 0.118$) and when patients who underwent regional anesthesia were compared with those who underwent general anesthesia ($p = 0.621$). However, it should be noted that patients typically undergoing general or regional anesthesia do so for more involved or painful surgical procedures such

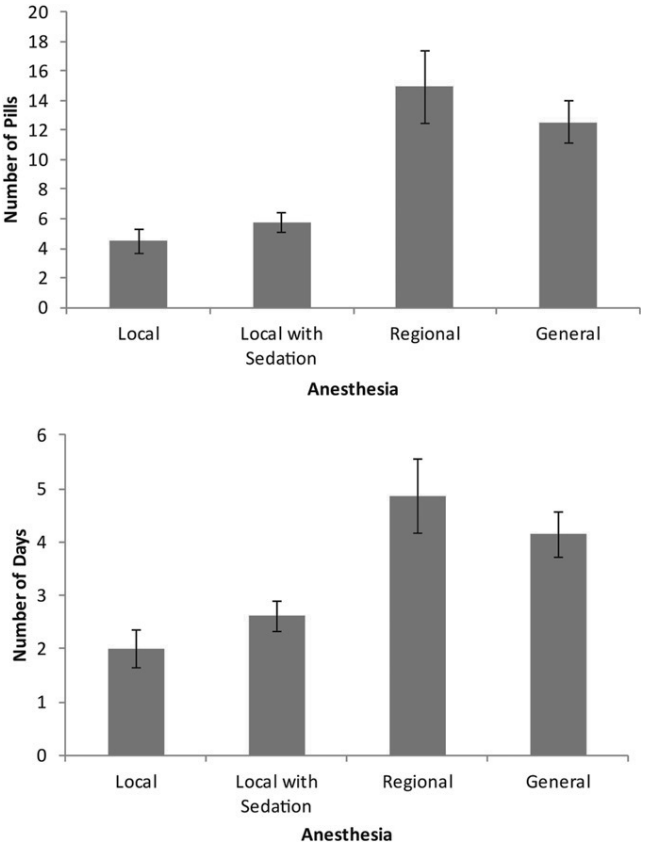

Figure 6. The mean number of pills and days by anesthesia. The error bars indicate the standard deviation.

as fracture, joint, or upper arm surgical procedures. Hence, the relationship between opioid consumption and anesthesia type is an inherently biased one.

Opioid Disposal Instructions

Only 5.3% of patients who filled their prescription received disposal information (n = 75). The sources of disposal information listed included the physician, recovery room nurses, and the pharmacy.

Discussion

There is a growing epidemic in the United States involving the misuse of prescription opioids. In 2013, *The Journal of the American Medicine Association* reported that there had been 38,329 drug overdose deaths in the United States in 2010, and 75.2% of these deaths involved prescription opioids.[7] Americans, who make up 4.6% of the world's population, consume 80% of the global opioid supply.[8] As the United States reports substantial opioid abuse, the number of opioid-related deaths continues to grow internationally with increasing availability of opioids.[9] A Global Burden of Diseases, Injuries, and Risk Factors Study found that there were an estimated 43,000 deaths worldwide in 2010 due to opioid abuse.[10]

Several studies have shown that opioids are being inadvertently overprescribed to patients postoperatively across all specialties, but especially in orthopaedic surgical procedures.[3, 4, 11] Stanek et al.[12] studied opioid-prescribing patterns by implementing a new prescribing protocol for patients undergoing common upper-extremity surgical procedures. An educational card with a multimodal pain management plan was given to participating physicians with specific opioid recommendations. No narcotics were recommended for small procedures such as Mohs excisions, trigger finger releases, or retinacular cyst, nevi, lump, or bump excision. Ten narcotic pills were recommended for small procedures such as mucous cyst excisions, carpal tunnel releases, de Quervain releases, Dupuytren excisions, nonoperative hand fractures, and small joint arthrodeses. Twenty narcotic pills were recommended for wrist ganglion excisions, hand fracture fixation, basal joint arthroplasty, and tendon surgical procedures. Finally, 40 narcotic pills were recommended for larger surgical procedures such as wrist arthrodeses and reconstructions.[12] After implementing the new protocol, Stanek et al. found a decrease in opioid prescribing of 15% for trigger finger release, 20% for metacarpal fracture repair, 48% for wrist cyst excision, and 39% for de Quervain release.[12]

In a study of 250 patients, Rodgers et al. evaluated patient pain control after elective outpatient upper-extremity surgical procedures and quantified the number of leftover pain medications up to 14 days postoperatively.[11] The authors found that bone procedures resulted in the greatest opioid consumption (14 pills) and soft-tissue procedures had the lowest consumption (9 pills). Overall, a mean of 10 opioid pills were consumed per patient, and 19 pills were left unused and available for potential abuse.[11] Similar results were found in our study, in which only 11.0% of 1,416 patients completed the entirety of their prescription. Moreover, surgeons in our series prescribed a mean number of 24 pills, but the reported mean postoperative consumption was only 8.1 pills, resulting in a utilization rate of 34%. The result was that 66% of the prescription was available for potential diversion or abuse. In fact, during our study period alone, with 9 surgeons over 6 months, a total of 21,788 theoretically unused prescribed opioid pills was delivered into the community. Results from the 2010 National Survey on Drug Use and Health showed that about 5.1 million drug users (of 22.6 million illicit drug users) used prescription pain relievers; only 1 in 6 or 17.3% recorded that they had received the drugs through a prescription from their doctor.[13]

One of the challenges of excess opioid prescribing is safe disposal. Per the U.S. Food and Drug Administration (FDA), certain opioids can be flushed away, but others require deliberate elimination.[14] The FDA currently recommends that opioids be disposed of via pharmacy or community take-back programs or by mixing them in the household trash

with substances such as coffee grounds or cat litter in a sealed bag. A complete list of which medicines can be flushed away is available on the FDA web site.[14] However, the U.S. Environmental Protection Agency (EPA) discourages flushing any medications away to avoid contamination of the water supply.[15] Unfortunately, unclear opioid disposal practices were found to be common in our study population. Only 5.3% of the 1,416 patients received any disposal information for excess opioids from their physician, nurses, or pharmacists. McCauley et al. similarly reported findings from a web-based intervention study that was designed to improve patient knowledge of safe medication use, storage, and disposal.[16] Of 62 patients, they found that one-third were unaware of the unsafe nature of retained leftover opioid pills and almost half of their cohort did not know where to or how to properly dispose of prescription opioids.[16] In our cohort, 94% of patients did not receive safe disposal information. Medical staff should be more aware and vigilant in properly educating patients on safe disposal of excess opioid medication.

Patients undergoing orthopaedic surgical procedures have been shown to have higher pain postoperatively compared with those undergoing surgical procedures in other specialties.[17–19] Ringwalt et al. found that orthopaedic surgeons have the highest odds (7.1 to 1) of prescribing opioids to Medicare patients compared with other medical providers, such as dentists or emergency medicine physicians.[20] Yet it has been shown that orthopaedic surgeons have the highest patient return rate to the hospital for persistent postoperative pain.[21] Our findings support these facts, as the study surgeons were routinely prescribing in excess of their patients' needs and utilization. Upon informally surveying the participating surgeons, the most common reasons given for prescribing the amount that they did were to avoid undermanaging postoperative pain, to minimize patient calls, and to limit hospital readmissions. However, this "defensive" overprescribing increases the number of opioids in the community available for potential diversion or abuse. Based on our series, risk factors for increased opioid consumption include younger age (patients in the age group of 30 to 39 years consumed the greatest opioids), certain insurance types (self-pay, Medicaid, and Workers' Compensation), fracture or joint surgical procedures, and surgical procedures involving the upper arm.

Opioid consumption was found to be most strongly statistically related to procedure type and anatomic location. Therefore, based on our study findings, we recommend that surgeons consider these general guidelines for prescribing opioids postoperatively after outpatient upper-extremity surgical procedures to optimize the number of opioids dispensed: ≤10 opioids for hand and wrist soft-tissue surgical procedures, ≤20 opioids for hand and wrist fracture or joint surgical procedures, ≤15 opioids for elbow and forearm soft-tissue surgical procedures, ≤20 opioids for elbow and forearm fracture or joint surgical procedures, and ≤30 opioids for upper arm and shoulder surgical procedures.

There were some limitations to this study. First, because of the subjective nature of patient recall, some patients may have overestimated or may have underestimated the number of pills and/or number of days that the opioid was used. Furthermore, our study included all patients who were undergoing an upper-extremity procedure, and therefore, it may have included patients with chronic pain who were currently taking opioids and had a predisposed tolerance for opioids. In addition, information on preoperative nicotine use was not collected. Nicotine can potentially affect postoperative opioid consumption and pain experience. Lastly, a few patients did not fill out the entirety of the survey, thereby potentially skewing the results (specifically, of 1,416 enrolled patients, 16 patients did not report the total number of pills used, 115 patients did not report the total number of days that the pills were taken, and 56 patients did not report the reason for discontinuation).

In conclusion, the pattern of prescribing high volumes of opioid pills is a common practice among orthopaedic surgeons. Overprescribing delivers excess opioids into the community, leaving them vulnerable to potential diversion or abuse. To avoid overprescribing opioids and to limit potential abuse, surgeons should consider the patient's preoperative opioid experience and should establish prescribing standards on a case-by-case basis depending on the nature and location of the surgical procedure, the type of anesthesia, and the age of the patient.

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Original Research

Unplanned Return to the Operating Room in Patients with AIS Lenke 1 Curves Treated with Pedicle Screw Constructs

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Abstract

Object: This study seeks to define the incidence, timing, reason, and risk for reoperation in patients with AIS Lenke 1 curves treated with pedicle screws.

Methods: A prospectively collected multicenter database was retrospectively queried to identify patients with AIS Lenke 1 curves treated with pedicle screws with a minimum two-year follow-up. The patients were stratified by lumbar modifier. All reoperations were identified and stratified into an early group (<60 days) or a late group (>60 days). The groups were further categorized by reason for return to the operating room, and univariate analysis was performed to identify risk factors for a reoperation.

Results: 265 patients met the inclusion criteria: Lenke 1A = 130, 1B = 70, and 1C = 65. There were seven reoperations (four early and three late) for a total reoperation rate of 2.6%. The reoperation rates within the curve types were Lenke 1A: 3.8%, 1B: 0%, and 1C: 3.1%. Early reoperations (1.5%) were mainly for malpositioned instrumentation, and late reoperations (1.1%) were mainly for infection. Univariate analysis revealed an increased estimated blood loss and a greater amount of cell saver transfused as risk factors for a reoperation ($p < 0.05$).

Conclusions: The reoperation rate for Lenke 1 curves is low, with equal reoperation rates between Lenke 1A, 1B, and 1C curves. Patients with Lenke 1C curves had similar reoperation rates whether they were treated with selective or nonselective fusion. Estimated blood loss and cell saver transfusion were statistically significant risk factors for reoperation.

Introduction

The use of pedicle screws has become commonplace in the treatment of adolescent idiopathic scoliosis (AIS) due to their ability to achieve better correction and maintenance of curves in all three planes when compared to prior fixation techniques including hooks[2, 13, 18, 31, 32] (O'Brien et al.: Pedicle screw vs. hook fixation in the thoracic spine: clinical and biomechanical implications. *8th International Meeting on Advanced Spine Techniques,* Paradise Island, Bahamas, July 12–14, 2001). However, because widespread use of pedicle screw constructs is relatively new, there are few studies on the long-term complications of the procedure, specifically reoperations. Furthermore, there is a wide variability of data published on the complications associated with the operative treatment of AIS (rates ranging from 0% to 89%)[6, 8, 20, 24, 35] (Yaszay B et al.: A comparison of perioperative and delayed major complications following 1,630 AIS procedures. *45th Scoliosis Research Society Annual Meeting,* Kyoto, Japan, September 21–24, 2010), and revision surgery rates for AIS vary from 3.9% to 22%.[1, 5, 9, 19, 23, 27] The indications for these reoperations usually include infection, pseudarthrosis, malpositioned instrumentation, implant dislodgement or breakage, neurological complications, and curve progression.

To date, the studies that have been published on the reoperation rates in patients with AIS mainly include hook and hybrid constructs, with few analyzing pedicle screw constructs[1, 5, 9, 15, 16, 19, 23, 27, 30, 33] (Shufflebarger HL et al.: The rate of unplanned second surgeries in adolescent idiopathic scoliosis. *42nd Scoliosis Research Society Annual Meeting,* Edinburgh, Scotland, September 5–8, 2007). Lehman et al.[16] reported a 4.4% reoperation rate of 114 patients with AIS who underwent pedicle screw fixation with a three-year minimum follow-up, and Suk et al.[33] reported a 1.5% reoperation rate for infection in 203 patients with AIS treated with pedicle screws with a five-year minimum follow-up. However, both of these studies had small sample sizes. In 2007, Kuklo et al.[15] published the only study with a substantial number of patients (1,428) treated with pedicle screws, but they did not include all Lenke curve types and did not report separate results for the most common curve (Lenke Type 1). There is currently no literature published on unplanned revision surgery for patients with AIS Lenke 1 curves treated with pedicle screw fixation. The purpose of the current study is to define the risk factors, incidence, timing, and reason for reoperation in patients with AIS Lenke 1 curves treated with pedicle screw constructs.

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 queried to identify a consecutive series of patients with AIS Lenke Type 1 curves who underwent pedicle screw fixation from July 2001 to May 2009 with a two-year minimum follow-up.

Clinical, radiographic, and intraoperative measurements were recorded. Data fields included age, gender, Lenke type, main and compensatory coronal Cobb angles and percent flexibility, kyphosis (T5-T12), lumbar lordosis (T12 to top of the sacrum), coronal balance (C7 to central sacral vertical line), proximal and distal junctional kyphosis, end instrumented vertebral angulation and translation, lowest instrumented vertebra (LIV), thoracic and lumbar rib prominences, triradiate score, surgery time, estimated blood loss (EBL), amount of cell saver transfused, use of antifibrinolytics (amicar, apoprotein, or tranexamic acid), use of anterior release (open or thoracoscopic), use of thoracoplasty, use of derotation (en bloc, segmental, or both), and complications requiring return to the operating room. The Lenke 1 curves (single main thoracic curves) were further divided based on the lumbar modifier (A = central sacral vertical line between pedicles of apical lumbar vertebra, B = central sacral vertical line touches the lumbar apical body, C = central sacral vertical line is medial to the lumbar apical vertebra). The patients with Lenke 1C curves were subdivided based on whether they received selective (LIV ending at T11, T12, or L1) or nonselective (LIV ending at L2 or distal) fusions. All returns to the operating room were identified and were stratified into an early group (<60 days) or a late group (>60 days) (these times were previously reported by Shufflebarger HL et al.: The rate of unplanned second surgeries in adolescent idiopathic scoliosis. *42nd Scoliosis Research Society Annual Meeting,* Edinburgh, Scotland, September 5–8, 2007). The groups were further categorized by reason for return: malpositioned instrumentation, hardware failure (secondary to implant dislodgement or breakage), infection, pseudarthrosis, and residual deformity.

Statistical analysis was performed using SPSS 12.0.2 statistical package (SPSS Inc., Chicago, IL). Results were reported as means ± standard deviation (SD). The Wilcoxon rank-sum test and Fisher's exact test were used to detect potential risk factors causing complications requiring return to the operating room with a significance level of 0.05.

Results

Patient Demographics (Table 1)

A total of 265 patients with AIS Lenke 1 curves met the inclusion criteria (Lenke 1A = 130, Lenke 1B = 70, and Lenke 1C = 65). The mean age of the patients was 14.8 ± 2.1 years, and 75.5% (200/265) of the patients were female. The mean preoperative radiographic findings were: thoracic coronal Cobb angle 51.1 ± 8.9°, lumbar coronal Cobb angle 32.7 ± 9.1°, thoracic coronal percent flexibility 48.8 ± 21.2%, lumbar coronal percent flexibility 72.5 ± 20.6%, coronal balance –0.2 ± 2.1 cm, thoracic kyphosis (T5-T12) 20.8 ± 12.9°, lumbar lordosis (T12 to top of sacrum) –58.5 ± 12.0°, thoracic rib prominence 14.1 ± 4.6°, and lumbar rib prominence 6.6 ± 4.2°.

Table 1. Patient Demographics

Patients (N)	265
Females n (%)	200 (75.5)
Males n (%)	65 (24.5)
Mean Age ± SD (years)	14.8 ± 2.1
Lumbar Modifier	
Lenke 1A n (%)	130 (49.1)
Lenke 1B n (%)	70 (26.4)
Lenke 1C n (%)	65 (24.5)
1C Selective Fusion n (%)	44 (16.6)
1C Nonselective Fusion n (%)	21 (7.9)
Mean Coronal Cobb Angle	
Thoracic ± SD (°)	51.1 ± 8.9
Lumbar ± SD (°)	32.7 ± 9.1
Mean Coronal Flexibility	
Thoracic ± SD (%)	48.8 ± 21.2
Lumbar ± SD (%)	72.5 ± 20.6
Coronal Balance (C7-CSVL) (cm)	–0.2 ± 2.1
Thoracic Kyphosis (T5-T12) ± SD (°)	20.8 ± 12.9
Lumbar Lordosis (T12-Top of Sacrum) ± SD (°)	–58.5 ± 12.0
Rib Prominence	
Thoracic ± SD (°)	14.1 ± 4.6
Lumbar ± SD (°)	6.6 ± 4.2

SD = Standard deviation, CSVL = Central sacral vertical line

Reoperation Rates (Table 2)

The overall reoperation rate for all Lenke 1 curves was 2.6% (7/265). The reoperation rates for Lenke 1A, 1B, and 1C curves were 3.8% (5/130), 0% (0/70), and 3.1% (2/65), respectively. Reoperations occurred in 5/265 (1.9%) of the patients with Lenke 1A curves for early misplaced pedicles screws (3), late hardware failure (1), and late infection (1). No reoperations occurred in patients with Lenke 1B curves. Reoperations occurred in 2/265 (0.8%) of the patients with Lenke 1C curves and were for early (1) and late (1) infections.

Lenke 1C Curves (Selective vs. Nonselective Fusions)

Of the 65 patients with Lenke 1C curves, 44 patients had selective fusion and 21 had nonselective fusion (Table 1). One patient in each group (1/44 selective, 1/21 non-selective [2.3% and 4.7%, respectively]) had a reoperation. When considering the entire group, reoperation for Lenke 1C selective fusions occurred in 1/265 (0.4%) of the patients and was for late infection. Reoperation for Lenke 1C nonselective fusions occurred in 1/265 (0.4%) of the patients and was for early infection (Table 2).

Table 2. Reoperation Rates (n = 265 Patients)

Total Reoperations n (%)	7 (2.6)
Lenke 1A n (%)	5 (1.9)
Lenke 1B n (%)	0 (0.0)
Lenke 1C n (%)	2 (0.8)
1C Selective Fusion n (%)	1 (0.4)
1C Nonselective Fusion n (%)	1 (0.4)
Reoperations by Curve Type	
Lenke 1A (%)	3.8
Lenke 1B (%)	0
Lenke 1C (%)	3.1
1C Selective Fusion (%)	2.3
1C Nonselective Fusion (%)	4.7
Early (<60 days) n (%)	4 (1.5)
Infection n (%)	1 (0.4)
Malpositioned Instrumentation n (%)	3 (1.1)
Late (>60 days) n (%)	3 (1.1)
Infection n (%)	2 (0.8)
Malpositioned Instrumentation n (%)	0 (0.0)
Hardware Failure n (%)	1 (0.4)
Pseudarthrosis n (%)	0 (0.0)
Residual Deformity n (%)	0 (0.0)

Early Versus Late Return to the Operating Room (Table 2)

Early returns to the operating room (<60 days) occurred in 4/265 (1.5%) of the patients. The most common reason for an early reoperation was malpositioned screws in 3/265 (1.1%) seen on routine postoperative CT scans performed by one of the contributing centers, followed by infection in 1/265 (0.4%). Late returns to the operating room (>60 days) occurred in 3/265 (1.1%) of the patients. The most common reason for a late return was infection in 2/265 (0.8%), followed by hardware failure secondary to a loss of fixation of setscrews in the distal L1 pedicle screws in 1/265 (0.4%).

Risk for Reoperation (Table 3)

Univariate analysis revealed increased EBL (reoperation 1666.6 ± 878.1 cc, no reoperation 922.5 ± 834.4 cc, $p < 0.05$) and a greater amount of cell saver transfused (reoperation 654.2 ± 222.7 cc, 252.2 ± 325.8, $p < 0.0001$) as risk factors for an unplanned return to the operating room. There was a trend towards statistical significance of potential risk factors associated with an unplanned reoperation with the surgical time ($p = 0.09$), first postoperative distal junctional kyphosis ($p = 0.06$), and first postoperative end instrumented vertebral angulation ($p = 0.06$).

The following were not significant risk factors for a reoperation in this cohort of patients treated with pedicle screws: lumbar modifier between the Lenke 1 curves (Lenke 1A versus Lenke 1B $p = 0.16$, Lenke 1A versus Lenke 1C $p = 1.00$, and Lenke 1B versus Lenke 1C $p = 0.24$), selective fusions ($p = 0.55$), age at surgery ($p = 0.99$), gender ($p = 0.67$), preoperative major coronal Cobb angle ($p = 0.16$), preoperative minor coronal Cobb angle ($p = 0.71$), preoperative percent flexibility of main coronal Cobb angle ($p = 0.81$), preoperative percent flexibility of minor coronal Cobb angle ($p = 0.75$), preoperative kyphosis measured from T5-T12 ($p = 0.34$), preoperative lumbar lordosis measured from T12 to top of the sacrum ($p = 0.42$), preoperative coronal balance measured from C7 to central sacral vertical line ($p = 0.30$), first postoperative proximal junctional kyphosis ($p = 0.14$), first postoperative end instrumented vertebral translation ($p = 0.96$), preoperative thoracic rib prominence ($p = 0.18$), preoperative lumbar rib prominence ($p = 0.15$), antifibrinolytic use ($p = 1.00$), open triradiate cartilage ($p = 0.36$), use of anterior release ($p = 0.17$), use of thoracoplasty ($p = 1.00$), and use of derotation ($p = 0.68$).

Discussion

Few studies have documented the rate of return to the operating room with pedicle screw fixation in the definitive treatment of AIS[15, 16, 30, 33] (Shufflebarger et al.: The rate of unplanned second surgeries in adolescent idiopathic scoliosis. *42nd Scoliosis Research Society Annual Meeting,* Edinburgh, Scotland, September 5–8, 2007). This study retrospectively reviewed a prospectively collected multicenter database to identify 265 patients with AIS Lenke 1 curves who underwent pedicle screw fixation with a two-year minimum follow-up. All returns to the operating room were identified and classified based on timing and reason for return. The results suggest patients with Lenke 1 AIS treated with pedicle screw constructs have low rates of return to the operating room (2.6%). The reoperation rates were similar between the patients with Lenke 1A curves (3.8%), patients with Lenke 1B curves (0%), and patients with Lenke 1C curves (3.1%). Furthermore, the patients with Lenke 1C curves treated with selective fusions had similar reoperation rates (2.3%) as the patients with Lenke 1C curves treated with nonselective fusions (4.7%), $p = 0.55$. The early reoperations (1.5%) were mainly for misplaced pedicle screws, and the late reoperations (1.1%) were mainly for infections. In addition, analysis of preoperative and intraoperative factors revealed increased EBL and more cell saver transfused as risk factors for a return to the operating room.

Kuklo et al.[15] published the only study on reoperation rates in AIS with a substantial number of pedicle screw patients (295). The current study found a reoperation rate of 2.6% for patients with Lenke 1 curves treated with pedicle screws, which was similar to the 2.4% reoperation rate that Kuklo et al. reported for patients with AIS treated with pedicle screws. This is most likely due to the fact that the most common Lenke curve type is the Lenke 1 curve, which was also supported by Lehman et al.,[16] who showed that 45.6% of their patients had Lenke 1 curves.

The authors of the current study found that the majority of the reoperations occurred in the Lenke 1A group, which was again most likely because 49.1% (130/265) of the patients in the study had Lenke 1A curves. Interestingly, the reoperation rates between the three groups were not statistically significant even though there were no reoperations in the patients with Lenke 1B curves. Most importantly, the rate of reoperation in the patients with Lenke 1C curves treated with selec-

Table 3. Mean Values ± Standard Deviation of Risk Factors for Reoperation

Risk Factors	Reoperation	No Reoperation	P-value
Coronal Cobb Angle			
Thoracic ± SD (°)	57.3 ± 11.6	51.0 ± 8.8	0.16
Lumbar ± SD (°)	34.3 ± 11.0	32.7 ± 9.1	0.71
% Flexibility			
Thoracic ± SD (%)	46.1 ± 19.4	48.9 ± 21.3	0.81
Lumbar ± SD (%)	76.0 ± 19.5	72.4 ± 20.7	0.75
Rib Prominence			
Thoracic ± SD (°)	16.3 ± 4.7	14.0 ± 4.6	0.18
Lumbar ± SD (°)	8.7 ± 3.9	6.5 ± 4.2	0.15
Coronal Balance ± SD (cm)	0.5 ± 1.5	–0.2 ± 2.1	0.30
Kyphosis (T5-T12) ± SD (°)	25.4 ± 12.7	20.6 ± 12.9	0.34
Lordosis (T12-Top of Sacrum) ± SD (°)	–55.7 ± 6.7	–58.6 ± 12.1	0.42
Proximal Junctional Kyphosis ± SD (°)	7.4 ± 3.4	5.5 ± 3.8	0.14
Distal Junctional Kyphosis ± SD (°)	–8.0 ± 7.7	–2.7 ± 7.0	0.06
EIV Translation ± SD (cm)	–0.7 ± 1.2	–0.6 ± 1.6	0.96
EIV Angulation ± SD (°)	–0.1 ± 5.7	4.0 ± 5.6	0.06
Age at Surgery ± SD (years)	14.8 ± 2.1	14.8 ± 2.1	0.99
Surgery Time ± SD (min)	330.4 ± 146.4	249.3 ± 94.9	0.09
Estimated Blood Loss ± SD (cc)	1666.0 ± 878.1	922.5 ± 834.4	**<0.05**
Cell Saver Transfused ± SD (cc)	654.2 ± 222.7	252.2 ± 325.8	**<0.0001**
Antifibrinolytic Use (%)	42.9	41.1	1.00
Triradiate Open (%)	14.3	5.8	0.36
Anterior Release Performed (%)	14.3	2.3	0.17
Thoracoplasty Performed (%)	14.3	22.9	1.00
Derotation Performed (%)	42.9	32.9	0.68
Selective Fusion (%)	14.3	16.7	0.55
Male Gender (%)	28.6	23.6	0.67

EIV = End instrumented vertebra, SD = Standard deviation

tive fusion (2.3%) was not statistically different than the rate of reoperation in the patients with Lenke 1C curves treated with nonselective fusion (4.7%), p = 0.55. In 2009, Sponseller et al.[30] suggested that patients with Lenke 1C AIS with open triradiate cartilages have less predictable lumbar correction when treated with selective thoracic fusion. However, none of these patients were treated with all pedicle screws. In our study, the majority of patients, 94.0% (249/265), had closed triradiate cartilages at the preoperative evaluation. Thus, the authors feel that patients with Lenke 1C curves treated with selective spinal fusion using pedicle screws may have similar reoperation rates to patients treated with nonselective fusion, especially in those patients with closed triradiate cartilages.

Early reoperations (<60 days) occurred in 1.5% of our patients, mainly for misplaced pedicle screws (1.1%). Suk et al.[33] reported a 1.5% rate of pedicle screw misplacement in spine deformity, mostly on the convex side of the upper instrumented vertebra with no clinical consequences, but other studies suggest a breach rate as high as 58%.[3, 11, 12, 17, 22] Results from our institution suggest a free-handed breach rate closer to 10% based on postoperative CT scans.[29] The patients in our series that underwent revision surgery for screw misplacement all had asymptomatic screws that were detected on routine postoperative CT scans. These screws were placed using the free-hand technique. One patient had an apical concave screw that was abutting the aorta and was revised. One patient had a left T12 screw that breached the vertebral body anteriorly and was replaced on postoperative day 5 (Fig. 1). The other two patients had medially placed screws that were revised. There are no clear guidelines as to whether or not to revise a medially placed asymptomatic screw, and the decision should be made on an individual patient basis.

Late reoperations (>60 days) occurred in 1.1% of our patients, mainly for infections (0.8%). The overall infection rate of patients treated with definitive surgery for AIS range from 0.9 to 3%[4, 7, 8, 25, 26, 28] (Buchowski JM et al.: Infections following spinal deformity surgery. A 20-year assessment of 2876 patients. *41st Scoliosis Research Society Annual Meeting,* Monterey, California, September 14–16, 2006), with the largest study performed by Coe et al.[8] studying 6,334 patients and reporting a rate of infection of 1.35% in patients treated with posterior spinal fusion. Charosky et al.[7] reported a 1.2% reoperation rate for late infections (>90 days) in adult patients with scoliosis treated with spinal fusions. Kuklo et al.[15] reported a 0.3% reoperation rate for infection in patients with AIS treated with pedicle screws, a 1.0% reoperation rate for infection in patients treated with hooks, and a 1.4% reoperation rate for infection in patients treated with hybrid constructs. The reoperation rate for infection in our study is possibly a little higher than those

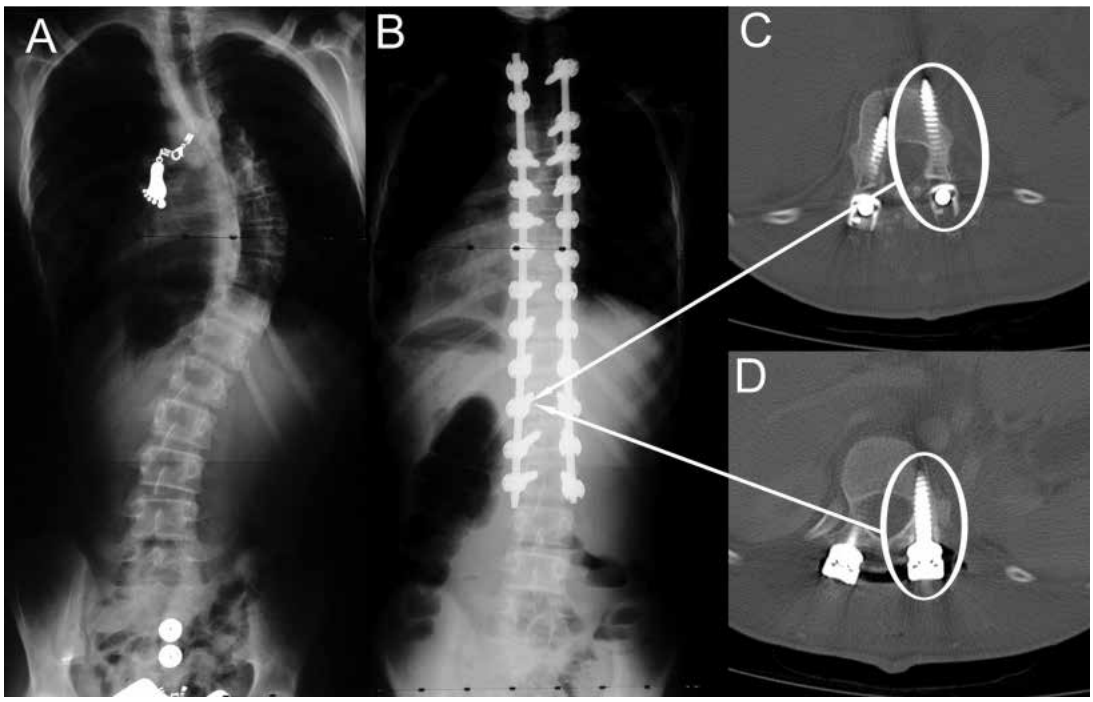

Figure 1. A) Preoperative standing PA radiograph of an 11-year-old female with a right Lenke 1A curve (56° main thoracic curve, and a 21° compensatory lumbar curve). **B)** First postoperative standing PA radiograph showing pedicle screw fixation from T2-L2. **C)** Postoperative CT showing the left screw at T12 breaching the vertebral body anteriorly abutting the aorta. **D)** The screw was replaced on postoperative day 5.

reported by Kuklo et al. because the current study was a multicenter study, whereas Kuklo et al. reviewed data from two institutions. However, our results are consistent with the generally low infection rate seen in patients with AIS treated with spinal fusions[4, 7, 8, 25, 26, 28] (Buchowski JM et al.: Infections following spinal deformity surgery. A twenty-year assessment of 2876 patients. *41st Scoliosis Research Society Annual Meeting,* Monterey, California, September 14–16, 2006).

Charosky et al.[7] published one of the only studies on risk factors for reoperation in scoliosis after spinal fusion and found that the number of instrumented vertebra, fusion to the sacrum, pedicle subtraction osteotomy, and a preoperative pelvic tilt of 26° or more were significant risk factors for reoperation in adult patients with scoliosis, with a 44% risk of reoperation in the six-year period after the primary procedure. Our study found increased EBL and more cell saver transfused to be statistically significant risk factors for a reoperation in patients with Lenke 1 AIS treated with pedicle screws. This difference may be due to shorter follow-up of the current study. The literature shows that increased EBL is associated with an increased risk for infection,[10, 14, 21, 34] which may lead to more reoperations. Our study did not find a statistically significant relationship between EBL and the rate of infections causing reoperation, but that may be a reflection of the small reoperation rate. Furthermore, the amount of cell saver transfused is an indirect way to measure EBL, and this was also found to be associated with a risk for reoperation. The use of antifibrinolytics (apoprotein, amicar, and tranexamic acid) did not significantly affect the reoperation rate.

The current study was limited because it was a retrospective review of a prospective multicenter database. However, this was necessary to obtain the greatest sample size. Another limitation of the study was that the reoperation group was much smaller than the non-reoperation group to which it was compared, although they were similar with respect to preoperative radiographic findings (thoracic and lumbar coronal Cobb angles, kyphosis, lordosis, coronal balance, and scoliometer scores) and patient demographics (age and gender). This was done since matched cohort groups would have limited the sample size and reduced the power of the study.

Conclusion

In summary, patients with Lenke 1 AIS curves treated with pedicle screw constructs appear to have low rates of reoperation (2.6%). The reoperation rates were similar between the patients with Lenke 1A curves (3.8%), patients with Lenke 1B curves (0%), and patients with Lenke 1C curves (3.1%). Furthermore, the patients with Lenke 1C curves treated with selective fusions had similar reoperation rates (2.3%) to the patients with Lenke 1C curves treated with nonselective fusions (4.7%), $p = 0.55$. Early returns to the operating room (<60 days) occurred in 1.5% of the patients and were mainly for misplaced pedicle screws. Late reoperations (>60 days) occurred in 1.1% of the patients and were mainly for infections. Increased EBL and greater cell

saver transfused were found to increase the risk of an unplanned return to the operating room.

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Original Research

Patient Satisfaction in the Preoperative Period: Preparing for Hand Surgery

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Abstract

Background: The potential impact of the number and type of preoperative encounters on satisfaction rates prior to elective surgical procedures is unclear, specifically scheduling and medical clearance encounters.

Methods: Questionnaires investigating satisfaction with the preoperative process were collected for 200 patients presenting for elective hand surgery. The number of telephone, surgeon and medical clearance encounters were recorded and satisfaction was determined for each type based on a four-category Likert scale. All patients 18 years or older were included, while only patients providing incomplete questionnaires were excluded. Outcome data was assessed for associations between different encounter totals or types and satisfaction rates.

Results: Among 200 patients, 197 completed the questionnaire and were included. Overall satisfaction with the preoperative process was 92.9%, with only 3% of patients dissatisfied. There was a significant association between satisfaction and the number of telephone and total encounters. Satisfaction fell below 90% after four or more telephone calls (66.6%, $p = 0.005$) and five or more total encounters (80%, $p = 0.008$). When considered individually, there was no significant association between satisfaction and the number of surgeon ($p = 0.267$) or medical office encounters ($p = 0.087$), or a patient's perceived health status ($p = 0.14$).

Conclusions: Greater than three telephone or four total encounters significantly decreases patient satisfaction, while surgeon and medical office visits are not associated with satisfaction rates when considered individually. This suggests the number, not the type, of preoperative encounters impact satisfaction and highlight the importance of efficient communication between patients and providers.

Introduction

With healthcare incentives and reimbursement transitioning from volume- to value-based, the business and patient-centered care models of practice are becoming increasingly intertwined. Patient experience is now widely accepted as a healthcare measure and component of healthcare quality, often reported as patient satisfaction scores.[8] With the introduction of the Affordable Care Act, The Centers for Medicare and Medicaid Services (CMS) has brought a focus on the need to deliver care that provides a quality patient experience as a part of overall healthcare delivery. The CMS now publicly reports patient satisfaction using the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey.[8] Furthermore, CMS adjusts reimbursements based on various quality measures including clinical processes of care, outcomes, efficiency, and patient experience.[2] These policies directly relate patient satisfaction to health care quality.[5]

While outpatient patient satisfaction metrics are not currently required, they are increasingly used by health systems to evaluate surgeon performance and to determine compensation.[1] Such publicly available statistics may impact patient referrals or patient's own practice selection for elective procedures. In addition, satisfied patients are more likely to be compliant and keep office appointments, while less likely to pursue litigation or file complaints.[3]

Several studies have investigated individual encounter characteristics including time spent in the waiting room and with the surgeon, surgeon empathy, and communication barriers such as language;[6,7,9] however, we are unaware of any prior studies evaluating the potential cumulative impact preoperative encounters may have on satisfaction rates, as multiple of various types are commonly required. Given the growing emphasis on patient satisfaction as a component of patient centered care and its role in patient referral, surgeon evaluation, and reimbursement, we sought to evaluate the potential impact of the number and type of preoperative encounters, including both telephone and office visits, on satisfaction rates prior to elective outpatient hand surgery.

Materials and Methods

Following institutional review board approval, 200 consecutive patients presenting for elective hand surgery were prospectively evaluated and asked to complete a question-

naire investigating satisfaction with the preoperative process. All patients had presented to a single academic practice, including five participating hand surgeons. The practice included both an urban and suburban clinical office location (two offices total) and was primarily outpatient surgical center based for procedures (including one urban and suburban location), with a single hospital setting available for scheduling at surgeon preference. All patients 18 years or older were considered eligible for inclusion, regardless of procedure type. Only patients with inability or refusal to complete the supplied questionnaire, or those submitting an incomplete questionnaire were excluded. Patients were consecutively enrolled at the two surgical centers and single hospital site from April 1, 2017 to August 1, 2017 and informed consent was obtained from all individual participants included in the study.

Upon presentation to the preoperative check-in at their surgical site, patients were provided informed consent and a printed questionnaire. The questionnaire was derived from the Clinician and Group-Consumer Assessment of Healthcare Providers and Systems (CG-CAHPS) Adult Visit Survey, a standardized survey instrument developed by the Agency for Healthcare Research and Quality to assess patients' experience and perception of care in ambulatory office settings, including hand surgery. Demographic data including age, sex, occupation (student, working, retired, disabled/unemployed), as well as procedure type and location (surgical center or hospital) were recorded. Next, the number of telephone encounters with staff, surgeon and medical clearance provider office encounters, and the total number of overall encounters from the time of initial presentation to the time of surgery were recorded. As a measure of patient satisfaction, each encounter type was evaluated on a four-category Likert scale, with responses of 1 (extremely satisfied), 2 (somewhat satisfied), 3 (averagely satisfied), or 4 (somewhat or very dissatisfied). Patients were considered "satisfied" if responding 1 or 2 (extremely or somewhat satisfied). Patients also evaluated their own perceived health status on a four-category Likert scale, with responses of 1 (very healthy), 2 (few, well controlled medical problems), 3 (moderate number of controlled medical problems) or 4 (mix of controlled and uncontrolled medical problems). Statistical analysis of continuous data was presented in terms of means and standard deviations, while categorical data was reported with frequencies and percentages. Fisher exact tests were used to evaluate the association between overall satisfaction and the number of encounters of each type, including the total number of encounters. In addition, satisfaction with surgeon and medical provider office encounters were evaluated individually via the same method.

A priori power analyses were conducted to estimate the required sample size. Given the nature of this research and the attendant uncertainties, a range of sample size estimates were generated reflecting these uncertainties. Based on these *a priori* analyses, a sample size of 200 respondents was estimated to be sufficient to achieve greater than 90% power at $\alpha = 0.05$ (adjusted to consider three multiple comparisons) to detect an effect size (Cohen's W) of 0.33 based on two groups measured on the five-unit Likert scale. However, when the study was executed, we saw much higher satisfaction ratings and much smaller group differences than we anticipated. Given these very high satisfaction ratings, data in the two lowest rating categories were very sparse. Accordingly, the two lowest categories were aggregated into a single category, and the data were analyzed based on a four-level ratings. As a result, the study as executed is underpowered for some tests or comparisons to achieve statistical significance given the very small observed differences between the various groups. Whereas the observation of both high satisfactions and small differences between groups is informative and encouraging, future studies in this domain should be sized to consider these high satisfactions and the resulting small differences between groups.

Results

Among 200 patients presenting for elective hand surgery, 197 completed the entire questionnaire and were included. The mean patient age was 57.9 ± 16.6 years and 56.3% of the population was female (Table 1). 86.3% of cases occurred at outpatient surgical centers, with the most common surgical procedures being carpal tunnel and trigger finger release (47.2% and 16.8%, respectively). Patient's most commonly categorized their occupation as actively working (50.2%) or retired (33%), with 11.2% of our patient population unemployed or disabled (Table 1).

Overall satisfaction with the preoperative scheduling and medical clearance process was 92.9% (extremely or somewhat satisfied), with only 3% of patients dissatisfied (Table 2). There was a statistically significant association between patient satisfaction and the number of telephone and total

Table 1. Demographics

Variable	N	Frequency/Percentage
Age	197	57.9% (Mean)
Sex		
Female	111	56.3%
Male	86	43.7%
Occupation Status		
Student	11	5.6%
Working	99	50.2%
Retired	65	33.0%
Disabled	11	5.6%
Unemployed	11	5.6%
Total	197	100%
Surgery Location		
Hospital	27	13.7%
Outpatient Surgical Center	170	86.3%
Total	197	100%
Surgery Type		
Carpal Tunnel Release	93	47.2%
Distal Radius ORIF	15	7.6%
Trigger Finger Release	33	16.8%
Other	56	28.4%
Total	197	100%

Table 2. Overall Patient Satisfaction (Combined Telephone, Surgeon, Medical Encounters)

Overall Satisfaction	N (Percentage of Total)
Extremely Satisfied	161 (81.7%)
Somewhat Satisfied	22 (11.2%)
Averagely Satisfied	8 (4.1%)
Somewhat or Very Dissatisfied	6 (3.0%)
Total	197 (100%)

encounters (combined telephone, surgeon and medical office). Patient satisfaction fell below 90% after four or more telephone calls (66.6% satisfaction, p = 0.005) and five or more total encounters (80% satisfaction, p = 0.008) (Table 3). The number of "extremely satisfied" patients progressively declined with each telephone encounter, with the most significant decline following the fourth encounter (33.3% satisfaction, p = 0.005). When considered individually, there was no statistically significant association between patient satisfaction and the number of surgeon (p = 0.267) or medical clearance provider office encounters, although data suggested the number of "extremely satisfied" patients steadily declined with each subsequent medical clearance encounter (p = 0.087) (Table 4). A patient's perception of their health status also was not significantly associated with their overall satisfaction rate with the preoperative scheduling process (p = 0.74) (Table 5).

Discussion

Patient experience is now widely accepted as a health care measure and component of health care quality, which is used by both healthcare systems and the public for evaluating physician performance. CMS, as well as private healthcare systems, may adjust reimbursement based on various quality measures that include not only outcomes and efficiency, but also patient experience.[2] Further, publicly available statistics may impact patient referrals or a patient's practice selection for elective procedures.[4] Despite growing emphasis on patient satisfaction as a component of patient centered care, satisfaction literature is limited and typically derived from postoperative surveys. We are unaware of any prior studies evaluating the potential impact the number and type of preoperative physician encounters may have on patient satisfaction, yet this may generate several points of potential inconvenience or frustration.

Patient satisfaction rates vary among medical specialties and are affected by several individual visit characteristics. In our study, overall satisfaction with the preoperative process was 92.9%, which is consistent with other office-based satisfaction investigations.[6, 7, 9] Specific to hand surgery, several authors have investigated different characteristics of individual office visits that may affect patient satisfaction. Teunis et al. reported time spent with the hand surgeon was not

Table 3. Patient Satisfaction Rates for Telephone and Total Encounters

	Extremely Satisfied	Somewhat Satisfied	Averagely Satisfied	Somewhat or Very Dissatisfied	Total	p-Value
Number of Telephone Encounters						0.0050
0	51 (87.9%)	4 (6.9%)	2 (3.4%)	1 (1.7%)	58 (100.0%)	
1	69 (83.1%)	10 (12.0%)	3 (3.6%)	1 (1.2%)	83 (100.0%)	
2	29 (82.9%)	2 (5.7%)	3 (8.6%)	1 (2.9%)	35 (100.0%)	
3	9 (75.0%)	3 (25.0%)	0 (0.0%)	0 (0.0%)	12 (100.0%)	
4+	3 (33.3%)	3 (33.3%)	0 (0.0%)	3 (33.3%)	9 (100.0%)	
Total	161 (81.7%)	22 (11.2%)	8 (4.1%)	6 (3.0%)	197 (100.0%)	
Number of Total Encounters						0.0082
1	25 (92.6%)	1 (3.7%)	1 (3.7%)	0 (0.0%)	27 (100.0%)	
2	40 (85.1%)	4 (8.5%)	2 (4.3%)	1 (2.1%)	47 (100.0%)	
3	54 (85.7%)	7 (11.1%)	1 (1.6%)	1 (1.6%)	63 (100.0%)	
4	22 (88.0%)	2 (8.0%)	1 (4.0%)	0 (0.0%)	25 (100.0%)	
5	13 (65.0%)	3 (15.0%)	3 (15.0%)	1 (5.0%)	20 (100.0%)	
6+	7 (46.7%)	5 (33.3%)	0 (0.0%)	3 (20.0%)	15 (100.0%)	
Total	161 (81.7%)	22 (11.2%)	8 (4.1%)	6 (3.0%)	197 (100.0%)	

Table 4. Patient Satisfaction Rates for Surgeon and Medical Office Encounters

	Extremely Satisfied	Somewhat Satisfied	Averagely Satisfied	Somewhat or Very Dissatisfied	Total	p-Value
Number of Surgeon Office Encounters						0.2674
0	12 (80.0%)	2 (13.3%)	0 (0.0%)	1 (6.7%)	15 (100.0%)	
1	139 (81.8%)	20 (11.8%)	6 (3.5%)	5 (2.9%)	170 (100.0%)	
2+	10 (83.3%)	0 (0.0%)	2 (16.7%)	0 (0.0%)	12 (100.0%)	
Total	161 (81.7%)	22 (11.2%)	8 (4.1%)	6 (3.0%)	197 (100.0%)	
Number of Medical Clearance Encounters						0.0866
0	51 (91.1%)	2 (3.6%)	3 (5.4%)	0 (0.0%)	56 (100.0%)	
1	90 (81.1%)	14 (12.6%)	3 (2.7%)	4 (3.6%)	111 (100.0%)	
2	14 (73.7%)	3 (15.8%)	1 (5.3%)	1 (5.3%)	19 (100.0%)	
3+	7 (63.6%)	3 (27.3%)	1 (9.1%)	0 (0.0%)	11 (100.0%)	
Total	162 (82.2%)	22 (11.2%)	8 (4.1%)	5 (2.5%)	197 (100.0%)	

Table 5. Patient's Health Description and Satisfaction Rates

	Extremely Satisfied	Somewhat Satisfied	Averagely Satisfied	Somewhat or Very Dissatisfied	Total	p-Value
Own Health Description						0.7372
Very healthy, no medical problems	52 (81.3%)	6 (9.4%)	4 (6.3%)	2 (3.1%)	64 (100.0%)	
A few, well-controlled medical problems	76 (86.3%)	7 (8.0%)	2 (2.3%)	3 (3.4%)	88 (100.0%)	
Moderate number of controlled medical problems	25 (78.1%)	5 (15.6%)	1 (3.1%)	1 (3.1%)	32 (100.0%)	
Mix of controlled and uncontrolled medical problems	10 (76.9%)	3 (23.1%)	0 (0.0%)	0 (0.0%)	13 (100.0%)	
Total	163 (82.7%)	21 (10.7%)	7 (3.6%)	6 (3.0%)	197 (100.0%)	

associated with patient satisfaction, while longer waiting room times correlated with decreased satisfaction.[9] Menendez et al. investigated the role of language as a potential barrier to a satisfactory experience, reporting only a 71% satisfaction rate of Spanish-speaking patients, versus 91% of English speakers, following an office visit.[7] None of these studies included analysis of multiple office visits or the potential cumulative effect of these characteristics on satisfaction rates. Within our data set, there was a statistically significant association between patient satisfaction and both the number of telephone and total encounters (combined telephone, surgeon and medical office), each suggestive of a negative correlation between satisfaction and an increasing number of encounters. Patient satisfaction remained very high, above 90%, until four or more telephone calls (66.6% satisfaction, $p = 0.005$) and five or more total encounters (80% satisfaction, $p = 0.008$) (Table 3). The number of "extremely satisfied" patients progressively declined subsequently with each telephone encounter, again highlighting the cumulative effect an increasing number of encounters may have on satisfaction and the importance of preoperative efficiency when scheduling and medically clearing patients for outpatient, elective procedures. Importantly, this includes not only office visits, but also telephone contact with office staff.

When considered individually, there was no statistically significant association between patient satisfaction and the number of surgeon ($p = 0.267$) or medical clearance provider office encounters. These results suggest the type of encounter may be less significant than the number of encounters when considering satisfaction. However, the type of encounter should not be entirely ignored. Although lacking statistical significance in our patient series, the number of "extremely satisfied" patients steadily declined with each subsequent medical clearance encounter, with the largest decrease occurring between zero and one encounter (91% vs. 81% extremely satisfied patients, respectively). This downward trend of "extremely satisfied" patients as the number of medical clearance encounters increased may approach significance in a larger series. This is an important consideration for physicians who prefer to request medical clearance visits for even "minor" outpatient procedures, as this data supports the conclusion that while patients do not view this request as an major inconvenience, minimizing the number of encounters supports high satisfaction. A patient's perception of their health status was not significantly associated with their overall satisfaction ($p = 0.74$) (Table 5). Satisfaction rates were similarly high among all groups in the preoperative period, regardless of presence or lack of medical comorbidities.

There are several limitations of our study. First, our questionnaire was modeled from items of the Consumer Assessment of Healthcare Providers and Systems survey relevant to our study without separate validation of our scoring characteristics. This may limit the reliability and generalizability of our satisfaction measure. However, this is not inconsistent with previous investigations,[9] as validation of most satisfaction instruments is limited. Second, the previously validated items included[8] cannot be considered a full representation of the likely multifactorial contributors to pre-operative patient satisfaction. This further supports the need for development of a more thoroughly validated and widely applicable satisfaction instrument that would benefit future research on this topic. Additional questions not included here that may be appropriate for further study include specific determinants for those patients expressing dissatisfaction. Satisfaction rates within our population were high (183 patients or 92.9% extremely/somewhat satisfied) and, as a result, some of the conclusions of this study are based on a small number of patients (14 patients or 7.1% average/somewhat satisfied or dissatisfied). A multicenter approach in the future may be of benefit for increasing the number and diversity of patients as well as clinical and surgical locations to provide more robust and generalizable data.

In conclusion, greater than three telephone or four total personal encounters in the preoperative period significantly decreases patient satisfaction prior to elective hand surgery. The lack of an association between patient satisfaction and the number of surgeon or medical office encounters when considered individually further supports the concept that the number of encounters is more significant than encounter type. Communication experts emphasize quality over quantity of communication,[10] and prior investigations suggest patient-rated physician empathy rather than visit duration strongly correlates with the degree of overall satisfaction in an outpatient hand surgery setting.[6] Effective communication with patients has been shown to instill trust, strengthen patient-provider relationships, increase patient compliance and outpatient follow-up rates, while also decreasing complaints or litigation.[3] Efforts to make hand surgery office, telephone, and medical clearance provider encounters more patient-centered, with a focus on improving dialogue qual-

ity, may decrease unnecessary visits or patient contact that may negatively affect a patient's experience.

Conflict of Interest

The authors declare that they have no conflict of interest.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.[5] Informed consent was obtained from all patients for being included in the study.

Statement of Informed Consent

Informed consent was obtained from all individual participants included in the study.

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Original Research

Total Hip Arthroplasty in Untreated Ankylosing Spondylitis — Tips and Tricks to Avoid Complications

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Abstract

Ankylosing Spondylitis (AS) is a seronegative inflammatory disease that progressively affects the spine and sacroiliac joints and is more common in men with the B-27 human leucocyte antigen. This leads to inflammation, synovitis and, eventually, secondary arthritis in the hips of those affected. Hips of those affected are often completely ankylosed at time of presentation to the orthopedic surgeon. Total hip arthroplasty offers a stable mobile hip for patients who are functionally disabled due to their debilitating disease. As disease progresses, the native hip anatomy, which is familiar to orthopedic surgeon in routine THAs for OA, can be distorted by complete ankyloses. These surgeons must be aware of the unique technical challenges and considerations regarding anesthesia, OR setup, patient positioning, implant choice, and potential complications. The tips and tricks presented in this case provided the patient with a successful outcome due to careful planning and utilization of the describe technical pearls.

Introduction

Ankylosing Spondylitis (AS) is a seronegative inflammatory disease that initially affects the spine and sacroiliac joints, which leads to inflammation, synovitis and, eventually, secondary arthritis in the hips of those affected.[1] The etiology of the disease is unknown, but is associated with a group of diseases that are positive for human leucocyte antigen B27. Men are more commonly affected that women, with a male to female ratio of 3:1, and age of onset is between 15 and 25 years of age.[2] The earlier age of onset, the more likely the disease leads to ankyloses of the hip through inflammation of tendinous attachments to the hip, leading to fibrosis, calcification, and complete ankyloses. Hip involvement affects 30–50% of those affected with AS, and 90% of these patients have involvement of bilateral hips.[3] Severe functional impairment is seen in 30% of those with disease affecting the hip.[3]

Total hip arthroplasty (THA) offers a stable, mobile hip for those with AS whose lives are severely affected and experience limitation in activities of daily living as they are unable to participate in actions that involve hip flexion.[4] The goals of THA are to provide increased range of motion, improve flexion contracture, aid in pain relief, and correct postural deformities.[3] Indications for THA include pain, postural, and functional disability.

Surgeons must be aware of the unique technical considerations and challenges in regards to anesthesia, operating room preparation, operative technique, implant choice, and outcomes that differ from conventional primary THA. The patient presented in this series suffered from completely ankylosed bilateral hips at the time of arthroplasty, which is especially challenging for orthopedic surgeons with little experience operating on patients with AS.

Anesthesia Considerations

Deformities of the spine often compound hip involvement in those with AS. Fixed kyphotic deformities of the spine lead to flexion contractures of the hip, which limits a patient's ability to walk. This leads to severe functional impairment in approximately 30% of patients with hip involvement.[5] A flexed and rigid cervical spine offers a unique challenge to anesthesiologists who must manage the upper airway of patients.

Kyphotic deformity of the thoracic spine leads to pulmonary restriction, which can lead to atelectasis and pneumonia in the perioperative period. Therefore, it is recommended patients undergo pulmonary function tests prior to THA.[3] It is also advised that patients have an echocardiogram to evaluated baseline valvular disease that can be caused by AS.[6] HLA B27 cardiac syndrome is comprised of conduction disturbances, aortic insufficiency, and compromised LV function.[1]

A rigid cervical spine can lead to injuries and difficult intubation. Arthritis of the cervical, temporomandibular, and cricoarythenoid joints can lead to hyperextension injury and is the most common site for fractures in AS.[7] However, complications are not limited to the cervical spine. Two case reports of paraplegia after thoracic hyperextension injuries during THA serves as a reminder that extremely care must be taken in positioning and transferring in patients with AS.[7] Cervical, thoracic and lumbar radiographs must be obtained prior to surgery to prevent complications. Based on the literature, the risks and benefits of undergoing general anesthesia should be considered and discussed in this patient population as they are at an increased risk for major complications.

Surgical Techniques and Considerations

A completely fused hip, as seen in the patient presented, offers a unique challenge to orthopedic surgeons and a special operative technique must be employed in these situations. Bilateral hip involvement and flexion contractures can make positioning especially difficult while draping the sterile field. Adequate visualization of the femoral neck head junction is of paramount importance. It is recommended that patients be positioned in the lateral decubitus position and that a standard posterior lateral approach be utilized.[4] No data exists in the literature using alternative approaches to the hip in patients with AS. Subperiosteal dissection should clear the femoral neck of all soft tissues in order to visualize the lesser trochanter and Hohmann retractors must protect the sciatic nerve to prevent iatrogenic injury.[4] The femoral neck cut is made *in situ* to allow external rotation of the femur. Babe et al. suggests removing a small sliver of the posterior acetabular wall or making a second anterior incision to make the neck cut in completely ankylosed hips,[8] although this was not necessary in our case. A circumferential capsular release is often required to allow anterior retraction of the femur. There is a paucity of literature regarding femoral neck visualization using approaches other than the posterior lateral approach.

Once the femoral cut is made *in situ,* the surgeon can proceed with removal of the femoral head from the acetabulum. Initially, the head can be split into pieces with an osteotome. Intraoperative fluoroscopy or radiographs can also be used as a guide to ensure that the acetabulum is spared. A rongeur is used to remove the femoral head fragments in a piece meal fashion to identify the acetabular fossa. Often the foveal soft tissues remain, which helps the surgeon identify the original joint line and assists in confirming the appropriate depth of reaming.[3] Intraoperative radiographs may be utilized if these landmarks are difficult to identify.[9]

The surgeon must remain cognizant of the potential pelvic obliquity which can lead to malposition of the acetabular component. Patients with hyperextension of the pelvis secondary to fixed kyphotic spinal deformities are at risk for anterior dislocation of the hip.[3, 10, 11] Tang et al. found that hyperextension of the pelvis can lead to excessive anteversion and that patients with more than 20 degrees of sagittal malrotation can cause the cup to be placed in up to 30 degrees of anteversion and 55 degrees of inclination.[10] Bhan et al. suggested using a bone spike at the superolateral part of the acetabulum as a tool for abduction of the acetabular component. The spinal deformities noted above lead to a sagittal imbalance that put higher stresses on implants in ADLs during activities of flexion and extension and lead to high rates of posterior dislocations.[10] A posterior approach to the hip increases the rates of posterior dislocation in the general population. Alternative approaches to the hip in patients with AS would help mitigate this risk if such approaches allow adequate exposure.

Literature review indicates that almost all surgeons use a posterior lateral approach in this patient population. This finding warrants future studies to find if alternate approaches could decrease rates of posterior dislocation in this patient population. Based on the data, we recommend using a posterior approach in order to provide the best exposure to the hip. Despite the high rates of dislocation, a paucity of data exists using alternative approaches.

Contracture releases are often required before trial reduction. Circumferential capsulotomy, adductor tenotomy, gluteus maximus release, and iliopsoas muscle release can aid in relieving the severe flexion contractions found in ankylosed hips,[3, 12, 13] although in our case there were no soft tissue contractures noted.

Cemented vs. Uncemented

Patients with fused hips opt for THA at a younger age than the general population. Young patients are expected to have increased rates of loosening and wear of components due to higher levels of activity and longer life span than older patients with osteoarthritis.[14] Therefore, it is important to determine if these patients fare better with cemented or cementless components. Several authors have examined the use of cemented compared to cementless arthroplasties.[14–16] Tang et al. reviewed the outcomes of 46 cemented and 49 cementless THAs and compared survivorship. Mean age at the index procedure was 38.9 years and 60% of the patients were under the age of 40.[10] The authors found the survival of cemented prostheses was 100% at five years, 97.7% at 10 years, and 66.5% at 15 years.[10] Cementless component survivorship was 95.5% at five and 10 years, but only 66% at 11 years.[10] The authors noted that the temporal difference in utilization as cemented arthroplasties were used primarily in the early stages of the study due to limited availability of cementless stems.[10]

Sochart et al. examined long-term outcomes of 23 patients (43 THAs) with AS between 1966 and 1978 treated with cemented THA. Average patient age at the time of THA was 28.8 years. At an average of 22.7 years follow-up, 88% of the femoral components and 74% of the acetabular components had survived.[17] Kaplan Meier analysis found the probability of survival was 91% at 10 years, 73% at 20 years and 70% at 30 years.[17] This study showed acceptable longevity of cemented implants. Bhan et al. retrospectively reviewed the outcomes of 92 hips (54 patients) who underwent cementless THA between 1998 and 2002. Average patient age at the index procedure was 25.5 years and average follow-up was 8.5 years. Eighteen hips were characterized as being completely ankylosed on plain radiograph, the rest were deemed to have varying degrees of bony ankyloses.[18] Harris hip score improved from 49.5 to 82.6 postoperatively and survivorship was 98.8% at five years and 85.8% at 8.5 years, with the most common cause of failure due to aseptic loosening.[18] Saglam et al. analyzed the outcomes of 61 AS

patients (105 hips) from 1997 to 2012 of 22 cemented and 83 cementless total hip arthroplasties in 61 patients, whose average age was 41 years. Eighteen percent of cemented and 8% of the cementless arthroplasties showed signs of aseptic loosening at mean follow-up of 5.4 years.[16] Shih el al. studied the outcomes of THA in cemented (52) and cementless (22) arthroplasties for patients with AS. The group found that 15 (28%) of the cemented arthroplasties and (5%) of the cementless arthroplasties showed evidence of aseptic loosening at 10-year follow-up.[15] The authors recommended using cementless arthroplasty based on their findings but were unable to make any definitive conclusions.

A recent meta-analysis by Goyal el al. examined 917 THAs in 585 patients, 351 (39.7%) of which were cemented, 501 (56.6%) uncemented, and 33 (3.7%) hybrid. The group found failure requiring a revision was needed in 90 cases (11.9%). Aseptic loosening was found to be the primary cause of failure and was more likely to occur on the acetabular side than the femoral side.[19] The meta-analysis did not examine failure rates of cemented and cementless arthroplasty individually; however, the authors noted a trend towards the use of cementless constructions over cemented constructs over the past 15 years, which could be attributed to surgeons' familiarity with cementless constructs and increased use in all patients undergoing THA for osteoarthritis (OA).

Based on the literature available, we would recommend using cementless arthroplasties in most situations. Most surgeons are more familiar with this implant vs. hybrid and cemented components. Using cementless implants make revision surgery less challenging, and is often eventually needed in this younger patient population who put higher stresses on implants due to increased activity. Studies indicating higher success rate of cemented arthroplasty were published before cemented arthroplasty technology had evolved and surgeons were less familiar with their use. Patient with AS undergoing THA tend to be younger and more active than the standard patient undergoing THA for routine OA and, therefore, are more likely to undergo a revision surgery in their lifetime.

Heterotopic Ossification

Clinically significant HO remains a devastating consequence for AS patients who hope to maintain their regained mobility after THA. Efforts at identifying risk factors for HO development, as well as optimal prophylactic treatment have become the focus in efforts to thwart this complication. It is unclear if those with AS are predisposed to the development of HO beyond the risk of the general population undergoing THA for OA. Brinker et al. reviewed radiographs of AS patient undergoing primary cementless THA with an average follow-up of 75 months. Six of 14 hips in AS patients and 43 of 49 hips in non-AS patients demonstrated HO formation; all received care from the same surgeons at the same institution. The authors suggested that routine HO prophylaxis is not indicated for primary THA in AS patients based on their findings, and that AS patients were not at increased risk.[20] Resnick et al. examined the radiographs of 21 hips in AS patients after THA and found clinically significant stage 3 and 4 Brooker HO in 11/21 hips.[22] Based on radiographic criteria, they deemed nine out of 11 cases "complete re-ankyloses."[22] However, all components were cemented as this study was conducted in 1976.[22] Thilak et al. aimed to identify risk factors of HO formation after THA in patients with AS. The authors analyzed radiographs of 47 hips in 24 patients and found that a preoperative ankylosed hip was a significant risk factor for HO development.[21] Elevated preoperative ESR and CRP were identifies as significant modifiable risk factors for the development of HO and the authors suggest measures to reduce inflammation before THA in AS patients may be beneficial.[20] Goya el al. performed a meta-analysis reporting on outcomes of THA in AS patients. The group found that overall incidence of any detectable HO on radiograph was 27.73%; however, clinically significant HO, defined at Brooker stage III or IV, fell to only 4.5%.[19] This review included studies with and without routine HO prophylaxis. Only six cases of complete re-ankyloses secondary to HO were reported.[19]

We recommend prophylactics measures for HO to be utilized in all patients undergoing TKA with AS. The increased trauma to soft tissue structures from contracture release and the genetic predisposition of these patients to aberrant bone formation warrant the use of preventive measures such as indomethacin and post-operative radiation to help mitigate this often devastating complication. We recommend using standard prophylactic measures of indomethacin for six weeks, and one treatment of radiation therapy within five days post operatively.

The majority of studies describe using a posterior approach to the hip in patients with AS. There is a paucity of data regarding alternative approaches, which warrants further studies to determine if other approaches would allow adequate exposure in ankyloses hips and have lower rates of HO formation. The posterior approach to the hip has the highest rate of HO formation in the available literature in patients without AS. A randomized controlled trial comparing a posterior approach vs. alternative approaches could shed light onto whether or not less traumatic approaches could allow satisfactory exposure and cut down on rates of HO in this population.

Case Report

An 18-year-old male presented to a charity hospital in the city of Kijabe, Kenya, Africa with complaints of bilateral hip pain and difficulty ambulating. Pre-operative function of his hips was very limited, with no motion present through the hip on both the right and left side. Pre-operative AP pelvis showed bilateral fused hip joints without presence of joint

space (Figure 1). The decision was made to undergo bilateral total hip arthroplasty (THA) in a staged fashion, with the right hip being done first, followed by the left hip three months later.

On the day of surgery, the patient was brought to the operating room. Positioning is difficult in these patients due to fused hips, and extreme care has to be taken to ensure sterile drape application and to prevent fracture. The patient was placed in a lateral position with Stuhlberg hip clamps on the anterior pubic symphysis and sacrum (Figure 2). A standard posterolateral approach was utilized. Due to the ankylosed hips, a circumferential capsular release is required to allow anterior retraction of femur. The lesser trochanter (LT) was then visualized through appropriate dissection of the soft tissue and measurements were made for the femoral neck cut. It is our recommendation to make the femoral neck cut a generous fingerbreadth proximal to lesser trochanter. The cut was made with the femoral head *in situ* and the head was removed (Figures 3 and 4). As a note, the femoral head typically is softer cancellous bone and the change in bone density can be noted as one reaches the acetabulum. The fragments were removed with a rongeur, and the fossa was identified (Figure 5). Once the fossa is identified, the surgeon can be assured of the anatomy and proceed much like a

Figure 1. Patient's preoperative X-ray demonstrating a completely ankylosed hip.

Figure 2. Picture demonstrating the lateral position with Stuhlberg hip clamps on the anterior pubic symphysis and sacrum.

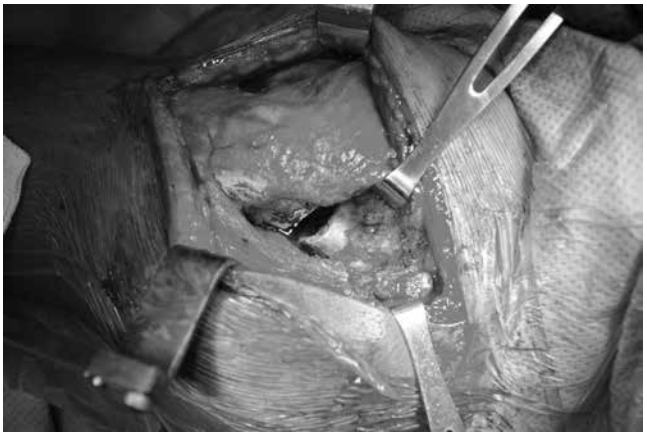

Figure 3. The patient's femoral neck cut was made *in situ.*

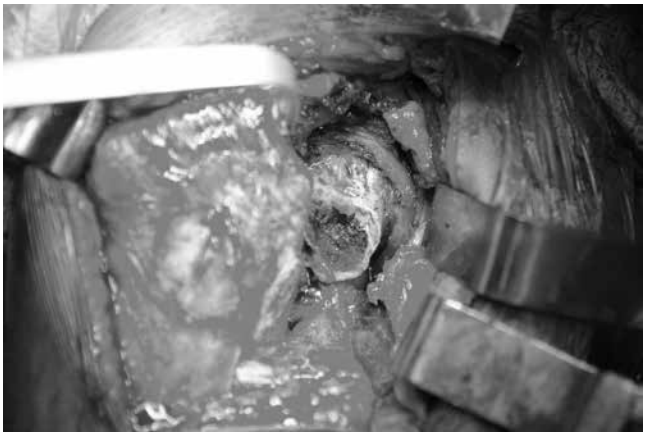

Figure 4. The femoral head was completely fused to the acetabulum on close-up.

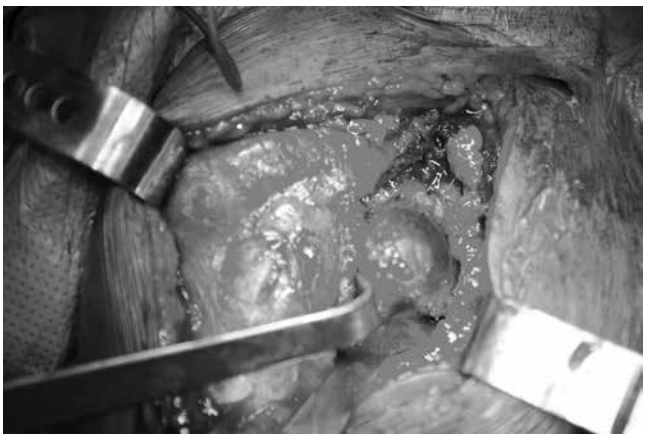

Figure 5. The acetabulum was reamed in standard fashion once the fossa was identified.

standard THA. The acetabulum was then reamed, leaving parts of the femoral head in the acetabulum, in the standard fashion using previously identified visual landmarks to an appropriate size (Figure 6). A 48-mm cup was placed in the acetabulum in a standard fashion (Figure 7). Following that, the femoral stem placement proceeded in a standard fashion (Figures 8 and 9). An uncemented, hydroxylapatite coated press-fit stem was used with a cobalt chromium 28 mm +5 head. It is important to note in this patient that once released off the femur, the soft tissues were not contracted at all and it was quite easy to retract the femur during acetabular exposure. Once reduced with final hardware in place, the hip also had an excellent range of motion (Figure 10). Post-operative radiographs showed good positioning of the implant (Figure 11). Three months later, the patient underwent the same procedure on the left, again producing a well-aligned hip with good range of motion (Figure 12).

Conclusion

Patients presenting to surgeons with completely ankylosed hips secondary to ankylosing spondylitis offer a unique challenge to surgeon who may be inexperienced working with this patient population. Surgeons must understand and anticipate challenges in order to adequately prepare for THA. Our case presentation and review article highlight the technical considerations and challenges in regards to anesthesia, operating room preparation, operative technique,

Figure 8. Following the insertion of the liner, the femoral stem was placed in a standard fashion.

Figure 6. The cup was inserted in a standard fashion.

Figure 9. Following the insertion of the liner, the femoral stem was placed in a standard fashion.

Figure 7. A 48-mm liner was used for the patient, placed in a typical fashion.

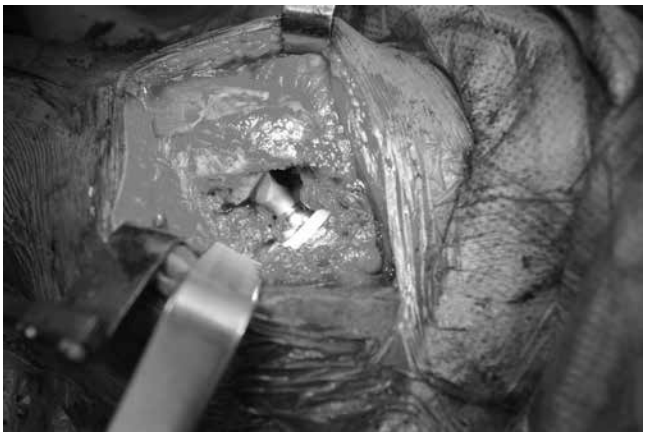

Figure 10. The hip had excellent range of motion after all hardware was placed.

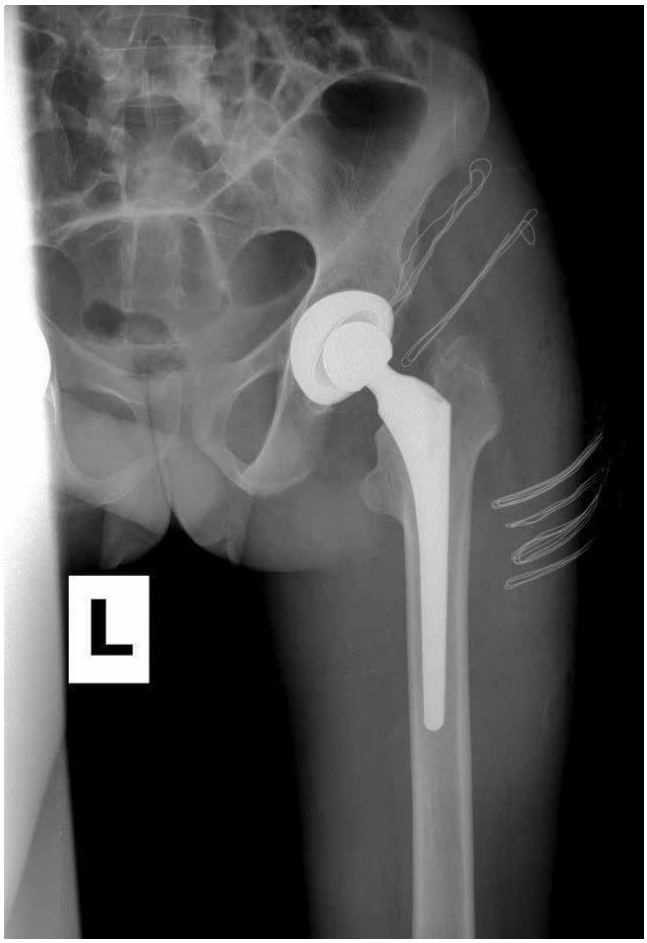

Figure 11. Radiographs taken postoperatively showed good position of implants.

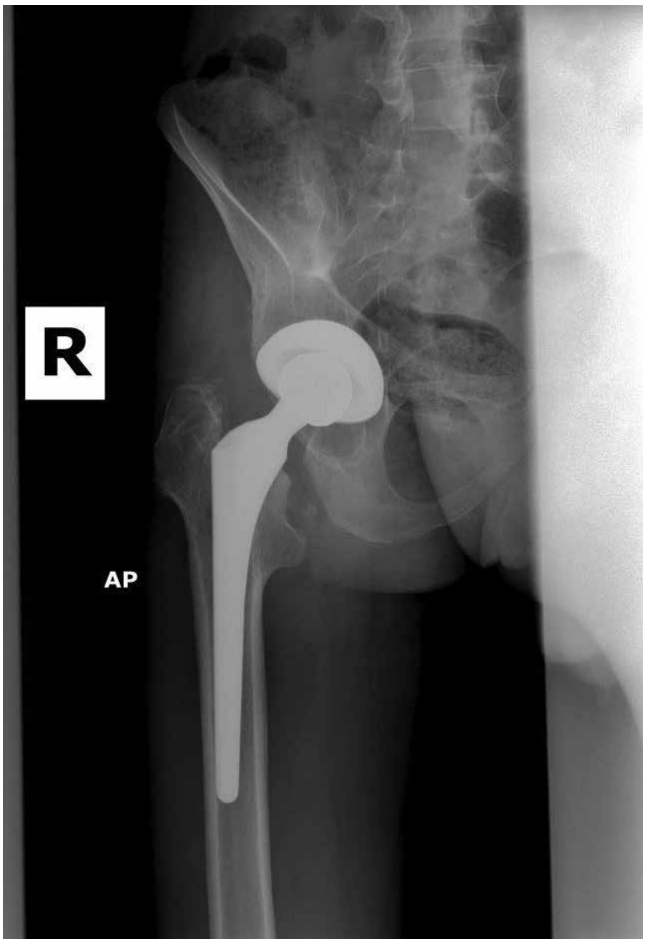

Figure 12. Three months after the index procedure, the patient underwent the same procedure on the left, again producing a well-aligned hip with good range of motion.

implants chosen and outcomes that differ from conventional THA. This can serve as a tool for an inexperienced surgeon who must remain cognizant of the unique challenges faced in THA in patients with AS.

Literature review demonstrates the need to study alternative approaches to the hip that may lead to decreased rates of heterotopic bone formation. Most of the literature available describes a posterior approach to the hip. A recent meta-analysis found that at two years post op, the relative risk of posterior hip dislocation in those with AS was 1.47 compared to control.[23] The study also found the relative risk of revision in early perioperative period was 1.42, which can be attributed in part to higher dislocation rates.[23] A prospective randomized study is needed to examine if alternative approaches would decrease rates of dislocation and HO, both of which contribute to subsequent surgical interventions after primary THA in patients with AS.

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Original Research

Incidence of Infection in Civilian Gunshot Arthrotomies: Does Formal Joint Washout Make a Difference?

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Abstract

Objectives: To determine if the incidence of joint infection is lower in patients with civilian gunshot arthrotomies treated with surgical irrigation and debridement (I&D) as compared to patients treated with antibiotics alone.

Design: Retrospective review.

Setting: Single urban level-1 trauma center.

Patients/Participants: All patients with gunshot arthrotomies of shoulder, hip, and/or knee treated between January 2008 and December 2016.

Intervention: Review of gunshot arthrotomy treatment methods with either antibiotics and surgical I&D or with antibiotics alone.

Main Outcome Measurements: The presence or absence of septic arthritis after at least three weeks follow-up.

Results: Ninety-four gunshot arthrotomies in 93 patients met the final criteria. Of those joints, 82.98% (78/94) were treated with antibiotics and formal I&D, with or without fracture fixation, 14.89% (14/94) of joints were treated with antibiotics alone, and 2.13% (2/94) were treated with antibiotics and fracture stabilization without I&D. There was no incidence of infection in any cases regardless of treatment at any point in follow-up (0/94; $p > 0.05$).

Conclusions: The incidence of infection is low in traumatic arthrotomies of the hip, shoulder, and knee due to civilian gun missiles when patients are treated with IV antibiotics with or without formal I&D. In cases in which there are no mechanical indications for surgical debridement (retained intra-articular missiles or bony debris), it may be safe to treat patients with IV antibiotics alone to prevent infection.

Level of Evidence: Level IV retrospective case series.

Introduction

Traumatic arthrotomies secondary to low-velocity gunshot injuries are relatively common in urban hospitals. Of the over 79,000 nonlethal firearm injuries in the United States each year, injuries to the extremities account for 77% of unintentional and 49% of assault-related gunshot injuries.[1, 2] Involvement of large joints (shoulder, hip, and knee) has been reported in about 17% of these injuries.[3] Therefore, it is important that the clinical burden of gunshot injuries to joints is understood and that the treatment strategies are evidence-based.

It is well documented that a bullet left in communication with joint fluid can result in the release of lead deposits locally, resulting in chondrolysis, periarticular fibrosis and hypertrophic arthritis.[4, 5] Additionally, systemic lead toxicity has been reported.[6–8] Retention of a missile or loose bony fragments in the intra-articular space can cause mechanical symptoms, cartilage damage, and ultimately, post-traumatic arthritis. Therefore, in circumstances in which there is debris (foreign or native) in the joint space following a gunshot arthrotomy, formal surgical irrigation and debridement (I&D) is necessary to prevent further morbidity.[9, 10]

Common practice in the literature, and at our own institution, is to perform a formal I&D of the joint in all traumatic arthrotomies to decrease the risk of infection, regardless of the presence of intra-articular loose bodies.[11–13] This practice is justified in the setting of transabdominal joint penetration, large overlying soft tissue injury, high-energy ballistics, or gross contamination of the wound.[14–18] What is unclear, however, is the incidence of infection of low-energy gunshot arthrotomy without intra-articular debris or obvious contamination following non-operative treatment. With limited investigation into this outcome in the literature, it would appear that the obligate formal washout of the joint in these circumstances is based on a theoretical risk of infection.

The purpose of our study is to determine the incidence of joint infection following treatment of a large joint (knee, hip, and shoulder) gunshot arthrotomy. Specifically, our interest is to evaluate whether there is a difference in the rate of infection depending on whether a formal washout was performed or whether non-operative treatment was pursued.

Methods

Approval was obtained from our University's Institutional Review Board to perform a retrospective chart review on all gunshot arthrotomies evaluated at our institution from January 1, 2008 to December 31, 2016. The chart review was conducted via CPT-10 codes searched using our electronic medical record, as well as a cross-reference with our ortho-

paedic department's electronic record-keeping system. Large joint (knee, shoulder, and hip) arthrotomies were the focus of this study. Gunshot arthrotomies were defined as a missile directly penetrating joint capsule and diagnosed clinically via fluid challenge or radiographically via intra-articular air or missile fragments on computed tomography (CT) scan with a missile trajectory consistent with direct joint penetration. Periarticular gunshot fractures in which a missile did not violate the joint but air was indirectly introduced into the joint via fracture were excluded. Additional inclusion criteria were age 18 years or older with at least three weeks of follow-up in the outpatient setting after discharge from the hospital. Patients were excluded if they had incomplete imaging, documentation, or follow-up. High-energy or military-style gunshot injuries were excluded, as were shotgun injuries.

The medical record was reviewed for the following information: age, sex, joint(s) involved, method of arthrotomy diagnosis, presence of intra-articular missile or missile fragments, antibiosis (timing, route, and duration), whether or not a formal irrigation and debridement (I&D) was performed in the operating room during the hospital stay, whether or not the fracture required internal fixation and what type, and whether a septic joint or soft tissue infection was diagnosed at any time point in the hospital or after discharge. The first author reviewed all imaging to confirm the presence of intra-articular native or foreign loose bodies. Figure 1 demonstrates examples of CT images depicting bony debris and a bullet in the joint space. Gunshot wound size and degree of contamination was inconsistently documented in our medical records; therefore, this information was not collected or included. However, the vast majority of gun trauma that is treated at our institution is the result of low-energy weapons, with smaller (<1–2 cm) gunshot wounds.

The status of infection was determined based on documented physical exam of wound and skin appearance, drainage, joint effusion, joint range of motion, and/or increasing pain. The medical records were searched for whether subsequent joint aspiration or I&D of the joint was needed for infection concern, whether positive synovial fluid cultures were obtained, or whether a second course of therapeutic antibiotics was prescribed beyond the initial prophylactic doses.

Figure 1. Figure 1A demonstrates a representative computed tomography (CT) image of an intra-articular gunshot injury of the knee resulting in fracture fragmentation into the joint space. Figure 1B demonstrates a CT scan image of a retained missile in the acetabulum that is in continuity with the hip joint.

Results

Ninety-three patients with 94 affected joints met final inclusion criteria. The average age was 29 years old (range: 18–62). Males constituted 94.7% (n = 89) of the included patients. The knee was the most common large joint involved (n = 61), followed by hip (n = 23) and shoulder (n = 10) (Figure 2). One hundred percent of patients received intravenous antibiotics for at least 24 hours starting upon admission. Every patient was given cefazolin unless there was an allergy to the penicillin class of medications, in which case clindamycin or vancomycin was provided at the discretion of the primary management team. Ten patients received additional coverage for gram-negative organisms due to concurrent abdominal injuries, while two other patients received additional antiobiosis for pulmonary concerns.

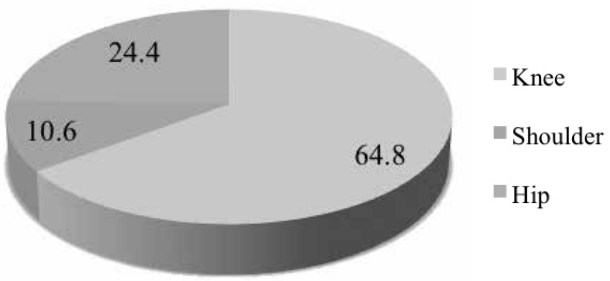

Figure 2. Chart demonstrating the percentage of each joint type comprising the total number of arthrotomies studied.

Of the 94 arthrotomies, 78 (83%) were treated with formal I&D within 24-hours of admission. Fourteen arthrotomies (14.9%) were treated non-operatively, and two (2.1%) were treated with fracture fixation without joint washout (Figure 3). Knee arthrotomies were more commonly treated surgically with formal I&D than were arthrotomies of the hip or shoulder, 95.1% vs 65.1% and 50%, respectively. Three arthrotomies of the hip were presumed to have bowel contamination, and all three were treated with surgery as well as antibiosis for enteric organism coverage.

Intra-articular loose bodies (bony fragments and/or missile debris) were present in 70.2% of affected joints (n = 66). Of those joints with intra-articular loose bodies, 93.8% were treated with formal I&D (the remainder treated conservatively), while only 60.7% of joints without loose bodies were treated with I&D (Figure 4).

There were zero infections of the joint or surrounding soft tissues of any of the 94 joints at any time point in the mini-

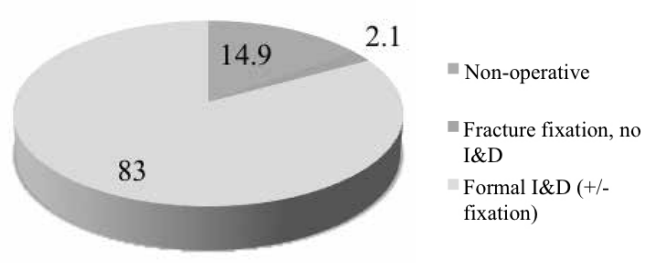

Figure 3. Chart demonstrating the percentage of arthrotomies (from all joint types) managed with each treatment type.

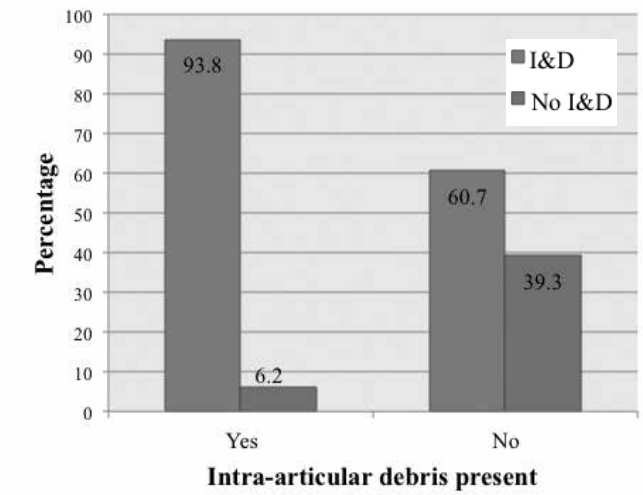

Figure 4. Graph depicting the percentage of cases that were managed with either I&D or no I&D based on the presence or absence of intra-articular debris.

mum three-week follow-up ($p > 0.05$). No patients required further antibiosis for joint or soft tissue concerns and none required joint aspiration or subsequent irrigation and debridement of the affected joint.

Statistical Analysis

Statistical significance for a difference between the two treatment arms (non-operatively vs. I&D) was determined at $p < 0.05$. Given that our data revealed zero infections in both groups, a p-value cannot be directly calculated. However, if one missed infection is assumed in the non-operative group, the p-value would be $p = 0.17$. Because we had less than one infection, we can presume $p > 0.05$, and that there is no statistical difference between the groups.

Discussion

A review of the literature shows several small studies that have results in concordance with our minimal infection rate with non-operative treatment. In a case series of 53 patients with intra-articular gunshot injuries to the hip, Long et al. treated 15 patients with antibiotics alone.[19] The criteria for non-operative treatment were low-energy gunshots, no passage of the bullet through abdominal organs prior to entering the joint, no retained bullet in communication with synovial fluid, and a stable fracture that does not require internal fixation. There was no evidence of septic arthritis in these 15 patients at follow-up. Recently, Nguyen et al. published a series of 55 patients with gunshot arthrotomies to major synovial joints (hip, knee, shoulder, wrist, ankle), 23 of which were treated with only antibiotics.[20] Similarly, none of these non-operative patients developed a joint infection. A review by Volgas also agrees that bullets from low-energy weapons that penetrated the joint but did not penetrate bowel, leave retained metal fragments in the joint, or cause bony articular debris may be treated with antibiotics alone.[10] Given this data in conjunction with our findings, it may be safe to treat patients with antibiotics alone in the setting of gunshot arthrotomy if there is no or minimal intra-articular debris or gross contamination.

A secondary finding of our study was that knee gunshot arthrotomies were more likely to be treated surgically than those of the hip or shoulder (95.1% vs. 65.1% and 50%, respectively). We suspect this may be due to the relative ease of access of the knee joint and on-call surgeon familiarity with both open and arthroscopic approaches to the knee, as compared to the other two joints. Additionally, gunshot injuries to the hip and shoulder may be more often associated with thoracic or abdominal visceral injuries, due to anatomic proximity, that preclude timely orthopaedic intervention for the arthrotomy, thus necessitating a non-operative treatment course.

Because there was no difference in infection rates between patients treated operatively or non-operatively, we did not choose to make a distinction between arthroscopic and open joint I&D. However, there is data to support that either technique is effective.[21–30]

There are several limitations of our study. The lack of adequate post-discharge follow-up for our patient population severely limited the number of patients we were able to include. With the overall incidence of infection in all-comers with gunshot arthrotomy being very low (exact incidence unknown), our 16 patients in the non-operative treatment arm do not provide adequate power for this investigation. Secondly, we found wound size or degree of contamination from external environment to be inadequately documented in the medical record and, therefore, it was not taken into account for this study. This omission has the potential to increase inconsistent results. However, the majority of the gunshot injuries treated at our institution are from low-energy weapons, producing relatively small (<1–2 cm) wounds. Larger wounds are rare and taken seriously; large wounds overlying an arthrotomy are and should be irrigated and debrided in a formal setting.

In conclusion, consideration for non-operative treatment should be made for gunshot arthrotomies if there is no gross contamination or loose debris intra-articularly, as we experienced zero infections in 16 patients treated with 24 hours of intravenous antibiotics alone. Additional studies with more

patients and eventually with prospective design are needed to further establish an evidence-based treatment algorithm for these injuries.

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Original Research

Plantar Plate Reconstruction for Stage IV Plantar Plate Tear Using Flexor Tendon Tenodesis

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Abstract

Background: Outcomes of the surgical treatment of dislocated lesser toes have improved significantly over the past few years due to the development of techniques to repair plantar plate tears through a dorsal incision. However, treatment of Stage 4 tears with no reparable plantar plate can be challenging. The current treatment involves flexor to extensor tendon transfer, requiring multiple incisions and additional surgical time. An alternative approach is presented using the same modern techniques of plantar plate repair but reconstructing the plantar plate using a flexor tendon tenodesis to the plantar base of the proximal phalanx.

Methods: Four fresh frozen cadaver foot and ankle specimens were used to determine the stability of this new technique. A simulated Lachman's test was performed on the 2nd, 3rd, and 4th metatarsophalangeal joints utilizing a force measurement instrument with displacement control on specimens with an intact plantar plate, an excised plantar plate, and following a flexor tenodesis reconstruction.

Results: The intact plantar plate force was 9.0 ± 2.6 kN for 2 mm displacement, and following excision of the plantar plate, the force reduced to 1.3 ± 0.4 kN. The flexor tenodesis reconstruction improved the force to 6.0 ± 1.9 kN.

Conclusion: Plantar plate reconstruction with a flexor tenodesis to the proximal phalanx resulted in stability equal to 53% of the intact plantar plate, for the shear displacements between 2 to 6 mm. This procedure may be an alternative treatment option in patients with Stage 4 irreparable plantar plate tears.

Introduction

Plantar plate repair has had a significant impact on the treatment of lesser toe deformities, resulting in better outcomes.[10] Repair of the plantar plate has now become the standard of care for metatarsophalangeal degenerative subluxation and dislocation.[1–2, 4–7] The repair of the plantar plate can be from a dorsal or plantar approach.[4] The dorsal approach avoids the risk of a painful plantar scar and, with the advent of newer instrumentation, has now made it easier for surgeons.[3, 10] Most foot and ankle surgeons are now quite familiar with this approach and typically plan on being prepared for a plantar plate repair whenever reducing a dislocated toe. This works well for Stage 1–3 plantar plate tears, which are amenable to primary repair of the plantar plate.[4–7, 9–10]

When a Stage 4 complex irreparable plantar plate tear is encountered, an alternative repair is required. Historically, a flexor tendon to extensor tendon transfer is performed.[6, 8, 10–11] This has been shown to have acceptable outcomes and provides good restoration of the joint stability. However, this requires more incisions and additional surgical time along with abandonment of the anticipated standard plantar plate repair.

A novel approach to reconstruction of Stage 4 plantar plate tears is to perform a tenodesis of the flexor digitorum longus tendon to the plantar base of the proximal phalanx. This would be accomplished using the same instrumentation and dorsal approach as is done with a standard plantar plate repair. Once the surgeon exposes the plantar aspect of the joint, if the plantar plate has completely degenerated and is irreparable, then the surgeon is looking directly at the flexor tendons. There would be no need to alter the surgical procedure, other than to pass sutures through the flexor tendon, rather than through the plantar plate.

The purpose of this study was to determine the stability of the metatarsophalangeal joint after reconstruction with a flexor tendon tenodesis to the plantar base of the proximal phalanx. Our hypothesis was that the flexor tendon tenodesis would restore a significant amount of the stability of the metatarsophalangeal joint. Based upon the results of the study, surgeons may consider doing this procedure for Stage 4 plantar plate tears rather than performing a tendon transfer.

Methods

Four cadaveric fresh frozen below the knee specimens were obtained through proper protocol (Science Care, Phila-

delphia). The ages of the donors were 55 to 94. There were three male and one female specimens. Each foot was dissected to expose the extensor digitorum tendons and the metatarsophalangeal joint on the dorsal aspect and subsequently the flexor tendons and plantar plate of the metatarsophalangeal joint on the plantar aspect. To perform a simulated modified Lachman dorsal drawer test, a 3.0 mm cortical screw was placed in the mid-shaft of the proximal phalanx. The specimens were mounted to a mounting plate fitted with an inverted screw through a hole drilled in the second metatarsal shaft, and this was held down with a U-shaped washer which cradled the bone and then tightened with a nut. The specimen on the mounting plate was clamped down onto an electromechanical testing machine [Tinius Olsen, Horsham, PA, capacity 50 kN (5000 kg/10000 lbf)] (Figure 1). Vertical shear was measured continuously as 6 mm displacement was applied at the rate of 8 mm/min. This displacement did not cause failure in the specimens. The tissue specimens were then removed from the machine and the plantar plate of each of the metatarsophalangeal joint was excised from the plantar incision. Shear forces with displacement control were again measured using the same electromechanical testing method.

In order to minimize confounding variables, the specimens in this study did not undergo a Weil osteotomy, and therefore the flexor digitorum longus tenodesis was performed plantarly (Figures 1 and 2). Shear forces with displacement control were again measured using the same electromechanical testing method.

This process was sequentially repeated to include the second, third, and fourth metatarsophalangeal joints of all four specimens.

Results

Of the original 12 toes to be tested (second, third, and fourth toes of four different specimen), one toe was discarded due to a proximal phalanx fracture, making the number of toes that completed all three measurements 11. Representative force-displacement data for intact and reconstructed toes of one specimen (Specimen 2) are shown in Figure 3. While some variability was observed in different toes, all toes showed similar change in the force due to reconstruction. The effect of the surgical procedures is demonstrated in one specimen (Specimen 3 toe 2) in Figure 4. As can be seen, the force vs displacement behavior is improved considerably at all displacement levels.

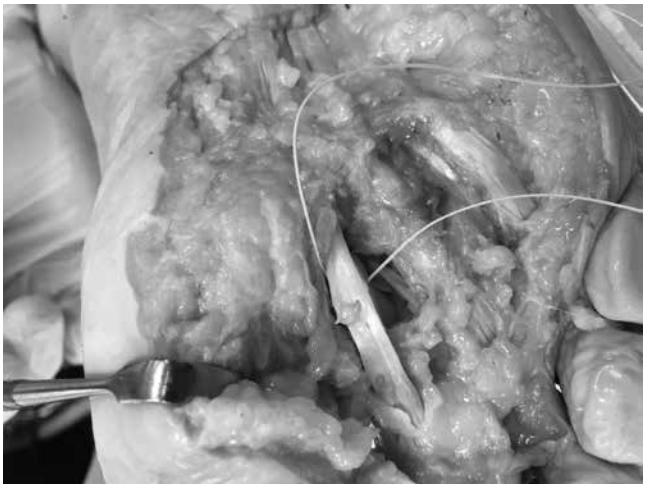

Figure 1. Tenodesis: suture through flexor digitorum longus prior to knot tie (plantar).

Figure 2. Tenodesis: suture is tied dorsally to complete the flexor tenodesis (dorsal; distal screw present for drawer testing).

Since the force vs displacement results were nonlinear, forces at 2, 4, and 6 mm displacement were chosen for comparison. The mean values of forces at these displacements with 95% confidence interval were calculated using Microsoft Excel and are summarized in Figure 5. At 2 mm of dorsal displacement, the intact force was 9.0 $\pm$ 2.6 kN, which was reduced in the resected plantar plate to 1.3 $\pm$ 0.4 kN and then restored by the plantar plate reconstruction with flexor tenodesis to 6.0 $\pm$ 1.9 kN. At 4 mm of dorsal displacement, these values were 19.4 $\pm$ 5.0 kN for the intact force, 2.1 $\pm$ 0.9 kN after resection of the plantar plate, and 10.0 $\pm$ 3.1 kN after the plantar plate reconstruction. At 6 mm of dorsal displacement, these values were 34.1 $\pm$ 10.1 kN, 3.4 $\pm$ 1.3 kN, and 13.8 $\pm$ 4.4 kN respectively.

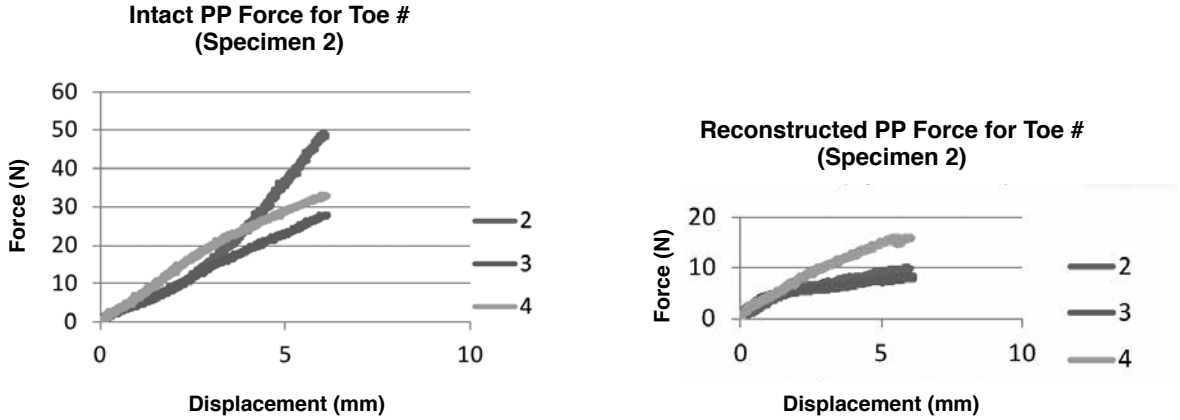

Figure 3. Representative force vs displacement data obtained for different toes in one specimen with intact (left) and reconstructed (right) plantar plate.

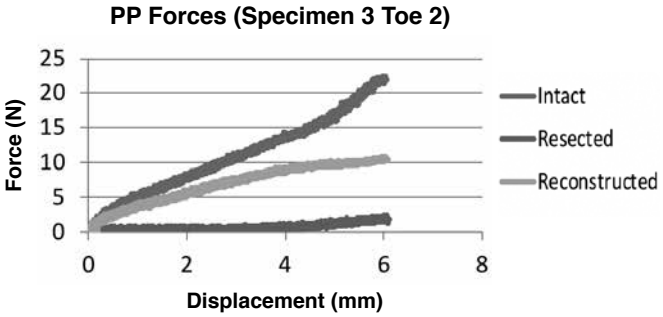

Figure 4. Representative force vs displacement data obtained for one specimen with intact, resected and reconstructed plantar plate.

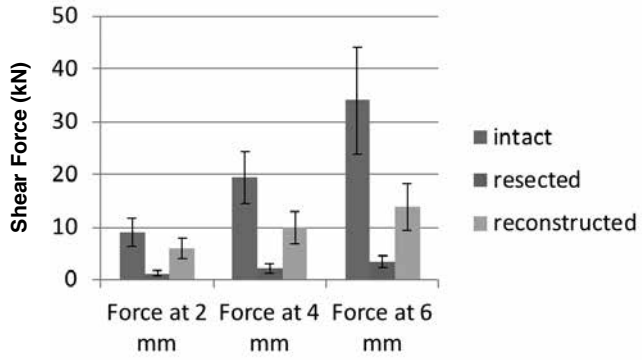

Figure 5. Mean force values at 2, 4, and 6 mm displacement. The error bars show the 95% confidence interval.

Multivariate Analysis of Variance (Manova) using JMP Pro (SAS Institute Inc., Cary, NC) showed that only the effect of plantar plate intervention is significant ($p < 0.01$, $N = 33$, $DFE = 27$). With the numbers available, no significant difference could be detected based on the toe number ($p = 0.275$).

Taking all tested toes into account, the paired t-test ($N = 11$) showed that all except one of the paired differences were statistically significance ($p < 0.01$). With the force at 2 mm, however, the intact and reconstructed data had a p-value slightly larger than the significance threshold ($p = 0.063$).

To analyze the effectiveness of the reconstruction, a restoring ratio was calculated by dividing the reconstructed plantar plate force by the intact force, which resulted in restoring ratio of 66 ± 28% at 2 mm displacement, 52 ± 21% at 4 mm displacement, and 41 ± 18% at 6 mm displacement. Based on the numbers available, no significant difference could be detected in the restoring ratio and the overall average restoring ratio for 2 to 6 mm displacement was 53%.

Discussion

Plantar plate repair has significantly improved the outcomes of degenerative lesser toe dislocation and subluxation. Stage 1–3 tears are amenable to this treatment, however, Stage 4 tears where the plantar plate is irreparable are not. The current treatment for Stage 4 tears is to perform a flexor tendon to extensor tendon transfer. Results with this procedure are acceptable, and cadaver studies support its ability to improve the stability of the joint.[8, 10–11] However, the tendon transfer requires additional exposure, and the surgeon cannot continue with the previously anticipated plantar plate repair. Instead of transferring the flexor tendon, a flexor tenodesis to the plantar aspect of the base of the proximal phalanx could be done. This would allow the surgeon to use the same instrumentation and approach as with doing a standard plantar plate repair, and would not add any additional steps or exposure to the procedure.

Dorsal metatarsophalangeal (MP) joint dislocation is typically treated with a shortening metatarsal Weil osteotomy.[9–10] This was not necessary in this study because the MP joint was already reduced in the cadaveric specimen. The addition of a repair of the plantar plate resulted in improved postoperative outcomes and lower risk for recurrence.[7, 9–10] For Stage 4 tears, however, the outcomes are poorer than for any other stage tear.[10] Therefore, rather than repair, a flexor tendon to extensor tendon transfer reconstruction is associated with better outcomes.[8–9, 11] In clinical practice, patient satisfaction can be variable, and post-operative outcomes can be associated with stiffness and swelling.[8–10] The deformity can

recur, or never be completely corrected, as Thompson et al. noted in their series with only 54% of those MP joint reconstructed with tendon transfer achieving complete correction. Still, the tendon transfer has been recognized as the most consistently effective way to reconstruct the plantar plate and correct the deformity associated with Stage 4 plantar plate degeneration. Part of the reasoning behind the efficacy of the tendon transfer is that a Weil osteotomy can change the center of rotation at the MP joint to convert intrinsic muscles to act as extensors and thus induce repeat subluxation or dislocation.[6] A tendon transfer can counteract these forces. A flexor tenodesis at the appropriate tension could also potentially counteract these forces.

Our cadaver study was performed to determine the stability of the metatarsophalangeal joint after performing a flexor tenodesis. For this purpose, the force vs displacement curves were determined in a simulated Lachman's test with up to 6 mm shear deformation. The same samples were tested with the plantar plate intact, after complete resection of the plantar plate, and after performing the flexor tenodesis. This allowed for conducting paired statistical analysis and eliminating the sample-to-sample variation. The force-displacement curves were nonlinear and the difference between the forces in intact and reconstructed cases slightly increased at higher displacements. However, on average, the flexor tenodesis restored 53% of the intact plantar plate stability. The actual stability in patients may be higher, since the flexor tendon would be expected to provide further dynamic stabilizing forces not present in a cadaver.

The main limitation of this study is that transfer of data from cadavers to patients needs to be done with caution. Although we were able to measure static effects of the flexor tenodesis, it was not possible to measure the effects of dynamic forces. Secondly, due to the lack of pliability of the cadaver tissues and avoiding a Weil osteotomy, we were unable to perform the tenodesis through a dorsal approach and, instead, it was completed through a plantar approach. Although this approach was different from what would be done clinically, the stability of the joint was assumed to be the same in either approach. Because the flexor tenodesis appears to be a viable option in reconstruction of a Stage 4 plantar plate tear, a future study could compare this technique with the traditional tendon transfer.

Conclusion

Tenodesis of the flexor tendon to the plantar base of the proximal phalanx restores 53% of the stability of an intact plantar plate for 2 to 6 mm shear displacement. The flexor tendon tenodesis may be an option for reconstruction of a Stage 4 plantar plate tear.

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Trends in Suicide Among Former American Football Players

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Abstract

A narrative exists in the popular media that American football players, particularly those in the National Football League (NFL), are at an increased risk for suicide. This narrative has been fueled by the increased understanding of chronic traumatic encephalopathy (CTE). However, much of the literature available in the scientific community does not support this narrative, and some directly contradicts it. The purpose of this paper is to investigate the link between suicide and American football. This was accomplished by identifying suicides among former NFL players since 1920. Additionally, a cohort of all NFL players since 1980 was established to evaluate recent trends. A total of 35 suicides were identified among former NFL players since 1920. Of these, 17 (49%) have occurred since 2010. Of the 14,153 total players identified as having entered the NFL between 1980–2017, 22 have committed suicide, giving a rate of 155.44 per 100,000. This study has identified recent suicidal trends among NFL players that warrant further investigation throughout the scientific community.

Introduction

The year 2012 was a grim look into what some argue is the future for many National Football League (NFL) players. A total of seven suicides were recorded among former players in 2012 alone, including the heavily publicized deaths of Hall-of-Fame linebacker Junior Seau[1] and Jovan Belcher.[2] Those that argue a connection between football and suicide mortality risk often point to the disease known as chronic traumatic encephalopathy (CTE). This neurodegenerative disease is thought to develop following repeated concussive and sub-concussive impacts to the head.[3] Suicide mortality risk increases as this disease progresses. Several case reports have been published linking suicide to those who play contact sports, especially football.[4, 5] Furthermore, Omalu and colleagues have published a series of autopsy reports on former NFL players linking them with CTE.[6–11] A result of these findings has been increased scrutiny from the media and general population about the potential dangers to the athletes playing football. This has manifested into lawsuits against the NFL,[12] and has caused the NFL to alter many of its rules in an effort to reduce the rate of concussions in its athletes.[13]

The NFL has not been the only league to feel the effects of this phenomenon. The recent deaths of Owen Thomas[14] and Kosta Karageorge[15] illustrate the sobering reality that CTE can manifest early in life. These college football players committed suicide at ages 21 and 22, respectively, and signs of CTE were found in both brains on autopsy. The uncertainty associated with CTE has even affected youth football, as participation rates have declined sharply in recent years.[16]

However, the scientific literature showing a clear connection between football and suicide has been lacking, and several articles actually show the opposite. Lehman and colleagues found that NFL players from 1959–1988 who played at least five years actually had a lower suicide rate than expected.[17] Many also argue the strong presence of a selection bias among those who submit their brains for study.

Suicide in athletes, at any level, garners a great deal of media attention due to the heightened awareness of the dangers associated with contact sports. However, the scientific literature on the link between suicide and football is conflicting. This paper will investigate the link between suicide and American football.

Methods

A procedure similar to that used by Webner and colleagues[18] was used to identify suicides in former NFL players. Relevant scientific literature was reviewed through queries on PubMed. The literature was obtained using search terms including "professional football suicides," "football suicides," "chronic traumatic encephalopathy and suicide," and "depression and football." Multiple internet searches were performed on search engines to identify suicide cases among former NFL players. Search terms included "NFL suicides" and "professional football suicides." Once individuals were identified, individual-specific queries were performed to confirm the cause of death and obtain published news reports and obituaries.

A cohort was then established using the Pro Football Reference database. All players in the NFL since 1980 were identified using the following settings on the player index: "Years 1980–2017," "League NFL," "Year of Player's Career 1st-1st." The suicide data of players whose career started in 1980 or later were compared to this cohort to establish a suicide rate.

Results

A total of 35 suicides were identified among former NFL players from 1920–2017. By decade, the suicides broke down as follows: 1920s — one, 1930s — one, 1940s — one, 1950s — zero, 1960s — one, 1970s — one, 1980s — three, 1990s — four, 2000s — six, 2010s — 17. The positional breakdown of these players is as follows: Quarterback — one, Running Back (includes Full Back, Tail Back, and Half Back) — seven, Wide Receiver — three, Tight End — two, Offensive Lineman — four, Defensive Lineman — four, Linebacker — six, Defensive Back (Includes Cornerback and Safety) — eight, Total Offensive Players — 17, Total Defensive Players — 18. The average age at death among these individuals was 43.7 years and the average number of years in the NFL was 5.7 years.

Table 2 shows the suicide rate among NFL players who have entered the league since 1980. A total of 14,153 players entered the league between 1980–2017. Of these players, 22 suicides were identified, giving a rate of 155.44 suicides per 100,000.

Table 1. Total Suicides, Average Age at Death, and Average Years in NFL for Former Players Who Committed Suicide

Total suicides	35
Average age at death	43.7 years
Average number of years in NFL	5.7 years

Table 2. Suicide Rate Among NFL Players Since 1980

Total NFL players since 1980	14,153
Suicides among these players	22
Suicide rate	155.44 per 100,000

Discussion

A recent surge in media attention has piqued the interest of the general public in the potential dangers of contact sports. Suicides in professional and college football players draw specific interest because of the uncertainty of the effects caused by CTE. However, much of the published literature is not in line with this narrative.[17–22] Several studies have shown that professional athletes, including football players, actually have lower suicide rates than the general population.

A 2016 study from Lehman and colleagues[17] examined a cohort of 3,439 former NFL players with at least five credited playing seasons between 1959 and 1988. This cohort was identified using a pension database set up for players with at least five seasons in the NFL. The results showed that this cohort of NFL players had a significantly lower suicide rate than expected and there was no difference in suicide rate between "speed" position players (quarterback, running back, halfback, fullback, wide receiver, tight end, defensive back, safety, and linebacker) and "nonspeed" position players (offensive and defensive linemen). Another study from Webner and colleagues[18] examined NFL player suicides between 1920–2015. This study identified 26 total suicides over this time, with 42.3% of those coming since 2009. Certain lifestyle factors may be confounding these numbers. For example, professional athletes in the NFL generally have better access to medical personnel and higher socioeconomic status than the general population. Iverson published a 2013 literature review[22] investigating the link between CTE and suicide in former athletes and concluded at present, there is no evidence of a causal association between CTE and suicide.

This study was conducted similarly to the Webner[18] study and identified a total of 35 suicides in former NFL athletes between 1920 and 2017. A total of 23 of these suicides (66%) have occurred since 2000 and 17 of them (49%) have occurred since 2010. Additionally, a cohort of all players to enter the league since 1980 was established and compared to this data, giving a suicide rate of 155.44 per 100,000 among NFL players who have entered the league since 1980. The data obtained in this study is not meant to serve as a comprehensive list of every suicide from an NFL player since 1920. It is likely some suicides were not identified due to a lack of reporting in the earlier years. However, based on this data, there seems to be a trend towards an increase in suicides among former NFL players, particularly in the last decade. Therefore, the question needs to be asked: What is causing this increase?

The seemingly most popular answer to this question would be CTE. This condition was first described in the

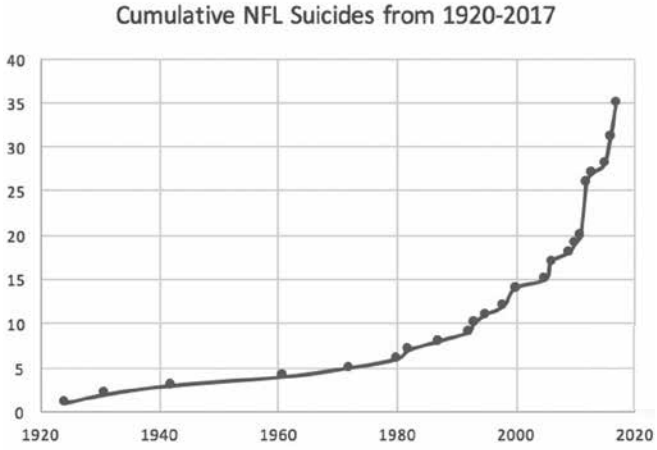

Figure 1. The total number of suicides in former NFL players from 1920–2017.

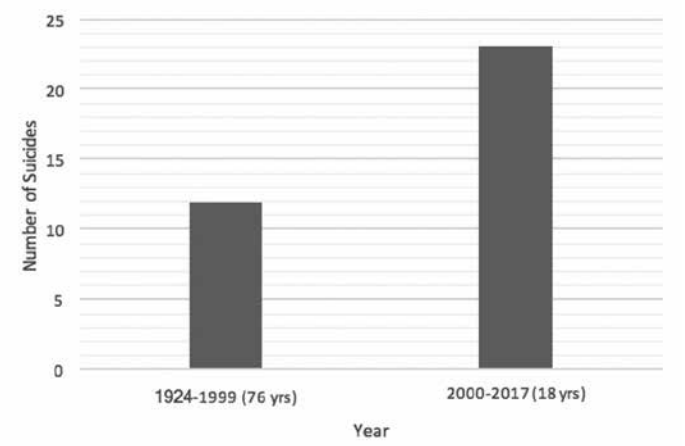

Figure 2. Comparison of total NFL suicides from 1924–1999 and 1920–2017.

medical literature in 1928 when Martland described a "parkinsonian syndrome" that progresses to a point where "marked mental deterioration may set in necessitating commitment to an asylum" in a series of boxers.[23] Martland coined this condition "punch drunk" to describe this. In the following decades, the term "dementia pugilistica" was adopted as more attention was paid to the neuropathological basis of the condition.[24–26] As it became clear this condition could develop in individuals outside of boxing, the term "chronic traumatic encephalopathy" was adopted.

Omalu and colleagues have published extensive work[6–11] relating to CTE and football, which became the inspiration for the 2015 film *Concussion*. They published the first autopsy-confirmed case of CTE in a former NFL player[6] in 2005, describing a 50-year-old former NFL player who died of a myocardial infarction. This subject had attempted suicide several times before his death. A second autopsy-confirmed CTE report[7] was published on a 45-year-old former NFL player in 2006. This subject was diagnosed with several mood disorders and attempted suicide twice before ultimately completing suicide in 2005. These cases, along with the cases of two other former NFL players and a professional wrestler, were published in a 2010 study.[8] Evidence of CTE was discovered in all five subjects. Two of the former NFL players and the professional wrestler had committed suicide and the remaining two NFL players exhibited parasuicidal behavior prior to their deaths. Omalu and colleagues have recently proposed a method for identifying CTE in living subjects using PET brain imaging.[11]

McKee and colleagues established a 4-stage progression of CTE in a 2013 paper.[27] Stages I–IV of CTE are characterized by focal tauopathies affecting progressively larger areas of the cortices and into midbrain structures and white matter. Neurofibrillary tangles are present adjacent to these lesions in stage II–IV. Stages III and IV are characterized by progressively worsening atrophy throughout the brain, septal abnormalities, and ventricular dilation. McKee has published several other papers that have expanded upon the symptoms associated with CTE.[28, 29] Clinically, stage I CTE is associated with headaches and lack of concentration. Additional symptoms present in stage II CTE include depression, mood swings, and short-term memory impairment. Stage III CTE is associated with executive dysfunction and cognitive impairment, while stage IV CTE is associated with dementia, language difficulties, aggression, and paranoia. Suicidal behavior is a less common symptom in stages II and III, but 31% of subjects classified as having stage IV CTE "were suicidal at some point in their course."[27]

This phenomenon has not been limited to just professional football players. A 2015 study[21] using an NCAA database identified 35 suicides among college athletes from 2004–2012, with football players having the highest risk of suicide in this population. An autopsy report was published about a 25-year-old former college football player.[5] This individual was diagnosed with CTE on autopsy and had suicidal ideations before dying of other causes. A recent study[6] published in 2017 examined CTE in former football players at all levels of play. Of the 202 brains studied, CTE was diagnosed in 177 (87%), including zero of two pre-high school, three of 14 high school (21%), 48 of 53 college (91%), nine of 14 semiprofessional (64%), seven of eight Canadian Football League (88%), and 110 of 111 NFL (99%) players. Additionally, in those with mild CTE pathology (stage I and II), suicide was the most common cause of death.

A portion of the increase in NFL suicides identified in this study can likely be attributed to improvements in reporting. This study obtained the suicide data largely through internet queries where there is a natural bias towards more recent suicides and earlier suicides were harder to identify. This likely cannot entirely explain the recent increase in NFL suicides, though. Particularly, the number seen since 2010 alone (17) is alarming and likely not due to reporting alone. The increased suicide rates of NFL athletes seen recently could also be partially explained by the increased media coverage of such events. A phenomenon known as the "Werther effect" occurs when a suicide reported by the media leads to increased suicidal behaviors in the population exposed to the story.[30] This idea of "contagious" suicide has been a topic of interest throughout the scientific community.[31–34] Niederkrotenthaler and colleagues found an increase of 0.26 suicides per 100,000 in the population following the suicide of a celebrity.[32] Suh and colleagues found a similar effect in a South Korean population following celebrity suicides.[33] The role of media coverage in additional suicides has led the World Health Organization to publish guidelines for responsible reporting of suicides by the media.[35]

Conclusion

The results of this study show there is a trend towards increased suicides among former NFL players. This may be explained by a number of factors, including better reporting, media attention, and CTE. However, there is a clear discon-

nect between published literature in the scientific community and the narrative in the media about suicidality among football players. Further studies need to be conducted to establish whether a true connection between football, CTE, and suicide exists. Particularly, there is a lack of literature dealing with recent suicidal trends in college and professional football players.

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Suture Tape Augmentation vs. Allograft Reconstruction in Patients with Complex Chronic Lateral Ankle Instability: A Literature Review

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Commentary

Based on the manuscript, the two procedures have been discussed independently rather than compared. A statistical analysis of the summation data from all of the studies would give a better sense of what "satisfactory results" means.

Another aspect of the paper that should be addressed is that allograft reconstruction is used in cases where there is no repairable ligament remaining. You can't do a suture tape augmentation in that case as there is nothing to repair and thus, augment. Suture tape augmentation can only be done in cases where there is a ligament to repair. The augmentation's intent is to prevent failure of the ligament repair due to earlier return to activity, or physiologic issues (Ehlers-Danlos, high BMI, etc.). So, it is difficult to really compare these two procedures since the indications are different, and it is not likely that a surgeon is going to have to decide between the two.

As noted in the comments, "contraindicated" is not quite accurate, as some of the factors noted are not contraindications for a MBG, but have poorer outcomes when compared to patients that don't have those outcomes.

A better future study or review would be to compare suture tape augmentation with the standard MBG procedure to see if outcomes are better even in the general population. (Most believe that it is.)

Abstract

Objective: The outcomes of allograft reconstruction and suture tape augmentation have yet to be compared in the literature. The objective of this review was to summarize the results of these two anatomic surgical options in an effort to guide future clinical decisions in the management of patients with chronic lateral ankle instability who are contraindicated for the modified Broström-Gould procedure.

Methods: A computerized database search was performed to identify all clinical studies conducted on allograft and suture tape surgeries of the lateral ankle. Using a set of inclusion and exclusion criteria, a list of articles was isolated for final review.

Results: The literature search yielded 122 results, of which 17 articles were selected for final analysis. This total was then subdivided into the two surgery groups focused on in this review: allograft reconstruction (n = 11) and suture tape augmentation (n = 6).

Conclusion: Both allograft reconstruction and suture tape augmentation for chronic lateral ankle instability have shown to achieve satisfactory clinical outcomes in patients who are contraindicated for the modified Broström-Gould procedure. However, we recommend that a randomized clinical trial be performed that compares these two procedures in the long-term to better determine the best treatment option for this patient population.

Introduction

Ankle sprain injuries are one of the most common lower limb injuries in the general,[1] athletic,[2] and military populations.[3] Most ankle sprains involve the anterior talo-fibular ligament (ATFL) following an inversion force on a plantar flexed foot. Conservative treatment leads to full functional recovery in most people;[4] however, up to 20% continue to experience lateral ankle instability, characterized by recurrent sprains or a feeling of the ankle 'giving way.' If this continues for longer than six months, the term chronic (lateral) ankle instability (CAI) is used.[5]

If CAI persists following conservative management via a neuromuscular rehabilitation program, then surgical treatment is usually considered.[5] Over 80 different surgical procedures to address CAI have been described in the literature.[6] The modified Broström-Gould procedure (MBG) is a *non-augmented* (uses local tissues), *anatomic* (restores natural orientation of the ligaments) repair that is considered the gold standard for lateral ligament reconstruction because it

is technically easy to perform and closely restores the kinematics of the ankle.[7–8] While the large majority of patients have successful outcomes following a direct anatomic repair using the Broström-Gould technique, several factors have been shown to contraindicate such a procedure. These include a history of failed primary repair, insufficient local tissues secondary to long-standing CAI, a highly-demanding or athletic lifestyle, high Body Mass Index, and general ligamentous laxity (as a result of a connective tissue disorder such as Ehlers-Danlos syndrome).[9] The authors of this study define patients who present with these contraindications as having complex CAI.

Initially, lateral ligament repairs for this subpopulation consisted of an augmented, non-anatomic approach to restore functional stability.[10–12] However, because the graft material in these procedures was positioned perpendicular to the plane of perceived instability, many adverse outcomes arose. Normal anatomy was not replicated, leading to stiffness at the subtalar joint, altered gait kinematics, and persistent instability. In addition, the abnormal resultant forces across the ankle became a major cause of degenerative joint disease.[13–14] For these reasons, a shift away from non-anatomic procedures in favor of anatomic alternatives has occurred in recent years.

Anatomic surgeries reportedly have lower complication rates, fewer wounds, less nerve damage, decreased incidence of degenerative disease, and little to no effect on subtalar motion when compared to non-anatomic procedures.[15] There are several anatomic techniques that fall into three general categories: 1) autograft, 2) allograft, and 3) suture tape repair. A suture tape (internal brace, synthetic ligament) repair uses a non-absorbable braided construct of polyethylene/polyester fiber to reinforce a Broström-Gould procedure. In this study, we have chosen to focus on the latter two methods as autograft (1) techniques have shown suboptimal results related to donor site morbidity, increased postoperative pain, and longer operation time.[16] As of yet, there are no studies comparing allograft reconstructions with suture tape methods. While each of the techniques have been shown to lead to good functional outcomes, each have their own shortcoming and concerns. The objective of this study is to conduct a comprehensive review of the current literature of allograph augmentation and suture tape repair in an effort to guide future surgical considerations for patients with chronic lateral ankle instability who are contraindicated for direct repair.

Methods

This literature review was performed following an electronic search of the bibliographic databases, MEDLINE via PubMed and Embase. All articles with the subjects of "ankle" or "chronic instability" AND "reconstruction" or "augmentation" or "repair" AND "allograph" or "suture tape" or "internal brace" or "synthetic" from the earliest record to the current day were considered. Studies were included if patients were contraindicated for direct repair, such as the Broström-Gould procedure and were above 16 years of age. Primary outcome measurements were ankle-specific function scores reported with a minimum average follow-up of six months. These outcome scores included (but were not limited to) the Foot and Ankle Outcome Score (FAOS), the American Orthopedic Foot and Ankle Society Ankle Hind Foot Scale (AOFAS), and the Foot and Ankle Ability Measure (FAAM). Secondary outcomes were considered, including talar tilt and anterior drawer test results, major adverse events or complications (including osteoarthritic changes, graft rejection, or revision surgery), health care cost of treatment, length of surgery time, and time to heal or return to activity. Case studies, review articles, and biomechanical investigations were excluded as well as papers not written in English or published before the year 2000. Studies were also excluded if the surgical procedure examined was non-anatomic. Additional sources were found in the references of the papers we reviewed.

Results

Search Results

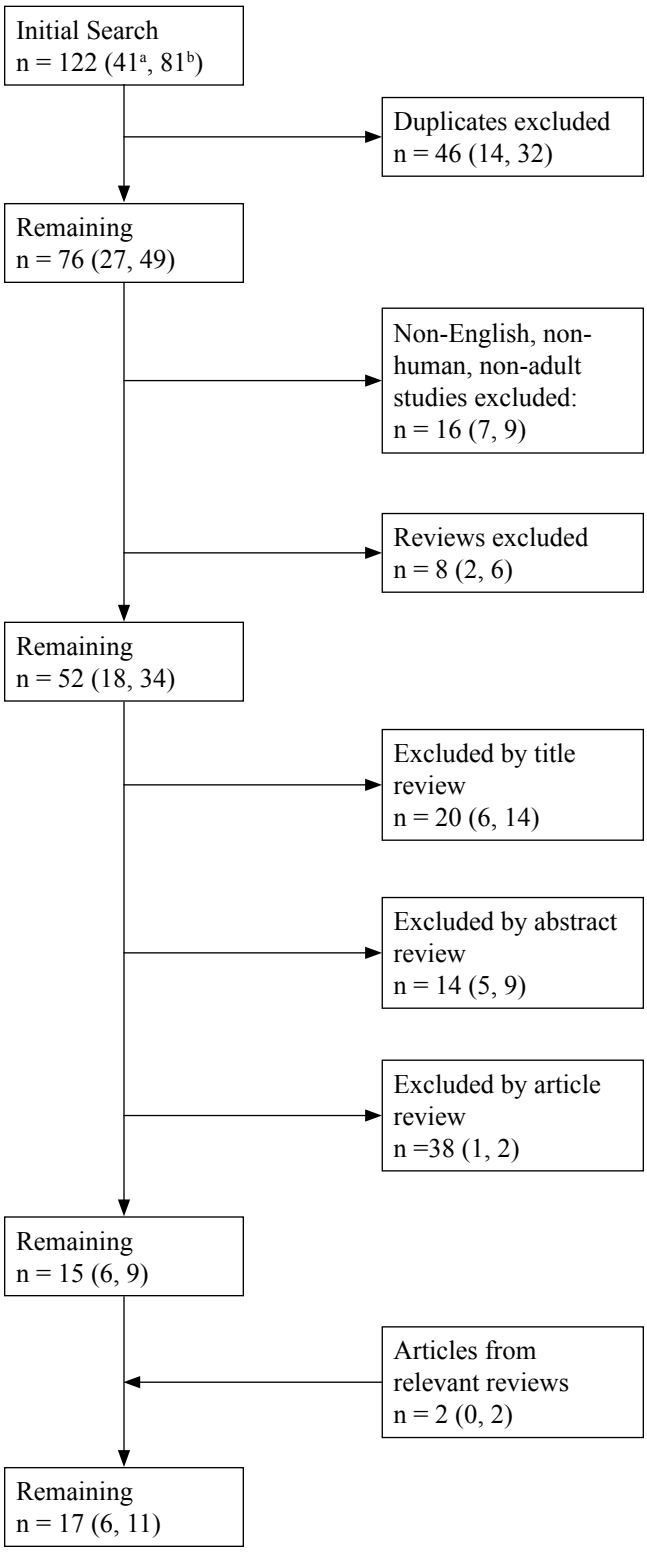
The initial search yielded 122 results, 46 of which were duplicates, resulting in 76 articles (Figure 1). Filters were then applied to remove studies that were not published in English, were not performed on human subjects, and used a patient population that was younger than 16 years old. Reviews were also removed from consideration, resulting in 52 articles for title review. Twenty articles were excluded through title review based on exclusion and inclusion criteria. The resulting articles were subjected to abstract and article reviews resulting in 15 papers. Two articles were added through the evaluation of references in relevant reviews. The final total (n = 17) was then subdivided into the topics focused on in this review: anatomic allograft reconstruction (n = 11) and anatomic suture tape augmentation (n = 6).

Allograft Reconstruction

The database search resulted in 81 articles that met the criteria for anatomic allograft reconstruction. After inclusion and exclusion measures were applied, we reached a total of 11 articles for final review, which have been presented in Table 1. Review of one 2015 article, by Jung et al., was limited to its abstract due to access restrictions. In total, there were two prospective case series, three retrospective comparative case series, and six retrospective case series.

Satisfactory results were achieved in most investigations reviewed in the study. One of the first prospective researchers of allograft reconstruction, Caprio et al., obtained a suboptimal mean AOFAS result of 55.4 points, which may have been attributed to a hurried patient return to activity (3–4 months) and a non-anatomic CFL insertion at the fibular tip.[26] This outcome, however, appears to be an early outlier

Figure 1. Method of Article Selection for Literature Review



[a]Suture tape augmentation
[b]Allograft reconstruction

in a string of otherwise positive results that came thereafter. The common conclusion reached among these reviewed studies described anatomic allograft reconstruction as an effective treatment option for CAI in patients contraindicated for MBG.

Despite allograft reconstruction offering a shorter operation time when compared to autograft reconstruction, Xu et al. found that it is also more expensive and requires a longer time to heal.[20] Choi et al. similarly reported that MBG using distal fibular periosteal flap augmentation presents a cheaper, faster, easier, less-invasive, and equally-effective treatment option for CIA when compared to allograft reconstruction.[17] Lastly, Youn and colleagues proposed a less-invasive technique of percutaneous allograft placement that is easier to perform, faster, and more cosmetically pleasing than open surgery while still offering satisfactory clinical outcomes.[23]

Complications that arose in these allograft studies included recurrent instability, limited flexion, nerve damage (sural, superficial peroneal), graft irritation, ankle swelling, post-exercise joint pain, and local wound infection.

Suture Tape Augmentation

The database search resulted in 41 articles that met the criteria for anatomic suture tape augmentations. After inclusion and exclusion measures were applied, we reached a total of six articles for final review, which have been presented in Table 2. Review of one 2017 article by Cho et al., on patients with a failed Broström repair, was limited to its abstract due to access restrictions. In total, there were two randomized controlled trials, one retrospective comparative case series, and three prospective case series.

Across the board, every surgical method performed in these studies resulted in a significant increase in standardized ankle scores from pre-operation to post-operation assessments. In the comparative studies, Porter et al. found a significant benefit in intermediate-term outcomes from using the LARS synthetic ligament when compared to the standard modified Broström-Gould procedure.[33] Likewise, Yoo concluded that patients obtain an earlier return to activity in the short term when treated with an internal brace compared to the Broström alone.[31] Overall, there was a consensus that the use of suture tape in lateral ankle reconstruction confers an effective alternative in the treatment of CAI in patients who are contraindicated for MBG.

In regards to cost-effectiveness, it was found in two studies that medical expenses associated with suture tape augmentation are significantly higher compared to conventional techniques.[28, 30] However, it was also found that suture tape repair allows for faster time to recovery when compared to MBG.[30, 31] Additionally, it was noted by Cho et al. and Yoo that their minimally invasive approaches of suture tape repair led to less postoperative pain and offered a reduced risk of wound infection, respectively.[31, 32]

Notable complications associated with suture tape repair included synovitis secondary to foreign body reaction, recur-

Table 1. Allograft Reconstruction — Study Details

Author, Year	Study Design	Population	Follow-Up	Results	Complications	Conclusions & Notes
Choi et al., 2017[17]	*Retrospective comparative case series:* Anatomic allograft reconstruction vs. MBG using distal fibular periosteal flap augmentation in patients contraindicated for MBG	*Reconstruction group:* 13 males and four females (mean age = 27.2 y/o) *Augmentation group*: 13 males and nine females (mean age = 27.9)	21.6 months (12–30 m)	*Reconstruction:* AOFAS: 54.7 to 92.9 KAFS: 46.4 to 92.7 VAS: 4 to 1.8 *Augmentation:* AOFAS: 60.1 to 94.9 KAFS: 52.6 to 94.1 VAS: 4.1 to 1.5	*Reconstruction*: 11.7% sural neuralgia, 5.9% graft irritation *Augmentation:* 4.5% superficial wound infection	Outcomes of MBG using distal fibular periosteal flap augmentation were effective and comparable to anatomic allograft reconstruction in patients contraindicated for MBG. Compared to reconstruction, MBG using periosteal flap takes less time to perform, is less invasive, less expensive, and is technically easier to perform.
Dierkman & Ferkel, 2015[18]	*Retrospective case series:* Anatomic reconstruction with semitendinosus allograft combined with MBG	16 male and 15 female patients (mean age = 28.3)	38 months (24–107)	AOFAS: 60.3 to 87.5 VAS: 7.3 to 1.9	6.5% sural nerve damage, 3.2% superficial peroneal nerve damage	Anatomic reconstruction with a semitendinosus allograft leads to high patient satisfaction, decreased pain, a stable ankle without arthritic changes, and significantly improved function.
Jung et al., 2015[19]	*Retrospective comparative case series:* Anatomic reconstruction with semitendinosus allograft with vs. without pretensioning in patients with insufficient local tissues	64 patients (mean age = 30.1)	22.1 months (12–68)	AOFAS: 71 to 90.9 KAFS: 55.1 to 90.3 VAS: 5.5 to 1.3	N/A	Anatomic reconstruction with a semitendinosus allograft yields satisfactory clinical outcomes in ankles with insufficient local tissues. No significant difference between pretensioned and non-pretensioned groups.
Xu et al., 2014[20]	*Retrospective comparative case series:* Minimally invasive anatomic reconstruction with semitendinosus autograft vs. allograft	Autograft: 19 males and 13 females (mean age = 32.4) Allograft: 22 male and 14 female (mean age = 33.2)	Autograft: 33.5 months Allograft: 28.5 months	Autograft AOFAS: 62.3 to 95.1 Allograft AOFAS: 60.2 to 94.8 No significant difference between groups	3% in autograft group complained of unsteadiness in daily life	Autograft reconstruction yields similar clinical success when compared to allograft reconstruction. Autograft time to heal was significantly shorter (11 vs 13.5 months). Minimal donor site morbidity was observed in the autograft group. Autograft operation time was significantly longer (85 vs 58 min). Allograft reconstruction is significantly more expensive than autograft.
Miller et al., 2013[21]	*Retrospective case series:* Near-anatomic reconstruction with semitendinosus allograft	13 males and 15 females (mean age = 47.7)	32 months (12–79)	FAAM: 41.7 to 95.2 VAS: 8 to 1	7% superficial peroneal nerve numbness, 10.7% continued instability graded as fair	Near-anatomic allograft reconstruction was a viable option in treating recurrent and complex lateral ankle instability.
Hua et al., 2012[22]	*Retrospective case series:* Anatomic reconstruction with semitendinosus allograft	24 males and 12 females (mean age = 29.2)	37.9 months (24–54)	AOFAS: 42.3 to 90.4 KAFS: 38.5 to 90.1	2.8% surface discomfort above graft placement; 5.6% mild positive anterior drawer test	Anatomic allograft reconstruction achieves a satisfactory surgical outcome for chronic ankle instability.
Youn et al., 2012[23]	*Retrospective case series:* Percutaneous near-anatomic reconstruction with allograft for patients contraindicated for MBG	Nine males and four females (mean age = 29)	17.3 months (12–34)	KAFS: 54.2 to 80.9 VAS: 3.7 to 1.6	6.7% partial graft rupture 2° to 6th-month post-operative injury, 6.7% limited dorsiflexion	Percutaneous allograft reconstruction is a useful method as a salvage procedure for CAI in patients contraindicated for MBG. The percutaneous technique is a fast procedure, minimally invasive, technically easy to perform, and provides a good cosmetic outcome.

Table 1. Allograft Reconstruction — Study Details *(Continued)*

Author, Year	Study Design	Population	Follow-Up	Results	Complications	Conclusions & Notes
Jung et al., 2012[24]	*Retrospective case series:* Anatomic semitendinosus allograft reconstruction of the anterior talofibular (ATFL) and calcaneofibular (CFL) ligaments	20 males and seven females (mean age = 36.5)	19 months (12–26)	AOFAS: 63 to 91 KAFS: 55 to 80 VAS: 6 to 2	3.7% transient sural neuralgia	Anatomic semitendinosus allograft reconstruction of the ATFL and CFL is a viable option for treating CAI.
Ellis et al., 2011[25]	*Retrospective case series:* Anatomic reconstruction with anterior tibial tendon allograft	Four males and seven females (mean age = 48.9)	3.5 years (1.2–5 y)	AOFAS daily activity: 93.4 FAOS sports activity: 78.6 VAS: 1.8 KAFS: 82.3 (No preoperative values were provided)	27% limited flexion of ankle, 18% felt their ankle was unstable, 9% constant swelling of the ankle	Reconstruction using tibial tendon allograft yields good clinical results in most patients contra-indicated for MBG.
Caprio et al., 2006[26]	*Prospective case series:* Anatomic reconstruction with allograft in patients with CAI	Eight males and three females (mean age = N/A)	14.4 months	AOFAS: 29.6 to 55.4	No immunologic rejection, disease transmission, or inflammatory foreign body reaction	Anatomic allograft reconstruction is a safe and effective method to manage CAI. Allograft cost is high ($496 when this article was published). Risk of disease transmission is possible so allografts should only be obtained from banks certified by the American Association of Tissue Banks.
Nakata et al., 2000[27]	*Prospective case series:* Anatomic reconstruction using fascia lata allograft	20 patients (mean age = 20.2)	4.2 years (3.1–10)	Good et al., Grade: 60% excellent, 35% good, 5% fair	5% slight anteromedial joint pain after strenuous exercise	Fascia lata allografts serve as a good alternative to and provide a significant advantage over autografts. No disease transmission or immunologic rejection found in allograft transfer, which can be attributed to the solvent-dried, gamma-irradiated nature of the preserved graft.

MBG = Modified Broström-Gould; AOFAS = American Orthopedic Foot and Ankle Society Ankle-Hindfoot Score; KAFS = Karlsson Ankle Functional Score; VAS = Visual Analog Scale for Pain; FAAM = Foot and Ankle Ability Measure

rent instability, inversion deficit, nerve damage (sural, superficial peroneal), suture anchor irritation, anterior tibial spurring, and local infection.

Discussion

The modified Broström-Gould procedure has been the gold standard treatment for chronic lateral ankle instability for the past 20 years. However, this technique has its limitations when performed on a specific subset of complex patients, including those with a history of failed primary repair, insufficient local tissues secondary to long-standing CAI, a strenuous work-related or athletic lifestyle, high Body Mass Index, or general ligamentous laxity.[9] Many alternatives have been proposed for the treatment of these individuals who are contraindicated for MBG. Of these, non-anatomic reconstructions, such as the Evans or Watson-Jones procedures, have gone out of favor due to their inability to reestablish normal ankle kinematics, which increases the risk of ankle stiffness and osteoarthritic changes in the long-term.[13, 14] Along these lines, anatomic reconstructions using an autologous graft transfer confer the risk of donor site morbidity, including the loss of eversion strength by peroneal tendon harvest, longer operation time and increased postoperative pain.[16] For these reasons, we conducted a review of the literature to compare the results of allograft reconstruction with those of suture tape augmentation in the treatment of CAI in complex patients.

Based on the results, complications, and conclusions reviewed among the included studies on allograft reconstruction, it can be concluded that this procedure provides satisfactory results for complex CAI patients in the intermediate term. Disadvantages associated with allograft reconstruction include the increased risk of disease transmission or immune rejection, the higher cost of allograft procedures, and the increased time to heal (due to slower graft-to-bone incorporation rates) when compared to autograft transfer. Despite this, the abolished risk of donor site morbidity in

Table 2. Suture Tape Augmentation — Study Details

Author, Year	Study Design	Population	Follow-Up	Results	Complications	Conclusions & Notes
Cho et al., 2017[28]	*Randomized controlled trial:* Suture tape augmentation (ST, n = 28) vs. modified Broström repair (MB, n = 27) in young female patients	55 female patients: mean age = 26.6 y/o (ST group) and 28.1 (MB group)	34.6 months (24–45 m, ST) 33.8 m (24–44 m, MB)	FAOS and FAAM showed significant improvement within both groups. No statistical difference between groups.	ST group: 7.1% recurrent instability, 3.7% sural nerve damage MB group: 3.7% local infection, 3.7% recurrent instability, 3.7% superficial peroneal nerve injury	Suture tape augmentation shows comparable outcomes to the Broström repair. Medical expense was significantly higher in ST group. Operation time was significantly shorter in ST group.
Cho et al., 2017[29]	*Prospective case series:* Suture tape augmentation in patients with a failed Broström procedure	13 males and 11 females (mean age = 31.8)	38.5 months (24–56)	FAOS: significantly improved to 87.5 FAAM: significantly improved to 85.1	N/A	Suture tape augmentation is an effective form of treatment for recurrent instability of the ankle following a failed Broström procedure.
Cho et al., 2017[30]	*Prospective case series:* Modified Broström augmented with suture tape in patients with general ligamentous laxity.	19 males and 9 females (mean age = 29.5)	35.8 months (24–52)	FAOS: 63.2 to 90.6 FAAM: 54.3 to 89.5	3.6% local infection, 3.6% superficial peroneal nerve damage, 3.6% recurrent instability	Suture tape augmentation of the Broström procedure appears to be an effective operative alternative for chronic ankle instability with general ligamentous laxity. An earlier rehabilitation protocol was implemented compared to the Broström alone. Suture tape modification increases operation time and medical expenses.
Yoo, 2016[31]	*Retrospective comparative case series:* Arthroscopic Broström with (n = 22) vs. without (n = 63) internal brace (IB)	85 male soldiers (mean age = 23)	Two, six, 12, and 24 weeks	AOFAS score significantly improved in both groups 6–12 weeks: AOFAS score in IB group was significantly higher than non-IB group 24 weeks: no significant difference	IB group: 13% grade 1 laxity, 100% synovitis, 4.5% anterior tibial spurring, 4.5% loose bodies, 9% inversion deficit Non-IB: 14% grade 1 laxity, 92% synovitis, 3.2% loose bodies, 4.8% inversion deficit, 3.2% intermediate dorsal cutaneous nerve neuritis	Offering soldiers and athletes a minimally invasive internal brace reconstruction would be advantageous given the earlier return to activity (compared to Broström repair) and reduced risk of wound complications (compared to open surgery).
Cho et al., 2015[32]	*Prospective case series:* Mini-open suture-tape augmentation without concomitant Broström	34 females less than 70 kg body weight (mean age = 26.2)	31.4 months (24–39)	FAOS: 63.2 to 93.2 FAAM: 56.2 to 92.5	3% chronic inflammation from foreign body reaction	Minimally invasive suture tape augmentation without Broström repair seems to be effective in young women with CAI. Shorter operation times and less postoperative pain compared to Broström repair.
Porter et al., 2015[33]	*Randomized controlled trial:* Modified Broström-Gould (n = 20) vs. ligament augmentation reconstruction system (LARS) (n = 21)	MBG: 10 males, 10 females (mean age = 24) LARS: 11 males, 10 females (mean age = 26.1)	12 and 24 months	Significantly better improvement in LARS group FAOS score at both one and two years follow-up	MBG: 5% pseudoaneurysm LARS: 4.8% suture anchor irritation, 4.8% superficial wound infection	Physically active patients with CAI have a superior outcome following LARS augmentation of a primary repair compared with MBG up to two years following surgery.

allograft procedures offers an important advantage over autogenous reconstructions, especially in the athletic, heavy laboring, or military populations. These individuals usually require proper eversion strength of the ankle following surgery, which may be compromised after an autogenous peroneal tendon harvest.[16] Additionally, allograft reconstructions require less operation time compared to autograft procedures. With regard to disease transmission, Dierkman and Ferkel have not seen a single report of transmission in over 20 years of extensive allograft use.[18]

After performing the same analysis of suture tape studies included in our final review, it can similarly be concluded that suture tape augmentation yields satisfactory outcomes for CAI patients contraindicated for the modified Broström-Gould procedure in the intermediate term. When compared to MBG, suture tape surgery is associated with a significantly increased cost and increased risk of synovitis secondary to a foreign body reaction. While suture tape augmentation reduces operation time and avoids donor site morbidity, the most important advantage lies in the procedure's ability to relieve patient instability almost immediately, allowing for an earlier start to rehabilitation. Again, this can be paramount in the recovery of specific populations, such as highly competitive athletes.

As part of future studies, a cost-benefit or cost-effectiveness analysis would be an influential aspect in comparing allograft reconstruction with suture tape augmentation. While the costs of operation may differ between the two, one must factor in the opportunity costs associated with a more lengthy return to work, as in the case of heavy laborers or military personnel. Considerations of an athlete's time to recovery should be taken into account as the value of a speedy recovery may outweigh an increased cost of operation.

Shortcomings of this review arise from the types of studies that were assessed. Foremost, there has yet to be a clinical study conducted that directly compares allograft reconstruction with suture tape augmentation. Of the articles that were included for final review, very few were randomized controlled trials. Follow-up periods in most of these investigations were limited to the intermediate term and some of the surgeries performed in them were complicated by the correction of concomitant ankle findings.

Over the course of our review, there were a couple surgeries that became of interest to the authors. First was the arthroscopic approach to the suture tape and allograft procedures, which poses the benefits of minimal invasiveness, decreased operation time, ease of performance, and a cosmetically good outcome. Second was the MBG using distal fibular periosteal flap augmentation, which is also a faster, less invasive, and technically easier operation to perform when compared to allograft reconstruction. Further investigation into these two novel approaches may prove worthwhile in the future treatment of complex CAI.

In conclusion, both allograft reconstruction and suture tape augmentation of chronic lateral ankle instability has been shown to achieve satisfactory clinical outcomes in patients who are contraindicated for the modified Broström-Gould procedure. However, we recommend that a randomized clinical trial be performed that compares these two procedures in the long-term and incorporates a cost-benefit analysis to better determine the most effective treatment option in this specific patient population.

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Medical Student Research Project

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Does Nutritional Deficiency in Lower Extremity Orthopaedic Trauma Patients Correlate with Delayed Healing and Complications?

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Abstract

Objective: Malnutrition is well-known to be correlated with perioperative complications. However, association with complications in orthopaedic trauma patients is unclear. The purpose of this study is to determine the prevalence of malnutrition in orthopaedic trauma patients and assess its correlation with wound healing complications and infection.

Methods: 133 charts of patients who had undergone surgical repairs of the lower extremity were evaluated. The data included incidence of postoperative infection or wound healing complication, pre-albumin, albumin, absolute lymphocyte count, vitamin D, transferrin, and BMI. Co-morbidities were noted.

Results: Lab data and the differences in medians between the patients who had healing complications or infections compared to those who did not are summarized in Tables 1 and 2 respectively. Statistical analysis using Chi-Squared and Wilcoxon tests found that none of the variables had a statistically significant association with infection or wound healing complication.

Conclusion: The lack of a clear definition of malnutrition and criteria for its evaluation was a significant obstacle in this study. The scarcity of available lab measures for the evaluated patients was also another limitation. This highlights the importance of establishing clear criteria, either in lab values or in physical assessments, for evaluating malnutrition that may be used moving forward.

Introduction

Malnutrition is a common problem in urban communities in the United States. The rate of malnutrition in hospitalized patients is 40–50%, with the range depending on the disease.[1] It is well documented that malnutrition often leads to poorer outcomes in hospitalized patients, including longer hospitalization rates and higher complication rates.[2] Malnutrition is an issue especially in underserved communities, where many patients are of low socioeconomic status.[2] Such a condition may lead to other comorbidities such as diabetes mellitus and obesity, and can further contribute to other complications perioperatively.[2]

Whereas there has been an increasing general body of literature on the issue of malnutrition in hospitalized patients, its role in orthopedic trauma patients is still not well understood.[2] It is also well documented that malnutrition is correlated with perioperative and related complications.[1, 3] Specifically, it is a significant risk factor for wound healing complications as impaired wound healing from malnutrition decreases white blood cell activity and increases susceptibility to infections.[4–6] This can lead to further complications and issues that affect clinical outcomes including unplanned hospital re-admission and longer inpatient stays.[4, 6] However, the extent to which malnutrition is associated with various complications in orthopaedic trauma patients is not clear. This study aims to determine the prevalence of malnutrition in orthopaedic trauma patients and assess its correlation with wound healing complications and infection. Obtaining a better understanding of the role nutritional deficiency plays in healing and infections among these patients could allow practitioners to provide targeted preoperative and postoperative care to decrease the occurrence of complications and infection.

Methods and Materials

Institutional review board approval was obtained and data was retrospectively collected from an orthopaedic patient database and the electronic medical records of patients treated at an urban level one trauma center between January 2012 to April 2017. Inclusion criteria included patients

between ages 18 and 89 that had surgical repairs of distal femur, proximal or distal tibia, ankle, or foot fractures within the past five years. Prisoners and patients undergoing revision surgery or non-union repair surgery were excluded. Data obtained included: date and type of surgery, any postoperative infection or wound healing complication, prealbumin and albumin, absolute lymphocyte count, vitamin D level, BMI, and transferrin levels. These data were recorded preoperatively, with the exception of BMI, which was recorded from the closest postoperative office visit, assuming there was no significant weight changes in the short time period after the operation. Multiple values were recorded and used to assess nutritional status since the Academy of Nutrition and Dietetics established that there is not a single parameter that can be used to identify malnutrition.[7] The traditionally used values of albumin and pre-albumin have also been found to be affected by multiple factors within the body that includes stress levels, hydration, zinc levels, and clinical condition.[7] This required the use of other values such as BMI and transferrin levels to evaluate nutritional status. Complications were defined as conditions that required return of the patient to the operating room or clinic due to healing or hardware issues or a condition that required treatment with antibiotics. In addition, since impaired wound healing and wound healing complications were previously described as a significant risk factor from malnutrition, wound healing complications were noted from the patients' charts. Wound healing complications can be defined as a variety of different conditions or issues, including dehiscence, infection, and delayed healing. For this study, a wound healing complication was defined as patients having incidences of subsequent nonunion of their treated fracture, abnormally delayed healing time, infections, or any hardware complications. In addition, co-morbidities such as diabetes and peripheral vascular disease were noted along with smoking status. The physician description of the patient's physical appearance in postoperative office visits (e.g., "well-nourished," "malnourished," etc.) was also noted. Each of the categorical values (age, sex, smoking status, diabetic) were analyzed against the outcomes infection and complication using the Chi-Square test. Furthermore, the continuous data were analyzed through a non-parametric approach using the Wilcoxon test (similar to a two-sample t-test), that uses the medians to describe the distribution.

Results

Over 700 charts were available for review; however, the final number of charts analyzed was 133. This was due to the inclusion and exclusion criteria of the study along with consultation from the study site statistician following a lack of consistent nutritional values recorded in the patients' charts. Available lab values were obtained for each and details on the included patients are included in Table 1.

The retrospective chart review found that 130 patients had values recorded for BMI, 126 patients had their total lymphocyte counts recorded, 34 patients has values recorded for pre-albumin, and 61 patients had recorded values for albumin. Only eight patients had a record of their transferrin levels, and only seven had values for their Vitamin D levels. Of the 133 charts that were analyzed, 20 patients were documented to have a postoperative infection, and 23 were noted to have a postoperative wound healing complication. Based on the results, none of the variables had a statistically significant association with either infection or wound healing complication. There was, however, a potentially significant association between diabetic patients and development of a complication (p-value = 0.070), where two out of 10 patients who had diabetes developed a postoperative complication worth noting.

Table 1. Available Patient Lab Values and Demographic Data

Criteria	Value
Sex	
F	56 (42.1%)
M	77 (57.9%)
Total	133 (100%)
Age Group	
18–44	72 (54.1%)
GE 45	61 (45.9%)
Total	133 (100%)
Smoker	
Yes	57 (43.8%)
No	73 (56.2%)
Total	130 (100%)
Diabetic	
Yes	10 (7.5%)
No	123 (92.5%)
Total	133 (100%)
PVD	
No	133 (100%)
Total	133 (100%)
Postop Infection	
Yes	20 (15.0%)
No	113 (85.0%)
Total	133 (100%)
Postop Wound Healing Complication	
Yes	23 (17.3%)
No	110 (82.7%)
Total	133 (100%)

The findings on the differences in the medians between the patients who had healing complications or infections versus those who did not is summarized in Table 2. No statistically significant differences were observed based on infection or complication.

Discussion

The presence of diabetes had a potentially significant association with wound-healing complications even though the study did not intend to directly examine the effects of diabetes on wound healing. This potentially significant association between the diabetes and nutrition may warrant further investigation. Individuals who had infections were seen to have slightly lower mean levels of albumin, pre-albumin,

Table 2. Comparison of Patients Who Had Complications or Infections vs Those Who Did Not

Variable	N	Mean	Median	p-Value
Albumin by Infection				0.3626
Yes	12	2.85	2.85	
No	49	3.08	3.20	
Albumin by Complication				0.3358
Yes	14	3.26	3.20	
No	47	2.96	2.90	
BMI by Infection				0.7136
Yes	20	27.98	28.03	
No	110	29.13	27.76	
BMI by Complication				0.8622
Yes	23	28.24	28.17	
No	107	29.10	27.80	
Prealbumin by Infection				0.9536
Yes	9	13.08	13.70	
No	25	13.88	13.10	
Prealbumin by Complication				0.6883
Yes	7	12.61	12.20	
No	27	13.94	13.40	
Total Lymphocyte Count by Infection				0.7212
Yes	20	1.99	1.85	
No	106	2.03	1.80	
Total Lymphocyte Count by Complication				0.2887
Yes	23	2.17	2.00	
No	103	1.99	1.80	
Transferrin by Infection				0.5698
Yes	3	187.33	160.00	
No	5	215.60	200.00	
Transferrin by Complication				0.6324
Yes	2	231.50	231.50	
No	6	196.17	180.00	
Vitamin D by Infection				0.4778
Yes	1	35.60	35.60	
No	6	26.75	21.75	
Vitamin D by Complication				1.0000
Yes	5	28.30	23.00	
No	2	27.30	27.30	

total lymphocyte count, and transferrin. Pre-albumin levels were lower in average for those who had infections (13.08 vs 13.88) and complications (12.61 vs 13.94). Vitamin D levels were higher on average for patients who had infections (35.60 vs 26.75) and complications (28.30 vs 27.30). However, none of these data were statistically significant.

Another finding from this study and possible limitation includes the significant issue of how to define malnutrition. Review of the literature found a lack of a clear definition for malnutrition along with a specific method or lab parameter to identify malnutrition.[7, 8] This is evident in the literature review providing several different methods and parameters for assessing malnutrition.[7–10] Therefore, many of the lab parameters were used in a variety of these assessments, hoping to refine them to be more definitive as more values were obtained. Unfortunately, the majority of records did not provide the same set of lab values for every patient, and there were particularly few Vitamin D values and transferrin levels in many of the patient records. As such, the sample size for these particular values decreased significantly, providing differing amounts of values for each lab parameter. On the other hand, multiple studies have attempted to assess nutritional status-based questionnaires and physical assessments such as the Nutritional Risk Screening (NRS) and Subjective Global Assessment (SGA). The authors were able to determine associations between clinical outcomes and malnutrition and life-style factors and malnutrition respectively.[8, 9, 11] Moving forward, an option to pursue accordingly is separately testing the correlation of each lab value with wound infection or healing complication, since each of these parameters have been studied as markers of nutritional deficiency. This also prevents patients from being definitively categorized as nourished versus malnourished, since the data and methods on this differs among specialists as Goost et al. focused on the use of BMI and subjective evaluations in general trauma patient populations while Ihle et al. and Lambert et al. focused on the effectiveness of the NRS and life-style factors in orthopaedic and traumatology patients.[8, 11–12]

In addition, another potential option to pursue would be the use of physical assessments as a clinical trauma nutritionist at the study site advised that nutritionists are shifting away from lab values and parameters and shifting more towards physical assessments such as the SGA and handgrip strength. The use of physical assessments is gaining support through its ability to encompass several different categories such as overall appearance, mobility and strength, wounds, nerves and cognition, and the cardiovascular and digestive systems. Recent studies comparing the SGA to other nutritional assessment methods have also found that the SGA evaluations were similar or greater in assessing nutritional status.[9–10] Furthermore, an association between hand grip strength and nutritional status has been determined by multiple studies, providing evidence that a simple physical assessment could be used for an initial evaluation of nutritional status and help physicians predict possible postoperative complications and length of hospitalization.[14, 16–17]

Another potential limitation of the study is the fact that the population studied was orthopaedic trauma patients. As such, many of their lab values, particularly the lymphocyte count, may have been abnormal as a result of the stress state these individuals were in and less of an indication of nutritional status.

While there are many difficulties with recording and assessing malnourishment in orthopaedic trauma patients, this process has highlighted the importance of evaluating the nutritional status of these individuals. Knowing the nutritional status of these patients, or even just abnormal levels of these biomarkers used here, may prove to be a tremendous benefit. It may allow physicians to anticipate any adverse outcomes and preemptively treat the patient to avoid any incidence of infection, healing complication, or preventable follow-up surgeries, and reduce the amount of stress on both the patient and the physician.

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Medical Student Research Project

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Heterotopic Ossification Post Elbow Fracture-Dislocations: A Literature Review of Incidence, Risk Factors, Prophylaxis and Treatment

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Abstract

Aberrant ectopic bone formation is a common clinical presentation in post traumatic injuries, representing a significant source of patient burden, delayed recovery and increased medical costs. This literature review identifies the incidence of heterotopic ossification (HO) of the elbow in elbow fracture/dislocation patient populations. We also sought to identify consensus regarding clinical presentation and management, including a discussion on risk factors, prophylaxis, and treatment of HO of the elbow. A PubMed search identified 17 studies that we utilized to determine incidence of HO in different types of elbow/fracture dislocation injuries (Table 1). HO incidence was lowest in Type I/II Regan-Morrey Coronoid Fractures and Monteggia fractures, and mid-level to highest risk in "terrible triad" injuries. The incidence of HO was also higher in distal humeral fractures over proximal humeral fractures. The literature also supported delay to surgery, delay in fixation/stabilization of the elbow, and genetics as risk factors for ectopic bone formation. 700 cGy radiation and NSAIDs are the main prophylactic treatments, with surgical resection being reserved for severe cases. These findings support that higher levels of injury and aggravation to soft tissue are related to higher incidences of HO formation.

Introduction

Heterotopic ossification (HO) is the abnormal formation of mature and metabolically active lamellar bone in soft tissue.[1] HO most commonly presents after traumatic injury and/or surgery, significant burns and neurological injuries. HO is a significant cause of discomfort, complications and dissatisfaction for patients postoperatively — often requiring additional surgical treatment when involving joint spaces and/or impinged neurovasculature. In one study of 142 patients with elbow fractures and fracture-dislocations, as many as 37% developed HO, with 20% of patients presenting with clinically relevant symptoms and up to 10% requiring additional surgical intervention.[2] Impaired elbow flexion/extension due to HO is of significance because it interferes with patients' ability to perform daily tasks and causes significant patient discomfort. The incidence and severity of HO correlates with the extent of injury and degree of surgical trauma.[3] In patients with combined neurological and elbow injuries, one study found the incidence of HO to be up to 70%.[3] Perhaps this is due in part to the high incidence of elbow fracture injuries, accounting for up to 30% of upper limb injuries.[4] There are a wide variety of complications involved with HO including limited range of motion, warmth/swelling, neuropathic pain, and joint contractures.[5] Understanding the risk factors and incidence of HO formation is important in evaluating current prevention and treatment strategies and minimizing patient burden.

Although there is a significant volume of literature on HO of the hip and HO of total arthroplasties, research on HO of the elbow, particularly after elbow fracture and/or dislocations, is scarce. Furthermore, there is little research directly comparing the incidence of HO with the type of elbow fracture and/or dislocation. The high incidence of elbow fractures and HO formation, combined with patient burden and high costs associated of additional medical intervention, warrants a closer investigation of current treatment modalities. This literature review seeks to evaluate current research to establish a consensus on the risk factors, prevention and treatment associated with postoperative HO in elbow fracture-dislocations. We also seek to collect data on the incidence of HO depending on the type of elbow fracture dislocations reported in current research.

Methods

Data was collected for this literature review via PubMed database searches. An initial search was done with the words "heterotopic ossification" and "elbow" for background and introductory information. Various additional searches were done to elicit elbow fracture/dislocation specific information on clinical presentation, risk factors, incidence, prevention/

treatment, and rehabilitation of HO. In order to systematically collect data on the incidence of HO, on 06/26/17 a PubMed search was conducted using the key words "heterotopic ossification" and "elbow" and "fracture dislocation." A total of 55 search results were found. Filters were set for studies with full text availability and for articles in English, narrowing our search results to 40. From this, we excluded articles on arthroplasties of the elbow, HO of joints other than the elbow joint, injuries/procedures other than elbow fracture and/or dislocations, or on patients less than 18 years old. A total of 17 studies were utilized from this PubMed search, which are reported in Table 1. A total of 47 articles were utilized for this literature review. The articles were reviewed to elicit information on classification, pathology, risk factors, incidence, prevention and treatment of HO.

Results

We attempted to determine the incidence of HO depending on the type of elbow fracture/dislocation. Table 1 provides a summary of our results from 17 studies, arranged via percentage incidence of HO in the studied patient population. Incidence was calculated as the percent of patients from respective samples that developed post-operative heterotopic ossification. Type I/II Regan-Morrey Coronoid fractures were found to have the lowest incidence of elbow HO formation.[6, 7] Lasso plate implant fixation had a lower incidence (0.08%) as compared to radial head/LUCL repair (7.10%).[6, 7] Two studies focused specifically on "terrible triad" injuries which are characterized by elbow dislocation, radial head or neck fracture, and coronoid fracture. Terrible triad injuries are thought to have a significant association with HO formation.[8, 9] Multiple studies found the incidence of HO to be particularly high in floating elbow injury, olecranon and radial head fractures, distal humerus fractures, and terrible triad injury.[2, 4, 8] The highest incidence of HO found in our search was in fact a study on terrible triad injury, where approximately 83% of the patient population had evidence of HO formation after "standard surgical protocol."[9] Many of these patients needed additional surgical intervention to improve ROM. However, Zhang et al. found only a 9.5% incidence of HO post-surgical repair of terrible triad injuries, which they attributed to using a less traumatic lateral/anteromedial combination approach.

Only two of 21 patients developed HO after treatment with a modified surgical technique that includes simultaneous fixation of the radial head and coronoid process and repairs of the LCL and MCL.[4] This surgical technique provided both bone and soft tissue stability, allowing earlier mobility and functional recovery of the elbow. HO incidence was found to be extremely high (77%) in a subset of patients being treated for fracture dislocations with multiple attempted closed reductions prior to surgery.[10] This is contrary to our earlier thought that external fixation/closed reduction would provide a less traumatic treatment option for fracture/dislocation injuries of the elbow. However, this could be due in part to repetitive interventions and prolonged aggravation at the effected site. The same study found a 43% incidence of HO associated with fracture dislocations when looking at their entire patient population. This reinforces the high degree of association of HO with traumatic fracture-dislocation injuries.

Monteggia fractures are characterized by ulnar shaft fracture accompanied with radial head dislocation. These types of fractures are most commonly seen as a result of falling on an outstretched hand. Our search found a wide range of HO incidence for Monteggia fractures, including 7.7%,[11] 18.8%,[12] and up to 37% when looked at as a part of proximal radius/ulnar fractures.[2] Proximal humeral fractures were found to have a lower incidence (9.10%)[13] than distal humeral fractures (14%[14] and 30.6%[4]). Other findings of note include a variation in the rate of HO restricting motion found by Wiggers et al., which ranged from 6% for olecranon fractures to 20% for coronoid fractures.[15] Finally, although arthroplasty was outside the scope of our study, we thought it relevant to mention that in a review of 104 total elbow arthroplasties, up to 48% of them developed heterotopic ossification.[16] This finding represents another potential patient population at significant risk for HO formation. Incidence of HO ultimately varied significantly based on the study design, diagnostic criteria, and type of injury studied, making direct comparison difficult. Even in cases of HO formation, not all were defined as clinically significant. Furthermore, not all studies clearly indicated or described their treatment protocol or techniques. The majority of these studies had a small patient population, ranging from 9–69 patients in all but five studies. Four of the remaining five studies had a range of 122–165 patients. Only one study had over 200 patients (417 patients).

Discussion

Classification

In order to systematically categorize HO severity and progression, many different classification methods have been created. Often times, the type of classification used will depend on the location of HO on the body. The Brooker classification is popularly referenced in the literature, but like many other classification systems it was originally tailored for HO about the hip. The following information is based on the Hastings and Graham classification.[17] This classification system allows us to categorize cases of HO about the elbow, particularly in reference to the patient's range of motion. Class I would be cases of HO formation, but without functional limitation. Class II would be cases of HO formation with functional limitation. Class III would be HO formation with ankyloses as well. Classes II and III can be further subdivided into A, B, and C, subcategories that are utilized to

Table 1. Incidence of HO Based on Elbow Fracture/Dislocation and Treatment

Authors	Number of Patients	Patients Who Developed HO	Fracture Type	Treatment/Technique	Incidence of HO (Post Treatment)
Wang et al.[6]	25	2	Type I/II Regan-Morrey Coronoid Fractures	Lasso plate implant fixation	0.08%
Papatheodorou et al.[7]	14	1	Type I/II Regan-Morrey Coronoid Fractures	Radial head repair or prosthetic replacement and repair of the lateral ulnar collateral ligament (LUCL) (no fixation)	7.10%
Singh et al.[11]	26	2	Monteggia fracture dislocations		7.70%
Dimakopoulos et al.[13]	165	15	Proximal humeral fracture	Transosseus suture fixation	9.10%
Zhang et al.[44]	21	2	Terrible triad	Extended lateral approach + separate medial approach	9.50%
Singh et al.[45]	10	1	Type IV Capitellum Fracture	Uniform surgical approach	10%
Wang et al.[46]	31	4	Coronoid fracture		13%
Douglas et al.[14]	125	18	Distal humeral fractures		14%
Beingessner et al.[12]	16	3	Monteggia fracture dislocations		18.80%
Douglas et al.[14]	69	15	OTA Type C distal humeral fractures		22%
Wiggers[15]	417	96	Elbow fractures — variable		23%
Hong et al.[4]	125	38	Distal humeral fractures		30.60%
Castelli et al.[47]	16	5	Coronal fracture of capitullum	ORIF	31%
Douglas et al.[14]	31	8	Ulnohumeral fracture dislocations		35%
Foruria et al.[2]	142	48	Proximal radius/ulna fractures/ dislocations (olecranon fractures, Monteggia fracture-dislocations, etc).		37%
Shukla[10]	9	7	Fracture-dislocation	Multiple attempted closed reductions	77%
Gupta et al.[9]	34	28	Terrible triad	Standard surgical approach	82.40%

describe the plane in which range of motion is compromised. These results are summarized in Table 2. HO medially at the elbow may most likely implicate the flexors of the hand/wrist, brachioradialis, as well as the ulnar nerve. Lateral HO may involve the extensors of the hand/wrist, brachialis, and radial nerve. Depending on the severity of HO, the biceps and triceps muscle can be involved where they cross the elbow.

Table 2. Hastings and Graham Classification

Class I	HO without functional limitation		
Class II	HO with functional limitation (limited ROM)	Class IIA	Flexion/extension limitation
		Class IIB	Pronation/supination limitation
		Class IIC	Both A and B
Class III	HO with ankylosis	Class IIIA	Flexion/extension limitation
		Class IIIB	Pronation/supination limitation
		Class IIIC	Both A and B

Pathophysiology

The literature remains unclear on the direct cause and pathophysiology of HO bone formation, but several mechanisms have been suggested. HO is a multifactorial process that is implicated with many different disease states. The formation of ectopic bone in HO is thought to be the result of local or systemic mesenchymal stem cells that migrate to the area of insult and are prompted to differentiate into osteocytes.[3, 18] This newly formed bone resembles normal bone, but is metabolically hyperactive and lacks a true periosteal layer.[1, 3] Studies suggest that the bone formation process is complex and involves many other body processes including the immune system, inflammatory response, and the CNS.[19] This begins to offer an explanation on the high incidence of HO seen in neurological injuries — even those that do not directly involve the elbow. All of these processes play a role in helping to create an environment that is conducive to hyperactive ectopic bone growth.

Several authors suggest the role of tissue expression of increased levels of Bone Morphogenic Protein (BMP), an impaired BMP pathway, and elevated alkaline phosphate

levels in the pathogenesis of HO.[3, 5, 20] The role of alkaline phosphate is to remove factors that prevent mineralization of bone, thereby an increase of this molecule would help create the environment necessary for ectopic bone formation. One study found a significantly elevated difference in ALP levels in patients that developed HO versus patients who did not.[21] Elevated CRP, CK, and ESR levels may similarly be implicated via their contribution to an inflammatory state where accelerated wound healing and bone formation may be promoted. Levels of these factors also serve to provide some insight into establishing plans for surgical resection, since declining levels may indicate when ectopic bone has fully matured and can be excised with minimal chances of recurrence. In addition to the factors mentioned above, there may also be rare cases where patients have a genetic predisposition towards the formation of ectopic bone in soft tissue. This could include genetic mutations anywhere along the implicated BMP pathway.[5] Patients with known genetic risks (such as family history of FOP) should be prime candidates for prophylactic therapy, particularly those exposed to additional risk factors (traumatic/surgical/neurologic/burn injuries). Otherwise, the majority of cases of HO seem to most commonly be triggered by acute traumatic injury and resultant hyperactive growth and inflammatory conditions. For this reason, prophylactic therapy often focuses on radiologic or NSAID (Indomethacin) treatment.[4, 8]

Clinical Presentation

Not all cases of HO are clinically significant. Symptoms may range from mild to severe depending on a case to case basis. After surgery or other traumatic event, it can take up to 3–4 weeks for HO formation to occur. Upon the onset of bone formation, patients may typically present with warmth, redness, swelling, and varying degrees of pain (from none to severe).[5] Patients, however, typically present to the clinic when faced with more severe symptoms, such as elbow stiffness/contractures, decreased/compromised range of motion (ROM), neurovascular compression, pain/discomfort, and in rare cases, bony elbow ankylosis.[5, 22] Elbow ankylosis is a more severe clinical finding but can reduce elbow ROM by up to 90%, which is clearly debilitating for the patient.[23] Such symptoms can severely compromise patients' ability to complete even the simplest of daily tasks, interfering with quality of life and impinging on patient independence. Furthermore, these symptoms may be severe enough to warrant surgery (recurrent in some cases), which can be a costly and significant endeavor for the patient.

Diagnosis of HO is primarily via these clinical findings and confirmed via radiography of the affected area. Ultrasound is a rapid, cost-efficient modality that may be utilized to detect early HO, but its efficacy is user dependent and requires a trained operator and experienced radiologist.[24] Triple phase bone scans remain the most sensitive method of detecting early HO and assessing maturity of HO bone formation.[25] MRI and CT scans can be utilized when neurovasculature is at risk of being compromised by HO, and can aid in surgical resection approaches. Recent research indicates that MRI/CT joint imaging may help in distinguishing early vs late HO in soft tissue.[26, 27] Serum levels of BMP, ALP, CRP, CK, and ESR can be utilized as markers to indicate that new bone formation is still occurring, and thus surgical resection should be timed accordingly.

Risk Factors

Since HO is a multifactorial disease process, it is difficult to ascertain direct risk factors. The results are often mixed depending on the type of study, the patient population, and the statistical analysis utilized. However, a great majority of the literature agrees that HO formation is generally greater in patients who have previously had HO,[28] as well as those who have been exposed to acute traumatic injury, thermal burns, or neurogenic insult.[3, 5, 26, 29] In acute injury, the presence of fracture and dislocation of the elbow, as well as joint instability is linked to increased risks of HO formation.[2–4, 8] Severe elbow injuries such as compound/open fractures and a delay in fracture fixation were found to be independent risk factors for HO.[2, 4, 8, 14, 15] As previously mentioned, acute injury not only includes trauma from accident/injury, but also by the physician's surgical technique/trauma during surgery. Several parts of the surgical method have been potentially implicated in HO formation, including the surgical approach used, total operating time, formation of a hematoma, extensive dissection and disseminated bone dust.[3] The research on these aspects of surgical intervention is not conclusive. Multiple studies emphasized delay to surgical treatment to be an independent risk factor for HO.[2, 4, 8, 15] This may be the result of longer periods of joint immobilization experienced by the patient, which would increase risks of HO.[4, 28] Additionally, Wiggers et al. found that the number of surgeries (within the first four weeks) was also an independent predictor based on their 417 adult elbow fracture patient sample.[15] They suggested this is due to high muscle manipulation and retraction, which supports the current association between acute injury and HO. Waiting over a week before surgery for fractures was found to result in 10 times the odds of radiographic HO formation, and seven times the odds of clinically relevant HO formation.[4] Literature suggests that fixation of unstable fractures within 48 hours of injury may reduce the chances of ectopic bone formation.[22, 30] For these reasons, it is important for any physician to weigh the benefits and risks between external fixation and stabilization versus open reduction internal fixation (ORIF) when treating elbow fracture/dislocation injuries. External fixation/closed reduction may provide a less traumatic approach to fixing elbow fracture/dislocations depending on the complexity of injury. However, the formation of HO at external fixator pin sites is also a possibility, and its risks have yet to be clearly determined.

The high incidence of HO formation related to neurogenic and burn injuries represents significant risk factors as well.

As mentioned in our introduction, this could be in part explained by the high frequency of elbow fractures implicated in these injuries. A systematic review of clinical reports on 626 patients undergoing HO excision of the elbow found that 55% of cases were in patients with trauma, 28% in burn patients, and 17% in patients with traumatic brain injury.[5, 31] It can be seen that burn and neurologic injuries compromise a significant HO of the elbow patient population, sometimes in injuries that do not even directly involve the elbow.[5] Sympathetic hyperactivity and dysregulation as a result of brain injury may be a possible risk factor for HO formation.[32] Neurogenic HO is found to most commonly form on the anterior and posterolateral aspects of the elbow.[3] The mechanism by which CNS injury causes HO remains unclear, but CNS dysfunction could play a role in creating the hyperactive environment necessary for bone growth. In patients with head and spinal cord injury, the healing response can often be found to be accelerated.[3] Dysfunction of this pathway could lead to bone formation in abnormal locations such as joint spaces and soft tissue. Interestingly enough, Bidner et al. found that the serum of patients with head injuries contained increased growth factor activity of cells of the osteoblast phenotype.[33] This suggests a central humoral and/or neurological mechanism involved in enhanced osteogenesis following head/CNS injury.[33]

Burn injury is a complex risk factor for HO that also consists of multiple pathways. In a study of nearly 3000 patients reviewed in the Burn Injury Model System Database, 3.5% of patients were found to have developed HO. In these patients, there were 11.5 times higher odds of developing HO if the patient had suffered more than 30% total body surface area burns, with a significant 96.4 times higher odds if the burns required skin grafts.[34] A literature review of 51 studies on HO and bony ankyloses formation in post burn injuries found incidences ranging anywhere from 0.1 to 35.3%.[35] Similar to neurologic injury, burn injuries activate multiple pathways that induce hyperactive inflammatory and resultant growth responses. Inflammation sets in motion pathways that prepare healthy cells to proliferate and replace dead cells and injured/necrotic tissue and matrix. This type of environment could clearly be conducive to abnormal bone formation.[26] It may be relevant to note that even in patients without HO formation, severe burns can lead to post burn contractures that limit the effected joint mobility quite significantly, thereby producing similarly debilitating symptoms. This highlights how the elbow is especially susceptible to becoming stiff after injuries, which makes the decision to resect HO if formed particularly challenging. Early mobilization is important in prophylaxis, and active range of motion (AROM) or passive range of motion (PROM) can help prevent stiffness of the elbow joint after injury or surgery.[1]

Severe chest trauma has also been implicated as a risk factor to HO formation.[2, 8] This is similarly likely due to induction of systemic inflammatory pathways in response to injury. As mentioned, there are mixed findings in the literature and not all studies agree on statistical significance of trauma and HO formation. Hong et al. found polytrauma and concomitant head injury to not be significantly associated with HO in their bivariate analysis.[4] Other risk factors found to be significant by some studies include male gender,[4, 14, 28] and excessive stretching of affected joints.[3] Demographic data such as age and sex also remain a source of debate in the literature, as some studies report no age[4] or other patient-related demographic factors to be significantly related to formation of symptomatic HO.[15, 28]

Genetic risk factors include a statistically significant association amongst three SNP variants (beta2-adrenergic receptor, toll-like receptor 4, complement factor H) to the development of HO or lack of protection against it.[19] These SNPs suggest cross involvement of the adrenergic, immune and alternative complement systems. Other genetic risk factors may include mutations along the BMP pathway such as those seen in Fibrodysplasia Ossificans Progressiva (FOP) where patients have disseminated HO formation of ligaments and soft tissues.[3, 20] Of course these patient populations would be prime candidates for prophylactic therapy, particularly if exposed to additional risk factors.

Prophylaxis/Treatment

High-risk patients should be considered for prophylactic treatment for HO. This includes patients with previous history of HO, those with genetic risk factors or predisposing conditions, and patients that must wait long periods before surgery.[15] Physicians can take three overarching approaches to HO management and treatment. One is prophylaxis in high-risk patients who have not developed HO but may be likely to. Second, to opt for no treatment in patients whose HO formation is minimal, not interfering with daily activity, or causing pain and/or discomfort (clinically insignificant). The third and most invasive approach would be surgical treatment and resection of HO in patients with advanced bone formation. This approach should be reserved to patients with significantly limited range of motion, neurovascular impediment, and/or pain and discomfort. Furthermore, before beginning a surgical intervention, it should be observed and confirmed that new bone growth has ceased and that HO formation is complete. Otherwise, there is a risk of recurrence of HO and additional surgical intervention may be required.

Prophylactic treatment of HO is currently limited, but can be either radiologic treatment or pharmacologic. The accepted approach currently seems to be 700 cGy single-dose radiologic treatment preoperatively or within 24–48 hours post operatively to limit growth and primarily for prophylactic purposes.[5, 22, 36–38] Single dose peri-operative radiation therapy (700 cGy) has been reported to reduce HO formation after surgical treatment for elbow fractures.[4, 36, 37, 39] Although current mainstay of treatment seems to be radiologic treatment, some of the literature argues that the risks

may outweigh the potential benefits. Post-operative single radiation therapy was found to potentially play a role in increasing the rate of nonunion at fracture sites.[18, 40] A systematic review of the literature in studies mostly administering single doses of 7.0 Gy could not find a strong association with radiation therapy and prophylaxis of HO of the elbow.[18] Hamid et al. had to terminate their study prematurely due to the significantly higher rate of nonunion in the treatment (radiation therapy) group.[36] Furthermore, radiation at the elbow specifically can cause a number of adverse skin effects such as ulceration, wound healing deficits, infection, carcinogenesis, etc.[18]

Pharmacologic treatment of HO can consist of NSAID or bisphosphonate therapy. NSAIDs offers a cheaper alternative to prophylactic care. By reducing inflammation and interfering with BMP pathways, NSAID administration has the potential to interfere with the environment conducive to ectopic bone formation.[5] In a retrospective review of 152 patients treated prophylactically with celecoxib, Sun et al. found more common and severe cases of HO in the untreated group.[41] Their regimen included celecoxib (200 mg) administration daily for 28 days and produced a significant difference. Indomethacin is another commonly used NSAID that can be prophylactic for complex elbow fracture cases.[8] Indomethacin, however, can be rather toxic with significant cardiac risk.[42] Other adverse reactions of NSAIDs can include gastrointestinal bleeding (which may be reduced with proton pump inhibitors), and (similarly to radiation therapy) reduced fracture healing.[4, 5] Strauss et al. advocates a joint radiation/NSAID therapy approach. Although HO formation was found to be high (48%) in their study, HO was found to be clinically insignificant and findings supported joint radiation/NSAID therapy to be safe and efficacious.[43]

Surgical treatment of HO should be reserved for the most severe cases since it is in itself a form of soft tissue trauma. There are internal and external fixation options depending on the type and severity of treatment. There are various surgical approaches to resection including lateral and medial surgical approaches, as well as anterior and posterior approaches.[3] The least invasive and traumatic resection approach should be selected to optimize recovery and decrease recurrence of ectopic bone formation.

Conclusion

Heterogenic ossification of the elbow represents a relatively common finding post traumatic injury, and can lead to significant patient burden and symptoms. The highest incidence of HO seems to be related to degree of severity of acute injury/trauma to the elbow and severity of burn/neurological injuries. The pathological mechanism thought to be implicated is an overactive inflammatory response due to injury, leading to hyperactive growth and resultant ectopic bone formation. This is likely to involve the dysregulation and hyper-responsiveness of BMP, inflammatory and sympathetic neural pathways. Other than traumatic injury, the literature supports delay to surgery, delay in fixation/stabilization of the elbow, and genetics as significant risk factors for HO bone formation. There seemed to be mixed or very little to no support for other patient demographics such as age and gender. Although nonspecific, monitoring serum inflammatory molecules such as ALP, CRP, CK and ERP may help determine completion of HO bone formation and the best time for surgical resection. Imaging modalities such as triple phase bone scans and ultrasound can help detect early HO and measure HO severity before considering prophylaxis and/or surgery. In terms of treatment, 700 cGy seems to be the mainstay prophylactic treatment but NSAIDs can also be used. Both, however, are related to potential increases in non-unions and present with their own side effect profiles that must be considered on a case by case basis.

Based on our PubMed search of 17 studies, we found that HO incidence was found to be lowest in Type I/II Regan-Morrey Coronoid Fractures and Monteggia fractures, and mid-level to highest risk in "terrible triad" injuries. The incidence of HO was also noted to be higher in distal humeral fractures over proximal humeral fractures. The overarching trend seems to follow the higher the level of injury and aggravation to soft tissue, the higher the chance of ectopic bone formation.

The major limitation to our study was standardization across the 17 studies we collected data from in Table 1. The studies varied considerably in sample sizes, methods of statistical analysis, and treatment protocols. The literature remains mixed on many aspects of the surgical process, prophylactic treatment and identifiable risk factors (such as patient demographics).

For future considerations, we would like to compare different surgical approaches and treatment plans for patients with similar types of fracture/dislocations of the elbow, and observe the incidence of HO formation. This would ideally include similar and larger patient sample sizes and would allow us to clearly observe differences if any in rates of HO formation that may be related to surgical technique. Since a high degree of trauma and inflammation seem to be related to higher incidence of HO formation, a study comparing incidence of HO formation of the elbow in response to external fixation versus ORIF could provide insight on the advantages of a less traumatic surgical approach. The high incidence of HO formation after terrible triad injuries and arthroplasty warrants a closer investigation of these patients to determine if they are ideal for prophylactic therapy.

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Medical Student Research Project

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Factors Associated with Both Bilateral and/or Recurrent Anterior Cruciate Ligament Disruption

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Abstract

Numerous studies have reported factors associated with bilateral and/or recurrent anterior cruciate ligament (ACL) disruption. However, a comprehensive review of the literature dealing with these issues has not been performed. This study attempts to systematically review the literature and provide an analysis of the currently reported risk factors.

The PubMed and Embase databases were searched using a combination of keywords such as "ACL reconstruction" and "bilateral or recurrent" and "risk factors" and medical subject headings. Studies were screened by two independent reviewers, and articles that met inclusion criteria were downloaded. The initial search yielded 129 articles and after eliminating duplicates, 23 articles remained. The reference lists of included articles were cross-referenced, and an additional two articles were included. Graft harvest site, allograft usage, return to sport, younger age, positive family history, increased posterior tibial slope, and the number of previous surgical reconstructions are well-reported risk factors for second ACL injury. However, any neuromuscular, rotational, or strength asymmetries could predispose the patient to second ACL injury after return to activity. The literature does not establish an association between sex or narrow femoral intercondylar notch and future ACL injury.

Introduction

Anterior cruciate ligament (ACL) disruption is a common injury among young active populations, with re-rupture after repair presenting a devastating and possibly career-ending complication. Injury to the ACL results in severe instability of the knee joint, for which surgery is the preferred method of repair. Patients undergo 6–12 months of rehabilitation after surgery to build strength, stability and range-of-motion before returning to athletic activities.[1, 2] The outcomes of initial ACL reconstruction remain excellent; the five-year survival rate for autografts is over 95%.[3–9] However, for the 5%, re-rupture of the reconstructed ACL can be catastrophic. While primary ACL reconstructions are associated with increased risk of residual knee pain, recurrent instability, and premature osteoarthritis,[2] these risks are elevated after revision ACL reconstructions. Moreover, the graft failure rate following revision surgeries is substantially higher than primary reconstruction.[2, 6, 10]

Some patients who successfully rehabilitate and return to cutting/pivoting activities tear their native contralateral ACL.[3, 5] The rate of contralateral ACL injury following primary ACL reconstruction has been reported between 3.0–20.5%.[2, 5, 7–9, 11–14] These patients are at an increased risk for bilateral knee pain, instability, and osteoarthritis.

Graft failure and/or contralateral injury is financially, psychologically, and physiologically catastrophic for the patient and their family. While prevention of primary ACL injury has been heavily studied, it is of interest to study the factors associated with bilateral and recurrent ACL reconstructions due to the formidable outcomes associated with each. A review of the literature reveals numerous reports of modifiable and non-modifiable factors associated with recurrent and bilateral ACL injuries,[2, 3, 6–12, 15–19] but no comprehensive evaluation. Awareness of both modifiable and non-modifiable factors allows for identification and intervention with at-risk patients to decrease the rate of recurring ACL rupture. This study will provide a review of the currently reported risk factors for recurrent and bilateral ACL reconstructions.

Materials and Methods

A comprehensive review of the literature was performed to identify studies which reported risk factors for recurrent or bilateral ACL reconstruction. The PubMed and Embase databases were searched from their earliest publications through December 31, 2017. The search utilized a combination of keywords such as "ACL reconstruction" and "bilateral or recurrent" and "risk factors." Where appropriate, our initial search included medical subject headings (MeSH), to ensure the consideration of all relevant articles.

All study designs were considered, apart from systematic reviews. Two authors independently searched the listed electronic databases between January 1, 2010 to December 31, 2017 for any eligible articles. Abstracts from all search results were reviewed; articles that met the inclusion criteria were downloaded and reviewed. A detailed overview of our search strategy is included (Table 1).

Table 1. Search Strategy Utilized in this Review

Criteria	Details
Searched databases	PubMed/MEDLINE, Embase
Search string	("Anterior cruciate ligament" OR ACL) AND (lesion OR tear OR rupture OR injury OR reconstruction OR repair) AND (bilateral OR recurrent OR contralateral) AND risk factors
Inclusion criteria	Non-contact ACL injury, study analyzed risk factors for contralateral ACL injury or graft rupture
Exclusion criteria	Study is a systematic review, study has no data, population studied is skeletally immature or elderly, study is evaluating risk factors for primary ACL injury, study was not published in English, study was not related to the ACL, access to full article was not available
Time filter	2010–2017
Language filter	English
Age filter	19–44, 19+
Other filters	Human studies

Results

The initial search yielded 129 articles, of which 36 were deemed relevant once inclusion and exclusion criteria were applied. Once duplicates were removed, 23 articles remained. An additional two articles were included, yielding a total of 25 articles included in this review.

The included articles had the following designs: five retrospective cohort studies,[7, 19–22] six prospective cohort studies,[2, 23–27] four case series studies,[28–31] five controlled laboratory studies,[32–36] three retrospective case control studies,[11, 17, 37] and two prospective case control studies.[18, 38] The risk factors catalogued in these studies are grouped into factors the patient can alter against factors the patient has no control over (Table 2).

Table 2. Risk Factors Associated with Graft Rupture and/or Contralateral ACL Rupture

Patient-controlled Factors	Factors Patients Cannot Control
Graft harvest site	Age at index procedure
Allograft vs. autograft	Sex
Return to activity	Significant history
	Rotational asymmetry
	Neuromuscular asymmetry
	Strength asymmetry
	Increased posterior tibial slope
	Narrow femoral intercondylar notch
	Technical errors during surgery

Discussion

Graft Harvest Site

While surgeons offer patients what they deem the most appropriate intervention, patients do have significant input from where their graft is harvested from. A patient's decision might be influenced by a friend, teammate, or family member that underwent successful ACL reconstruction with a certain graft. Furthermore, if a patient has experienced graft rupture, the patient and surgeon might have limited graft options.

In a prospective 20-year case series of 90 patients, Thompson et al. reported a 90% survival rate of the bone-patellar tendon-bone (BPTB) graft, which is notably higher than the 67% survival rate of the contralateral ACL.[28] This suggests the BPTB graft may be more durable than the native ACL, but there are many neuromuscular or biomechanical factors representing possible confounders. One obstacle for the BPTB graft is pain upon kneeling; 67% of patients reported kneeling pain at 20 years post-reconstruction.[28]

A 15-year prospective study concluded BPTB autografts were associated with an increased risk for contralateral ACL injury.[27] The authors noted a trend towards an increase in the incidence of graft rupture in patients who received a hamstring tendon (HT) autograft.[27] The BPTB autograft carried an increased risk for osteoarthritis, knee extension deficits, and decreased single-legged hop performance at 15 years post-ACL reconstruction,[27] which are important factors to consider. Though the longevity of this study is advantageous, the surgeries were performed in 1993–1994, so these results could be influenced by outdated surgical techniques. Bourke et al. retrospectively analyzed the 15-year outcome of ACL reconstruction on 755 patients and reported no significant difference in rates of graft rupture between the BPTB autograft and HT autografts.[31] However, the authors reported the odds of contralateral ACL rupture were more than doubled in patients with a BPTB autograft, while the cohort with HT autografts experienced similar rates of contralateral ACL injury or primary graft rupture.[31]

In a retrospective cohort study of the Kaiser Permanente ACL Reconstruction registry, it was concluded that HT autografts had a higher risk of revision compared with BPTB autografts.[19] Nonetheless, BPTB autografts were associated with a higher risk for contralateral ACL injury.[19]

Though both HT and BPTB autograft have achieved good long-term results, neither are perfect options. The BPTB graft appears to be more durable and have lower rates of graft ruptures than HT grafts.[19, 27] However, the BPTB autograft increased the odds of contralateral ACL injury,[19, 27, 31] and may be associated with osteoarthritis, anterior knee pain, and kneeling pain.[27, 28] The process of harvesting the BPTB graft may interrupt the afferent signals from the injured knee more than harvesting the hamstring tendon graft, which may alter central nervous system (CNS) feed-

back loops and explain the higher rates of contralateral ACL injury.[31]

Though not mentioned in the above studies, the quadriceps tendon (QT) autograft has become a popular choice because it is easier to harvest, requires a smaller incision, and has comparable strength to the BPTB autograft.[39] A study performed by Sasaki et al. demonstrated similar functional outcomes in cadaver QT and HT autografts.[39] Several studies comparing the BPTB and QT autografts found no difference in functional outcomes between the two grafts.[40, 41] Similarly, studies comparing the QT and HT autografts have also reported equal outcomes.[42–44] While the outcomes of the QT autograft appear promising, this requires further study with longer follow ups to identify rates of graft rupture and contralateral ACL injury.

Autograft vs. Allograft

The outcomes of allograft vs. autograft ACL reconstruction have been debated in the literature, with some studies finding that allografts carry an increased risk of future injury,[2, 7, 19, 26, 45] while others have not. Some surgeons believe allograft reconstructions have fewer postoperative complications, offer a faster rehabilitation, and are a better choice for older patients.[7, 45] Others believe autografts provide fast bone-to-bone healing, encourage return to sport, and are less likely to rupture.[26]

Kaeding et al. found that patients with an allograft had 5.2 times greater the odds of experiencing graft rupture than autograft.[2] Similarly, in a retrospective cohort study on the outcomes of almost 13,000 primary ACL reconstructions, Wasserstein et al. reported patients with an allograft have 68% greater odds of requiring revision ACL reconstruction.[7] Both authors suggested allograft irradiation and chemical sterilization renders them more vulnerable.[2, 7]

Maletis et al. also reported the allograft usage to be associated with higher risk of revision ACL reconstruction in a retrospective review of 17,436 ACL reconstructions.[19] A prospective cohort study on 1205 patients undergoing revision ACL reconstruction reported that patients who received an autograft were 2.78 times less likely to experience subsequent graft rupture than patients who received an allograft.[26] The study standardized the source of allografts that had undergone minimal to no irradiation,[26] suggesting the processing of allografts may not be the reason for the graft's high failure rate, and there might be something inherent to the allograft that makes it less successful. An *in vivo* sheep model compared the healing of allografts and autografts and concluded allografts took longer to heal biologically, which could impair the strength of the graft and the stability of the knee joint.[45] This supports the theory that allografts may be intrinsically inferior regardless of sterilization.

The recent literature has clearly demonstrated that allografts carry an increased risk for graft rupture. While allografts might be an appropriate choice for some older patients, patients who will return to a high level of activity should be appropriately informed of the risks associated with the graft. Though the rehabilitation process for allografts is often shorter than allografts, this is inconsequential if the patient requires repeat ACL reconstruction.

Return to Activity

Returning to high-intensity activity is one of the most reported risk factors for ensuing ACL injury.[11, 21, 24, 25, 31] Moreover, activity level at index surgery has also been reported as a risk factor for both graft rupture and contralateral ACL injury,[2] which is an indirect indicator for returning to activity after surgery. Patients who return to high-intensity sports involving cutting, pivoting and jumping movements are especially predisposed to both graft and contralateral rupture.

Though return to high-intensity sports is a clear risk factor for future ACL injury, avoidance of all athletic activity after index ACL surgery is unrealistic. However, studies have demonstrated that the timeline of a patient's return to activity can affect their risk for future ACL injury.[23, 24, 36] Importantly, Grindem et al. observed that for each month a patient's return to sport was delayed, the re-injury rate was reduced by 51%, until nine months postoperative.[24] Moreover, the study reported significantly higher injury rates in athletes that did not meet return-to-sport criteria of regaining 90% of hamstring, quadriceps, and hopping performance on injured leg before resuming athletic activities.[24] Likewise, Kyritsis et al. found athletes who did not meet discharge criteria before returning to sports had a four times greater risk of re-injury.[23] In a controlled laboratory study comparing results of a vertical hop test between athletes with unilateral ACL reconstruction to healthy controls, Myer et al. reported deficits on the reconstructed limb up to 11 months post-surgery.[36] Thus, a delayed return to sport after athletes have successfully met specific clinical discharge criteria will possibly decrease the risk of second ACL injury.

One other element both patients and surgeons should consider is the sport in which the patient participates. Certain sports such as soccer,[2, 30] lacrosse,[35] basketball,[2] and football[2] have been found to carry a high risk of second injury. Identifying high-risk sporting activities allows physicians, patients, and coaches to attempt interventions to decrease the risk for future injury.

Age at Index Surgery

Age at index surgery is a well-reported risk factor for secondary ACL injuries.[2, 7, 11, 19, 25, 28, 30, 38] Webster et al. found 29% of patients younger than 20 years experienced a graft rupture or contralateral ACL injury within five years of their index ACL reconstruction, compared to 8% of patients older than 20.[11] Similarly, a cohort study of 17,436 patients reported higher rates of revision and contralateral ACL reconstruction for younger patients.[19]

A long-term prospective cohort study of 90 patients with a 20-year follow-up on concluded that patients younger than

18 years of age at the time of index surgery did not have significantly higher rates of graft ruptures, but did have higher rates of contralateral ACL rupture (56%) compared to patients older than 18 years (25%).[28] Despite the long-term design of this study, the relatively small sample size could account for the lack of association between age and graft rupture.

It is unclear whether age is a confounding factor, or if there are specific age-related risk factors that predispose young persons to future ACL injuries. Younger persons are more likely to return to their pre-injury level of activity, which is an established risk factor for both graft rupture and contralateral injury.[11, 24, 25, 31] Younger patients also engage in more risk-taking behavior, be affected by intense emotions related to their injury, or are less compliant with rehabilitation protocols, which could explain the association between age and secondary ACL injury.

Sex

Disparities in the incidence of revision or contralateral ACL reconstruction have been widely reported in the literature.[19] Maletis et al. has reported that males had a higher risk of revision ACL reconstruction, while females had a higher risk of contralateral injury and reconstruction.[19] They suggested males have a higher risk of revision ACL reconstruction because males return more often than females to high-level sports involving cutting, pivoting and jumping. They also proposed the higher risk of contralateral ACL reconstruction in females may be caused by a larger graft size than the native female ACL, which could have a protective effect on the operated leg.[19] This finding is supported by other studies.[31, 46]

A statistical analysis of the Swedish National Anterior Cruciate Ligament Register found that 22% of female soccer players between the ages of 15–18 underwent either revision or contralateral ACL reconstruction, compared to 9.8% of male soccer players between ages 15–18.[30] Moreover, 11.8% of female soccer athletes aged 15–18 underwent revision ACL reconstruction, compared to only 5.4% of male soccer players ages 15–18.[30] This result directly contrasts Maletis et al.'s conclusion that males have higher rates of revision reconstruction, and suggests sex-specific characteristics may predispose female athletes to future ACL injuries. Females have a larger quadriceps femoral angle (Q angle), are subject to hormonal fluctuations throughout the menstrual cycle, exhibit more overall joint laxity, are more likely to have valgus knees, and are more prone to lower extremity neuromuscular imbalances than males.[47–50]

Webster et al. found no relationship between patient sex and the risk of graft rupture,[11] but the study did not investigate the relationship between sex and contralateral ACL injury. Similarly, Kato et al. showed no significant difference between males and females in rates of graft or contralateral ACL rupture.[25] It is worth noting that these studies report rates of rupture, not reconstruction, which might affect the statistical analysis. Nonetheless, there is currently no definitive relationship between sex and rates of revision or contralateral ACL reconstruction.

While the cohort sizes for these studies were impressive, they are limited by their retrospective design. These studies investigating a relationship between sex and future ACL injury/reconstruction included patient populations from over a decade ago. Due to the yearly increase in the number of female athletes, it is likely that these populations represent an outdated demographic.

Significant History

Several studies have reported the number of previous revision surgeries or a positive family history as risk factors for revision or contralateral ACL reconstruction.[11, 26, 31] Wright et al. found patients who were undergoing more than three revisions were 25.8 times more likely to sustain a graft rupture within two years.[26] Surgeons operating on patients who have undergone multiple ACL reconstructions are limited in their graft selection, which might compromise the surgical outcome. Moreover, re-injury is an overwhelming experience, which might offset the patient's ability to fully rehabilitate their injury.

The literature quantifies a patient's family history as positive if a first-degree relative suffered an ACL injury. Webster et al. concluded that a positive family history doubles the odds of a patient sustaining either a graft rupture or a contralateral ACL.[11] Likewise, in a prospective study of 673 patients who underwent a primary reconstruction, Bourke et al. reported that a positive family history doubled the odds of both graft rupture and contralateral ACL injury.[31] The literature has reported a positive family history as a risk factor for index ACL injury, so it is logical that a positive family history would be a risk factor for graft rupture and/or contralateral injury.[51–53] Certain collagen and proteoglycan polymorphisms have been proposed to be associated with these injuries,[54–56] but it is also possible other factors such as body morphology or active family lifestyle play a role in predisposing patients to ACL injuries.

Rotational, Strength, and Neuromuscular Asymmetries

A biomechanical study performed by Paterno et al. found that male and female athletes who had underwent ACL reconstruction had asymmetries in peak vertical ground reactive force (VGRF) while landing at the time of return to sport.[57] A similar controlled laboratory study concluded that athletes with unilateral ACLR had deficits in force generation and absorption on their injured leg, and these asymmetries were not associated with time since reconstruction.[36]

A case-control study compared the performance of ACL-reconstructed patients to healthy controls and concluded that ACL-reconstructed patients showed reduced range-of-motion (ROM), single-leg jumping distance, and hamstring strength on their operated leg 18–30 months post-reconstruction.[33] Similarly, Kyritsis et al. concluded that

reduced hamstring strength is a risk factor for future injury.[23] The hamstring muscles impart strength on the knee joint, resist anterior tibial translation, and protect the ACL; weak hamstring muscles are a reported risk factor for injury,[58, 59] and reduced hamstring strength is associated with poor knee function.[60] Furthermore, a cadaveric laboratory study concluded that limiting the degree of internal femoral rotation incites earlier ACL fatigue failure.[34] Interventions to improve femoral internal rotation on patients with limited hip mobility may decrease the load on the ACL and decrease the odds of ligament failure.[34, 61, 62] This study also found the ligament is vulnerable to a repetitive loading injury, suggesting the risk of future injury may be decreased by limiting movements which stress the knee.[34]

Dai et al. suggested restoration of anatomic knee symmetry in a clinical setting does not translate to kinetic knee symmetry and found more than a 24% asymmetry between the surgical and non-surgical limb in patients who returned to activity.[32] Kinetic knee asymmetries are traditionally observed via an inverse dynamics approach with motion capture and ground reaction force measurements, which is expensive and not practical for standard use in the clinical setting. The authors proposed that a force plate sensor could be used to identify kinetic knee asymmetries, which would allow for interventions to decrease them and lower the risk of ACL re-injury once the patient returns to activity.[32]

If the performance of one leg is significantly reduced, the patients rely on their uninjured leg more than healthy controls, which could be further enhanced if patients are psychologically deterred from fully utilizing their injured limb out of fear of re-injury or subconscious mistrust. These asymmetries carry obvious biomechanical repercussions for both limbs, which could predispose patients to future injuries. Additionally, because asymmetries were observed over one year post-ACL reconstruction, it is possible that the injured leg may never recover to its pre-operative state.

Posterior Tibial Slope

Posterior tibial slope (PTS) is most often measured on lateral radiograph with specialized software.[38] An increased PTS, particularly the lateral PTS, has been reported as a risk factor for both index and recurrent ACL injury,[20, 29, 38] resulting in an increased anterior tibial translation, which places strain on the ACL during both activity and rest.[29, 63–65]

Hendrix et al. used lateral radiographs to retrospectively compare the PTS of 50 patients who had either unilateral, bilateral, or no ACL injury.[20] The mean posterior-tibial slope angle of the group without ACL deficiency was significantly lower than the mean PTS of both ACL-deficient groups.[20] Moreover, the study reported that a 1° increase in PTS was associated with a 20% increase in the odds of unilateral ACL injury and a 34% increase in the odds of bilateral ACL injury.[20] Similarly, Webb et al. reported the mean PTS was higher in patients with subsequent graft or contralateral ACL rupture compared to patients with no further injury after index procedure.[38] The study also reported the odds of patients with a PTS higher than 12° sustaining a subsequent ACL injury were five times higher than patients with a PTS less than 12°.[38] These studies are supported by a finite element computer model, which found that PTS was directly related to anterior tibial translation and ACL stress in both active and passive gait models.[66]

Patients with increased PTS are at risk for future ACL injury, and should be counseled on their predisposition to future injury. Aside from informing patients of the possible risks, it has been suggested without statistical analysis that performing a tibial wedge osteotomy could also restore stability to the knee.[29, 65] Sonnery-Cottett et al. performed proximal tibial anterior closing wedge osteotomies in with ACL re-revision on patients who had a "pathological PTS" greater than 12° and reported no further injury on the patients who returned to sport.[29] Though the case series was limited to five patients, and only four returned to sport, the study was one of the first to report outcomes of a combination tibial osteotomy with ACL re-revision. Other studies have since been performed which have also reported better functional outcomes after ACL reconstruction with tibial osteotomy in patients with remarkably increased PTS.[15, 67]

Narrow Femoral Intercondylar Notch Width

Femoral intercondylar notch width can either be measured on radiograph or intra-operatively and is often reported as the notch width index (NWI). The notch width index is a ratio of the width of the intercondylar notch to the width of the femoral condyles.

A radiographic study of 190 patients reported a significantly smaller NWI in patients who experienced bilateral ACL injury when compared to patients with unilateral injury and healthy volunteers.[17] A case-control study compared several factors between an injured and uninjured group and reported the intercondylar notch to be significantly narrower in injured patients compared to uninjured patients.[37] Levins et al. performed a similar study that analyzed geometric risk factors associated with ACL graft rupture, and concluded intercondylar notch width was significantly associated with ACL graft injury in female subjects.[18] Moreover, the study reported a 28% decrease in the risk of graft rupture for every 1-millimeter increase in femoral intercondylar notch, but no significant association between graft rupture and intercondylar notch width in males.[18]

In contrast, Wolf et al. intraoperatively measured the femoral intercondylar notch of 137 patients, and concluded that a smaller intercondylar notch was not a risk factor for graft rupture.[22] The authors proposed that using the NWI to report intercondylar notch width is an unreliable measurement, and accredited discrepancies in the literature to different measurement tools being used.[22] One major disadvantage of this study is that it utilized arthroscopic measurement, which may be more unreliable than radiographic measurements.

The relationship between femoral intercondylar notch width and graft rupture or contralateral ACL injury requires further study utilizing the same method of measurement or comparing notch widths measured both intraoperatively and radiographically on the same patient.

Miscellaneous Factors

In a 20-year prospective study of 180 patients, Thompson et al. found patients with non-ideal tunnel position were more likely to rupture their graft.[28] Ideal tunnel position was quantified as being 80% along the Blumensaat line, a graft inclination angle of greater than 17 degrees from vertical, and the tibial tunnel being 40–50% along the tibial plateau.[28] Though ideal tunnel position is poorly defined in the literature, it is well reported that various surgical techniques can affect knee stability.[68–70] More anterior tibial tunnel placement decreases anterior tibial translation,[68] while increasing sagittal and coronal obliquity decreases anterior tibial translation and rotary motion.[68, 69]

A retrospective cohort study analyzed risk factors for recurrent ACL reconstruction and found that index surgeries performed in a teaching hospital were associated with a revision ACL reconstruction rate of 3.6%, compared to a revision rate of 2.1% if the index procedure was performed in a non-academic institution, with surgeon volume having no significant impact on reoperation rates.[7] Residents and medical students are trained in academic institutions, which might contribute to the observed trend. However, the author proposes that the higher revision rate in academic settings may reflect that academic hospital surgeons are more willing to perform revision ACL reconstruction, instead of an increased failure rate of the index surgery.[7] The study reported an overall revision rate of 3%, indicating that ACL reconstructions performed at both academic and nonacademic centers are successful,[7] but patients and providers should be aware of all contributing factors to graft failure in order to accurately assess the risks of revision surgery.

Psychological Impact

Almost all studies regarding rehabilitation and prevention of ACL injuries focus on tangible factors, such as those referenced above. One area far less studied is the effect psychology has on healing. Low confidence, fear of re-injury and low perioperative self-efficacy are associated with performance years after surgery,[71, 72] which could affect adherence to rehabilitation throughout recovery. Moreover, athletes who returned to sport and suffered a second ACL rupture had a higher fear of re-injury in the five weeks before and after index ACL reconstruction.[73]

Thus, it is important to counsel patients on their fears and attempt interventions to improve self-efficacy and confidence. A randomized controlled trial performed by Maddison et al. had patients undergo nine guided imagery and relaxation sessions designed to improve coping skills, simulate motor activities, and improve self-confidence to encourage healing.[74] When compared to controls, the treatment group had less knee laxity, lower noradrenaline levels, and lower dopamine levels which may support improved healing.[74] Moreover, the treatment group experienced a smaller reduction in self-efficacy throughout recovery than controls.[74] After such a severe and painful injury, patients may be apprehensive to fully utilize the leg with the injured ACL, which could encourage injury-predisposing neuromuscular imbalances. The effects of the guided imagery and relaxation sessions may alleviate the patient's potential fears and allow equal employment of their lower limbs. Another study performed by Lebon et al. found motor imagery increased muscle activation, which might enable a more complete strength rehabilitation.[75] The role a patient's psychological state plays in recovery and predisposition to future ACL rupture requires further study; it is important to correct muscular imbalances in the operated leg, but it is also important to intervene if a patient is determined to be mentally predisposed to suboptimal rehabilitation or poor functional outcomes.

Conclusion

The literature demonstrates predisposition to second ACL injury is indeed multifactorial. Because many of these factors cannot be controlled, the responsibility lies on the medical profession to assess these risk factors and find appropriate interventions, so patients are able to return to the lifestyle they enjoy. Graft harvest site, allograft usage, return to sport, younger age, a positive family history, and the number of previous ACL reconstructions were predictors for second ACL injury. It is crucial to address any neuromuscular, rotational or strength asymmetries between the injured and uninjured leg before the patient returns to sport because these are well-reported risk factors for contralateral ACL rupture and graft rupture. An increased posterior tibial slope (PTS) predicts future ACL injury, which might require a tibial osteotomy in patients with a pathological PTS of over 12°. There was some debate in the literature whether narrow femoral intercondylar notch predicts future ACL injury, which can be attributed to a variety of measurement tools used in different studies. This area requires further study with a unified method of measurement. The association between sex and future ACL injury was widely debated in the literature and requires prospective study to represent a current patient demographic. Lastly, it appears that a patient's psychological state throughout rehabilitation is associated with long-term functional outcomes. This also requires future study to prove a definitive relationship and examine possible interventions for improved outcomes.

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Case Report

Acute Traumatic Thoraco-Lumbar Paraspinal Compartment Syndrome: A Case Report

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Abstract

Although compartment syndrome can occur in any compartment in the body, it rarely occurs in the paraspinal musculature and has therefore only been reported in a few case reports. Despite their rare occurrence, acute paraspinal compartment syndrome has been shown to occur secondary to reperfusion injury, traumatic and atraumatic causes. Diagnosis can be based upon clinical exam findings, MRI or CT studies, or through direct measurement of intramuscular pressures. Conservative management should only be used in the setting of chronic presentation. Operative decompression via fasciotomy in acute presentation may improve patient's symptoms and outcomes. When treating acute paraspinal compartment syndrome via surgical decompression, an important aspect is the anatomic consideration. Although grouped under one name, the paraspinal muscles are each enclosed within a distinct fascial compartment, all of which must be addressed for an adequate decompression. Our patient was a 43-year-old woman who presented to the emergency department reporting increasing lower back and flank pain after a fall. Associated sensory deficits in cutaneous distribution, with imaging and clinical findings contributed to the diagnosis of acute traumatic paraspinal compartment syndrome. We present this case along with a surgical technique for management of acute paraspinal compartment syndrome.

Introduction

Acute compartment syndrome is a condition where pressures within a compartment exceed to an extent that limits the perfusion within that specific compartment. This can result in muscle and nerve ischemia. Untreated or undiagnosed compartment syndrome can lead to muscle necrosis, nerve injuries, wound closure problems, long-term pain, amputation and even death.[3] In general, once identified, compartment syndrome fasciotomies should occur within six hours of onset of presentation, and no more than 12 hours after onset.[2, 13] Although this condition can occur in any compartment in the body, it rarely occurs in the paraspinal musculature and therefore is not well studied. In our review of the literature, we found that 17 patients have been previously identified as having an acute paraspinal compartment syndrome; however, none of the cases address the details of surgical management with a technique description.[1, 4, 5, 10, 11] We describe a case of acute, traumatic paraspinal compartment syndrome and the path leading to its diagnosis and treatment. Surgical fasciotomy led to a positive response without any significant neurological deficits postoperatively in this patient.

Case Report

History

A 43-year-old woman with no significant spine-related history presented to the emergency department reporting lower back and flank pain that had been present for less than a day. The pain initially began after a fall off her bed. She reported falling several feet off her bed and hitting her lower back on a nearby step stool. Afterwards, she was unable to ambulate due to back pain and her symptoms rapidly progressed, leading to her presentation in the emergency department. She rated her pain as a 10 out of 10 on the Visual Analog Scale (VAS) for back pain and described it as excruciating. Although present throughout her entire middle and lower back, the pain was described as worse on the left compared to the right.

Examination

On physical examination, she was found to have tenderness to palpation in the Thoracic 10 (T10) to Lumbar 3 (L3) paraspinal region bilaterally. Body habitus of the patient made it difficult to assess for swelling (Body Mass Index: 45.2). Her left-sided paraspinal tissues were found to be firm and non-compressible, as well as exquisitely tender. She had a sensation deficit to light touch on the left flank and left lower back roughly from the T10 to L3 level from the middle of her back to the mid-axillary line. She had normal sensory and motor function of her lower extremities bilaterally.

Studies Performed

A urine specimen and blood chemistry studies were sent upon initial presentation. These studies revealed a creatinine kinase of 86,174 U/L (normal 38–140 U/L) and large blood on urine analysis (protein level of 100). While awaiting lab results, a lumbar spine computerized tomography (CT) study with intravenous contrast was ordered and showed enlargement of the left paraspinal musculature compartment (Fig. 1). No abnormalities were seen related to the kidneys, retroperitoneum, bowel, or vasculature.

Due to the patient's history of trauma, pain out of proportion that was unresponsive to medications, clinical exam, laboratory findings, and findings on her imaging study, paraspinal compartment syndrome was suspected. Compartment pressures were then measured in the trauma bay with the patient in a lateral position using a compartment pressure monitoring kit (Compartment Pressure Monitoring Kit; Centurion Medical Products, Williamston, Michigan). Pressures were measured in the paraspinal musculature at approximately the L2 level, the level the patient reported the most pain with palpation. Right paraspinal musculature pressures measured 13 mmHg and left paraspinal musculature pressures measured 21 mmHg.

Surgical Technique

The patient was taken emergently to the operating room for thoracolumbar paraspinal fasciotomies. A midline incision directly over the spinous processes from approximately T10 to L4 level was performed and dissection was carried to the thoracolumbar fascia. Following this, a plane was dissected out between the thoracolumbar fascia and the individual tendinous aponeurosis layers of the paraspinal musculature (Fig. 2). Once this plane was developed, decompression of the individual muscle fascias was performed. The multifidus was decompressed by releasing the muscle bilaterally along the spinous processes to the junction of the spinous process and lamina (Fig. 3). The longissimus and iliocostalis were each decompressed bilaterally by making a longitudinal incision in their tendinous aponeurosis respectively. Upon inspection of the left-sided musculature, from level T12–L3 there was reduced contractility as well as pale appearing muscle belly without evidence of necrosis (Fig. 4). Findings on the right side revealed healthier, bleeding, contractile muscle.

Following the release, a skin-only closure was performed with drain placements to avoid seroma development in the opened fascial plane (Fig. 5). If there is considerable tension on the skin during closure, then consideration should be given to placing a VAC device followed by delayed closure in 3–5 days. If concern for the amount of muscle necrosis found at initial presentation and decompression, VAC device should be placed with a repeat debridement scheduled in 2–3 days for further debridement. After the surgery, the patient was taken to the surgical intensive care unit.

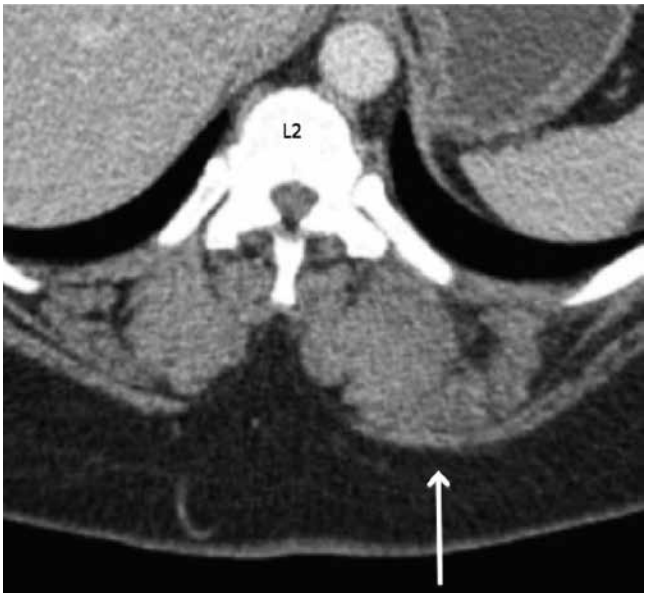

Figure 1. CT Scan at the level of T12, demonstrating left-sided paraspinal musculature swelling (white arrow).

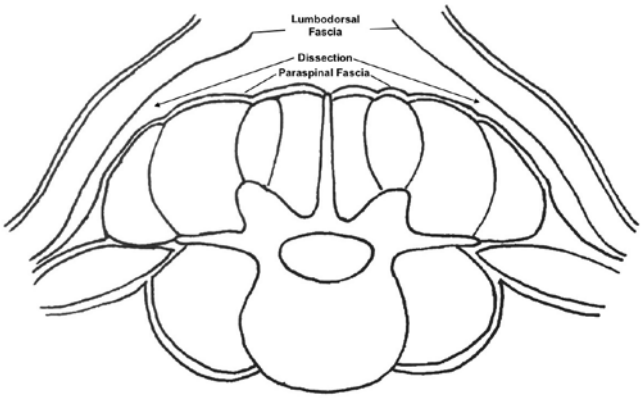

Figure 2. Illustration demonstrating the fascial plane between the thoracolumbar fascia and individual muscle compartment fascias, which requires dissection and individual release.

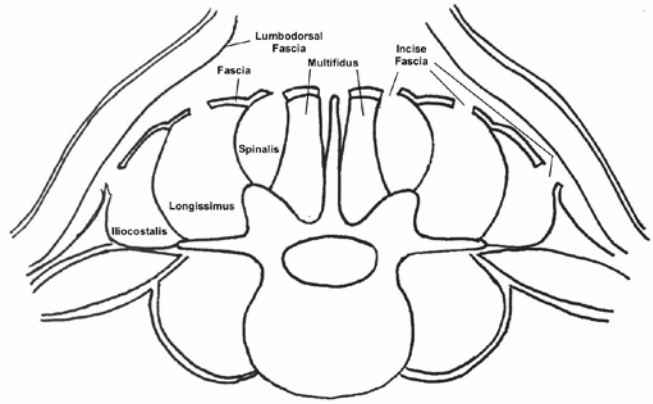

Figure 3. Illustration demonstrating the location of each individual fascial incision, resulting in the decompression of iliocostalis, spinalis, longissimus and multifidus muscle bellies.

Figure 4. An intra-operative photo of the fasciotomy, showing the paraspinal muscle exposure, with muscle bulging on the left hand side and dusky color of the muscle bellies throughout the compartment.

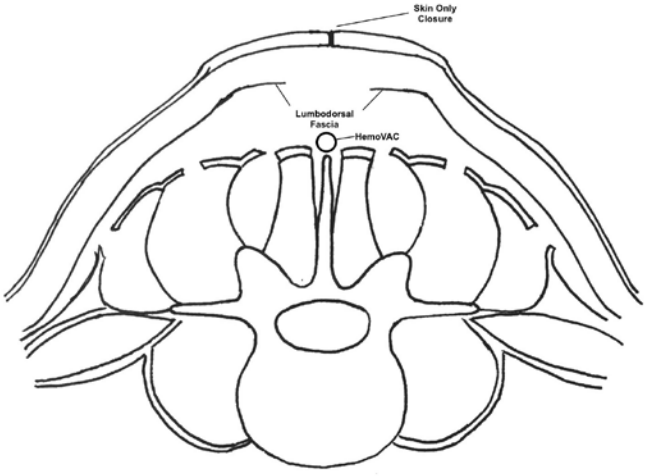

Figure 5. Illustration demonstrating a skin-only closure of the back with the thoracolumbar fascia left open and hemovac drains in place to avoid seroma development.

Postoperative Course

During a post-operative evaluation four hours after surgery, the patient stated significant improvement in not only her pain but also her flank sensation, though a deficit was still present. Throughout her six-day hospital stay, the patient's back pain and sensation continued to improve, with only a deficit remaining directly over the left paraspinal muscle. Creatine kinase levels were followed throughout her stay with a downward trend from 86,174 U/L at presentation to 36,163 U/L on post-operative day one to 2,512 U/L on day of discharge. By six months post-operatively, she reported a significant improvement in back pain. She rated her back pain as 5/10. At time of last follow-up, she had completed her physical therapy course and was experiencing no deficits in her activities of daily living. She has returned to her baseline activity levels.

Discussion

Paraspinal compartment syndrome can be classified as either acute or chronic. Typical presentation for patients with chronic compartment syndrome is a prolonged history of atraumatic back pain. Patients with acute compartment syndrome will report a shorter duration of symptoms with a possible inciting factor: trauma, exercise, or surgery related. Our patient presented with acute, traumatic paraspinal compartment syndrome as she had a recent trauma with no history of back pain prior to the onset of her acute pain.

In our review of the literature surrounding acute paraspinal compartment syndrome, the majority of cases were caused by exercise or surgical-related causes (i.e., reperfusion injury).[1, 4, 6, 8, 10, 14, 15] Only one case was found to be secondary to trauma. Similar to our patient, this case occurred in a female of the same age. In a review performed by Alfaraj et al., the majority of acute paraspinal compartment syndrome most commonly occurred in men and in patients under the age of 40.[5] Other than the previously mentioned traumatic cause, the remaining cases were secondary to exercise-related activity, surgery, or drug abuse.[5] Although both conservative and operative management were performed in these case reports, no evaluation assessing the 17 previous patients have identified patient demographics and how they may influence presentation and response to different treatment options has been performed.

In the few studies of paraspinal compartment syndrome, imaging studies such as MRI and CT were performed that provided some aid in the diagnosis. In the case report by Khan et al., both imaging studies were used. Initial CT findings showed paraspinal muscle swelling and paralytic ileus. A MRI study was later performed demonstrating increased signal in the paraspinal muscles bilaterally on T2 imaging.[4] In some cases, MRI was used secondarily to further assess the musculature due to negative CT findings and continued or worsening symptoms.[1, 8] In a review by Nathan et al., MRI was used in several reports as the initial imaging modality.

Our patient had CT lumbar spine performed as the initial imaging modality.[10] An MRI was determined to be unnecessary as there was swelling evident on CT scan along with laboratory findings and physical examination findings that all suggested a diagnosis of paraspinal compartment syndrome. With several reports including our own contributing to the literature, no study has determined which modality is best in the initial diagnosis of paraspinal compartment syndrome. Further studies need to be performed assessing the use of MRI and CT and their sensitivity and specificity in diagnosing paraspinal compartment syndrome.

Other than imaging, laboratory values can also aid in the diagnosis of paraspinal compartment syndrome by evaluating secondary conditions such as rhabdomyolysis that the patient may also demonstrate. Laboratory values evaluating for rhabdomyolysis and kidney function such as creatinine phosphokinase, basic metabolic panel, urinalysis, serum and urine myoglobin were performed in the majority of case reports.[1, 4, 10, 14] In the case of our patient, only creatinine kinase, basic metabolic panel, and urinalysis studies were completed.

In patients presenting with acute back pain, other etiologies besides paraspinal compartment syndrome must be considered and ruled out. What must also be considered are certain findings more specific to paraspinal compartment syndrome that may aid in differentiating it from other causes. This includes disc herniation, retroperitoneal pathology, and fractures. Our patient presented with tenderness to palpation over paraspinal musculature, firm, noncompressible paraspinal muscles, and decreased sensation in paraspinal region to mid-axillary line. Similar findings have been found in other studies such as decreased or absent bowel sounds.[4, 10] MRI and CT studies used to aid in the diagnosis of paraspinal compartment syndrome can also be used to rule out other etiologies. Most importantly, the patient's history pertaining to any trauma that may have caused the pain, activities performed prior to or when the pain began, as well as a history of similar back pain in the past should also be assessed.

The anatomy and position of the patient come into play when measuring compartment pressures, no different than extremity measurements. When measuring compartments in the extremity, the monitor should be held parallel to the ground and calibrated just prior to insertion into the compartment. The extremity being measured should not be resting on the bed, as this can artificially increase the pressure measurement, and should be in a position parallel to the ground. When measuring pressures in the paraspinal compartments, the same principles mentioned above apply, especially those pertaining to positioning. Unlike in the extremities, where a value within 30 mmHg of diastolic blood pressure[9] or 45 mmHg absolute value[7] is considered a diagnosis of compartment syndrome in compartments with normal values of 8 mmHg,[12] control values for paraspinal compartment pressures have not been well established. Anatomic studies assessing the different pressures measured within the paraspinal muscle compartments have shown large variability in values depending on the patient's position. Songcharoen et al. measured baseline compartment pressures in varying positions. While in a prone position, the resting intramuscular pressure was found to be 3.11 mmHg, 4.47 mmHg while standing, and 7.95 mmHg while sitting.[15] Previous studies have shown a diagnosis of compartment syndrome with measurements anywhere from 26 mmHg,[4] up to 108 mmHg.[8] This shows the wide ranges of pressures where patients may become symptomatic, and no study had identified patients at risk at lower values.

Non-operative and operative management of paraspinal compartment syndrome can be used with varying degrees of success. Conservative management has included intravenous fluids, pain control, bed rest, and monitoring of kidney function.[1, 4, 10] When non-operative measures provide no improvement, operative management via surgical decompression is considered as the optimal form of treatment. Many studies have shown ongoing long-term sequela in patients managed conservatively when presenting with exertional compartment syndrome, with these long-term outcomes improving with surgical decompression.[4, 5, 8, 11] While many studies exist in optimal timing for extremity decompression (ideally within six hours, with no more than 12 hours to assure minimal muscle necrosis),[2, 13] no studies have evaluated the optimal timing to surgical decompression to avoid long-term sequela in the paraspinal muscles. Our patient's ongoing pain may very well be due to her delayed presentation of one day. Therefore, in patients presenting with acute, rapidly progressing muscular back pain, acute paraspinal compartment syndrome must be considered.

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Case Report

Spinal Cord Injury Associated with Failure of VEPTR Treatment for Progressive Congenital Kyphosis in VACTERL Syndrome — A Case Report

James T. Bennett, MD;[1] Yusef I. Mosley, MD;[2] Jason R. Smith, PA-C;[3] Elias Dakwar, MD;[2] Joshua M. Pahys, MD;[3] Patrick J. Cahill, MD;[4] Amer F. Samdani, MD[3]

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Abstract

Study Design: Case report.

Objective: To present a case documenting a treatment method to manage patients with progressive congenital kyphosis and neurologic decline.

Summary of Background Data: Patients with VACTERL association commonly have vertebral malformations that may lead to severe angular kyphotic deformities. These deformities are challenging to manage due to limited fixation techniques and the potential for curve progression.

Methods: A 6-year-old boy with VACTERL association and congenital kyphoscoliosis presented to our institution with lower extremity weakness and loss of bowel and bladder control. The patient had prior placement of a vertical expandable prosthetic titanium rib (VEPTR) device with multiple lengthenings. Due to his neurologic compromise, he was taken to the operating room for a vertebral column resection (VCR) at T6 and a posterior spinal fusion (PSF) from T4 to T8.

Results: Postoperatively, his lower extremity weakness and loss of bowel and bladder control resolved within three months.

Conclusion: Patients with congenital sharp-angled kyphoscoliosis are often difficult to manage. VEPTRs and other growth-friendly devices have shown limited success in controlling the progression of kyphosis. If a patient's deformity continues to progress with neurological decline, one should consider decompression with segmental fusion as a viable treatment option.

Level of Evidence: 5

Introduction

Nearly 80% of patients with VACTERL association have vertebral malformations that may lead to severe angular kyphotic deformities. These deformities are challenging to manage due to limited fixation techniques and the potential for curve progression.[1] The vertical expandable titanium rib (VEPTR) was originally developed to treat thoracic insufficiency syndrome (TIS), but its application was later expanded to help treat early onset scoliosis.[2] This article describes the management of a patient with a progressive congenital kyphotic deformity who developed a spinal cord injury after treatment with a VEPTR.

Case Report

A six-year-old boy with VACTERL syndrome and progressive kyphosis (49° to 70°) (Figures 1A–E) was initially treated with a VEPTR at an outside institution. The patient underwent eight lengthenings over a four-year period, but later developed bilateral lower extremity weakness. The patient continued to have progressive neurologic deficits with loss of bowel and bladder control, requiring detethering of his spine, with no improvement in neurologic status.

At presentation to our institution, he was able to ambulate with assistance although his motor strength was 2/5 for bilateral ankle plantar and dorsiflexion and 3/5 for all other muscle groups. He had patchy sensation in his lower extremities and a neurogenic bladder. Radiographs revealed a proximal sharp apical kyphosis in his thoracic spine (Figures 2A–B). Magnetic resonance image (MRI) (Figures 3A–B) and 3-D computed tomography (CT) reconstruction (Figure 4) demonstrated cord signal changes with compression at the apex of the deformity at T9 but no vertebral instability.

The patient underwent a T6 decompressive vertebral column resection (VCR) with posterior instrumentation and fusion from T4–T8. Postoperatively, the patient had immediate improvement in his sensation and strength, and at his 15-month visit, he was ambulating with full strength and sensation in his lower extremities. His exam revealed no myelopathy, abnormal reflexes, clonus, or Babinski, and his radiographs demonstrated a stable fusion (Figures 5A–B).

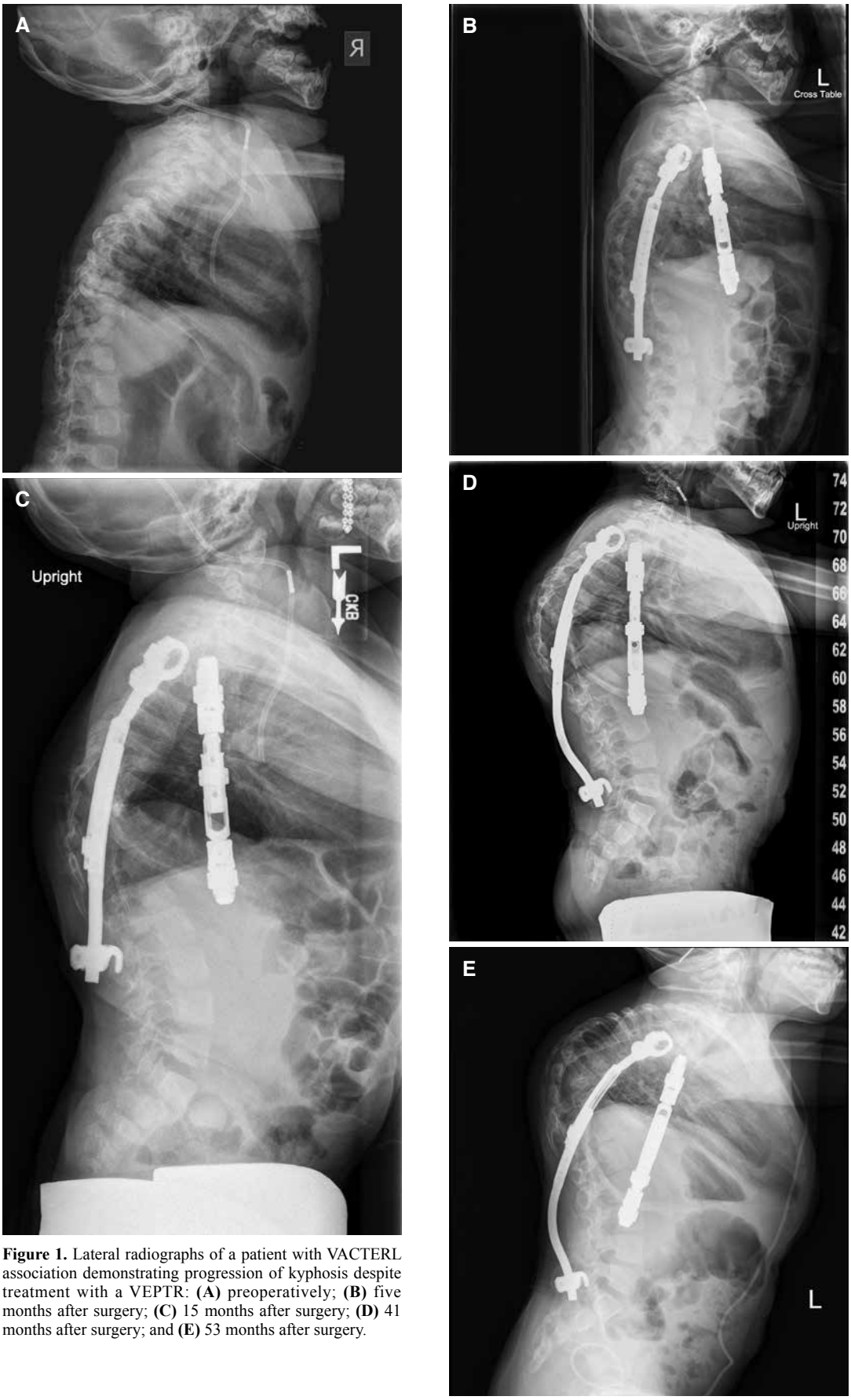

Figure 1. Lateral radiographs of a patient with VACTERL association demonstrating progression of kyphosis despite treatment with a VEPTR: **(A)** preoperatively; **(B)** five months after surgery; **(C)** 15 months after surgery; **(D)** 41 months after surgery; and **(E)** 53 months after surgery.

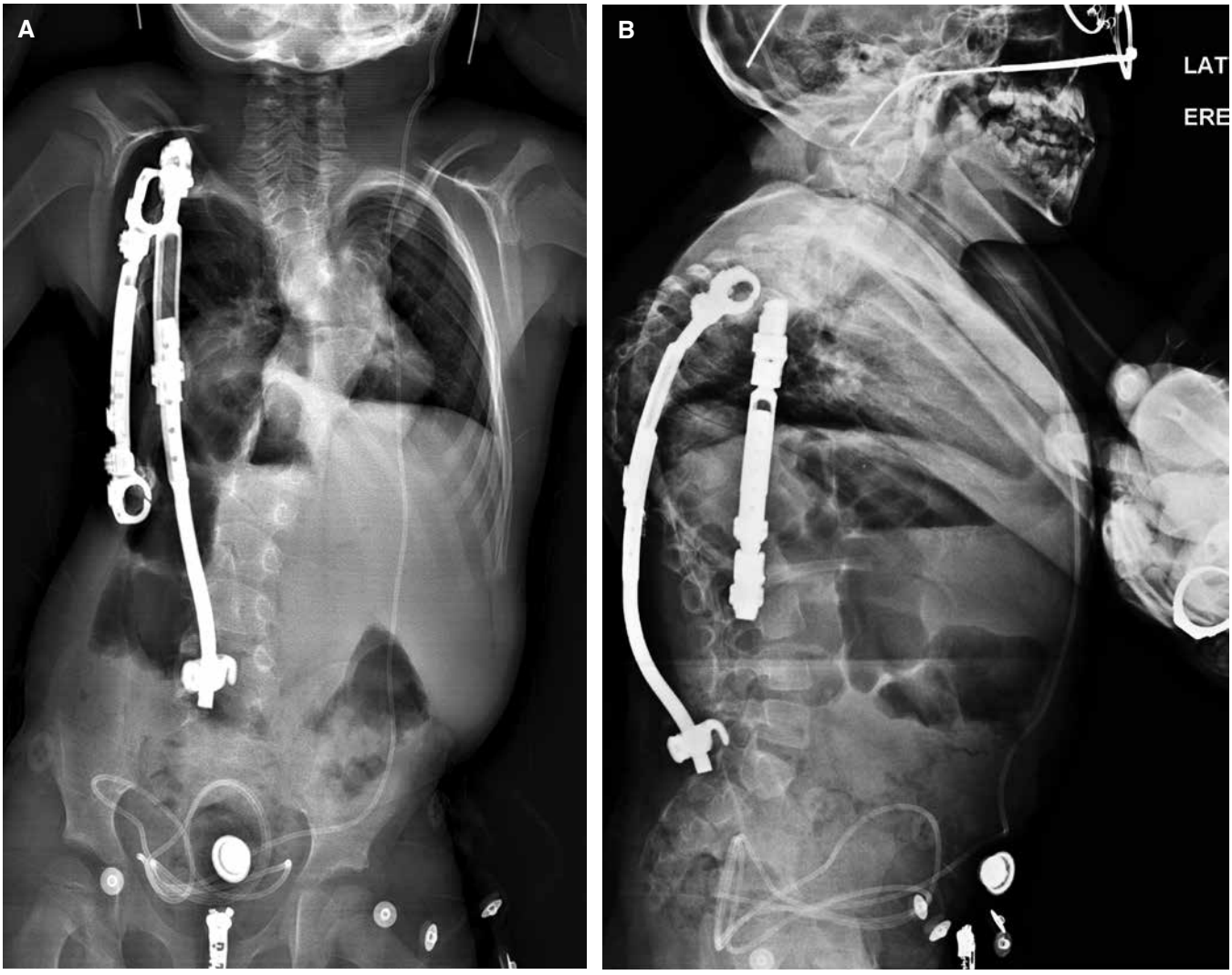

Figure 2. Preoperative **(A)** posteroanterior (PA) and **(B)** lateral radiographs of the patient prior to T6 decompressive vertebral column resection and posterior instrumentation and fusion from T4–T8.

Discussion

Congenital sharp-angled kyphotic deformities such as those seen in VACTERL association often present with a high risk of thoracic insufficiency and progression of deformity, often necessitating early operative intervention. Spinal fusion is typically not recommended in younger patients because of the growing spine, and an optimal treatment plan may be complicated by associated comorbidities.

The rates of neurologic complications related to the use of growth modulation devices are low, although one series reported a rate of 5.6%.[3, 4] Most cases occur after the initial placement of the device involving the brachial plexus.[3–6]

Progression of kyphosis in patients with early onset kyphoscoliosis has been well documented in the literature.[7] In a report by Reinker et al.,[8] patients with early onset kyphoscoliosis treated with a VEPTR had an increase in kyphosis by 22° at last follow-up. However, Astur et al.[9] published a series showing a decrease in thoracic kyphosis, from a preoperative measurement of 65° to a final postoperative measurement of 62°. The authors did note an increase in proximal junctional kyphosis above the level of the construct, possibly due to the posterior distraction of the VEPTR.

It is likely that both the natural history of early onset kyphoscoliosis and the VEPTR construct itself contribute to the progression of kyphosis. In an article by Banta and Hamada,[10] patients with a congenital kyphotic deformity associated with myelomeningocele were shown to have three different rates of progression. Patients with flexible paralytic kyphosis increased by 3° per year, kyphoscoliosis increased by 6.8° per year, and congenital rigid kyphosis increased by 8.3° per year. Smith et al.[11] used a hybrid rib-to-pelvis VEPTR to treat a kyphotic deformity in a patient with a myelomeningocele, and Samdani et al.[12] published a series of 11 patients with early onset scoliosis treated with dual rib-to-pelvis VEPTRs. The latter study demonstrated a decrease in kyphosis from a preoperative measurement of 43° to 37°

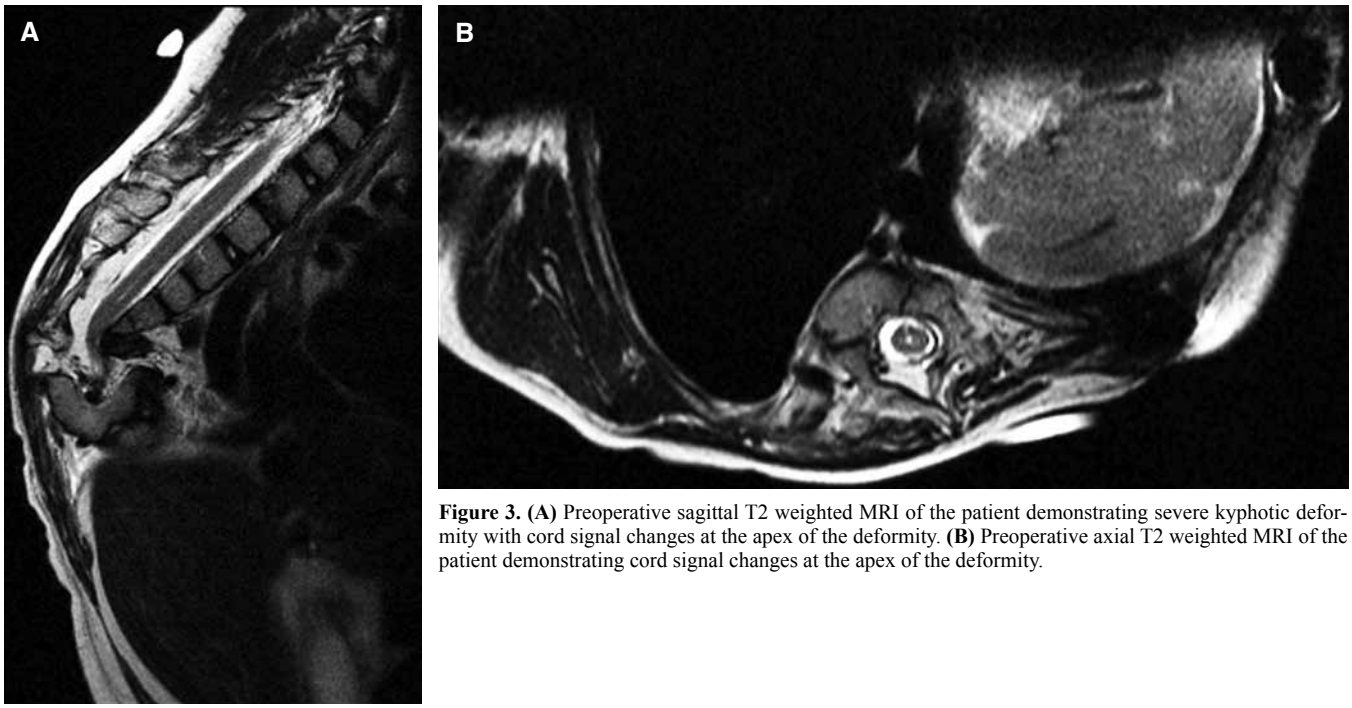

Figure 3. (A) Preoperative sagittal T2 weighted MRI of the patient demonstrating severe kyphotic deformity with cord signal changes at the apex of the deformity. **(B)** Preoperative axial T2 weighted MRI of the patient demonstrating cord signal changes at the apex of the deformity.

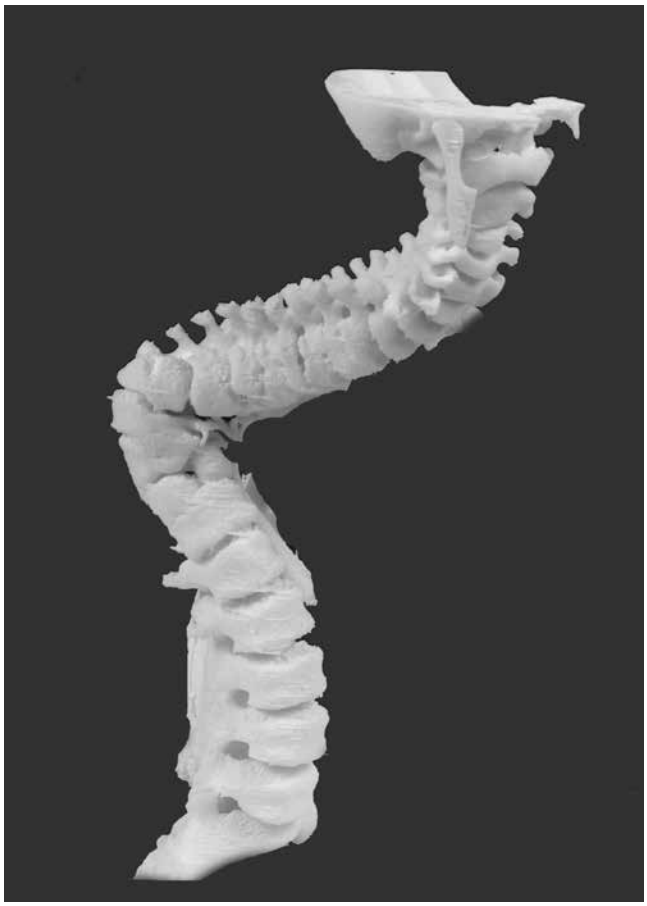

Figure 4. A 3-D CT reconstruction showing the severe kyphotic deformity.

at final follow-up. In addition, Wang et al.[13] published a case report describing a system with fusion across the apex but growth modulation above and below.

In the current patient, the construct's inability to control kyphosis could be due to the limited extent of its distal anchor point or failure to use a dual rod system, such as that used by Samdani et al.[12] Congenital sharp-angled kyphotic deformity should be followed closely for progression of the kyphosis. Alterations in management could include selecting a more distal anchor point such as a rib-to-pelvis construct, use of dual rod constructs, or using segmental fusion with a growing system attached proximally and distally.

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Figure 5. Postoperative **(A)** PA and **(B)** lateral radiographs of the patient following T6 vertebral column resection and T4 to T8 posterior spinal fusion demonstrating reduction of kyphotic deformity.

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Senior Abstract

Senior Bio Questionnaire

- Full Name: James Take Bennett
- Birthdate: 1/9/1984
- Hometown: Charlotte, VT
- Undergraduate University: Colby College
- Undergraduate Degrees: BA, major in Biology
- Medical School: St. Georges University SOM
- Fellowship: Children's Hospital of Los Angeles, Pediatric Spine
- Significant Other: Mary Mantey
- Hobbies: Skiing, mountain biking, rock climbing, sailing
- Interesting Fact: I have lived in eight different states for at least one year

Reoperation in Patients with Cerebral Palsy After Spinal Fusion: Incidence, Reasons, and Impact on HRQoL

James T. Bennett, MD, Amer F. Samdani, MD, Joshua M. Pahys, MD, Baron S. Lonner, MD, Peter O. Newton, MD, Firoz Miyanji, MD, Suken A. Shah, MD, Burt Yaszay, MD, Paul D. Sponseller, MD, Patrick J. Cahill, MD, Harms Study Group, Steven W. Hwang, MD

Summary: Patients with cerebral palsy (CP) undergoing spinal fusion experience a high rate of reoperation, although this has not been previously quantified. This report seeks to establish rate and major reasons for reoperation in this population. We report a 13.9% reoperation rate with 7.1% due to infection and 6.8% instrumentation failure. Patients with lower percent correction were at highest risk. Reoperation impacted HRQoL scores.

Hypothesis: The reoperation rate in patients with CP is high and lowers HRQoL scores.

Design: Retrospective review of a prospective data set.

Introduction: Patients with cerebral palsy (CP) undergoing spinal fusion experience a high rate of reoperation, although this has not been previously quantified. This report seeks to establish a rate, major reasons, and effect of reoperation on HRQoL, and explore potential risk factors.

Methods: A prospectively collected multicenter database was retrospectively reviewed to identify consecutive patients with CP who had undergone spinal fusion with a minimum two-year follow-up. We compared patients who underwent reoperation (Y) versus those who did not (N) with respect to preoperative, intraoperative, and postoperative factors.

Results: A total of 251 patients were identified with an average of 2.3 ± 0.6 years follow-up. 35 patients (13.9%) underwent a total of 37 reoperations. Of the 35 patients reoperated, 18 (7.1%) were for infection and 17 (6.8%) were instrumentation related. The majority of infections were deep (17/18). Of the 17 instrumentation related reoperations, the majority were for loosening (13.5%), prominence (13.5%), followed by junctional kyphosis (8.1%), broken instrumentation (5.4%), and pseudarthrosis (5.4%). The patients with lower percent correction of the major curve were at highest risk for a reoperation (Y = 54.3% correction versus N = 63.6% correction, p = 0.02). Patients who underwent an unplanned return to the OR had longer hospitalizations (Y = 19.5 days versus N = 10.7 days, p = <0.01, Table 1). These patients had lower comfort and emotions CPCHILD domain scores at two years after surgery (p = 0.04), with a trend toward lower personal care scores at two years (p = 0.08).

Conclusions: At an average of 28 months ± 6.7 months postop, spinal fusion for patients with CP have a significant rate of reoperation (13.9%), which impacts HRQoL and hospital length of stay. Infection, proximal junctional kyphosis, and instrumentation prominence/loosening are the most common reasons for reoperation.

Table 1

	Yes (n = 35)	No (n = 216)	p value
Age at Surgery ± SD (years)	14.4 ± 2.9	13.7 ± 2.6	0.15
Females N (%)	14 (40.0)	105 (48.6)	0.47
Primary Indication for Surgery			
Scoliosis N (%)	29 (82.9)	200 (92.6)	0.10
Kyphosis N (%)	6 (17.1)	17 (7.9)	
Major Cobb			
Pre-op ± SD (°)	83.9 ± 32.3	82.2 ± 23.6	0.71
2 Year ± SD (°)	33.9 ± 18.7	54.3 ± 40.0	0.17
Percent Change ± SD (%)	29.8 ± 15.6	63.6 ± 16.8	**0.02**
Pelvic Obliquity			
Pre-op ± SD (°)	26.7 ± 16.6	27.8 ± 15.7	0.73
2 Year ± SD (°)	9.9 ± 9.5	9.1 ± 8.9	0.68
Kyphosis (T5-T12)			
Pre-op ± SD (°)	42.2 ± 23.1	36.3 ± 23.3	0.19
2 Year ± SD (°)	23.3 ± 10.1	21.9 ± 10.5	0.49
Lordosis (T12-S1)			
Pre-op ± SD (°)	28.5 ± 30.6	41.0 ± 32.2	0.06
2 Year ± SD (°)	49.7 ± 19.0	54.5 ± 16.0	0.13
Estimated Blood Loss ± SD (cc)	1934.7 ± 1500.4	1658.8 ± 1206.0	0.23
Surgical Time ± SD (minutes)	427.2 ± 179.2	388.7 ± 109.7	0.09
Hospital Length of Stay ± SD (days)	19.5 ± 17.6	10.7 ± 6.9	**<0.01**
ICU Length of Stay ± SD (days)	6.3 ± 9.0	4.7 ± 5.3	0.15
Staged Procedure N (%)	4 (11.4)	21 (9.7)	0.77
Spastic CP N (%)	28 (80.0)	178 (82.4)	0.37

Senior Abstract

Senior Bio Questionnaire

- Full Name: Katharine Danielle Harper
- Birthdate: 3/28/1987
- Hometown: London, ON, Canada
- Undergraduate University: McMaster University
- Undergraduate Degree: Science of Kinesiology
- Medical School: Royal College of Surgeons in Ireland
- Fellowship: Houston Methodist, Adult Reconstruction
- Significant Other: Eric Maiorino
- Children: None
- Hobbies: Hockey, painting/ crafting
- Interesting Facts: I know how to juggle, and multiple attempts at furniture making have resulted in exactly zero usable pieces

Are We Informing Our Patients Properly About Their Care? A Prospective Study on Patient Education Following Traumatic Orthopaedic Injury

Katharine Harper, MD

Introduction

Inadequate health literacy and poor comprehension have been identified as being particularly prevalent in orthopedic patients. Discharge instructions are typically lengthy and text-based, presenting a potential obstacle for patients in understanding information regarding their care, while research has demonstrated that the use of illustrations in patient education materials can improve information recall. The goal of this study is to evaluate the effect of enhanced discharge instructions on comprehension in orthopedic trauma patients treated with surgery following a fracture.

Methods

A prospective cohort control study conducted from June 2016 to May 2017. Patients were provided either standard of care discharge instructions or enhanced instructions. They were then given a survey at their two-week follow-up appointment to test their knowledge of their medical care. All inpatient orthopedic trauma surgical patients were considered. Exclusion criteria included multiple fractures, poly trauma, outpatient management of injury, non-English speaking, traumatic brain injury, revision surgeries and lack of follow-up. Final evaluation had 50 control and 53 intervention patients.

Results

There was no statistically significant difference in demographics of our control group to our intervention group. Patients who had completed a higher level of education, on average, got more questions correct in the survey ($p = 0.0029$) regardless of whether they received the intervention. Patients who received the improved instructions got more questions correct than those who did not ($p = 0.0052$). Patients in the intervention group were more likely to know their weight-bearing status ($p = 0.05$) regardless of their education level; they were also more likely to know how their fracture was fixed ($p = 0.002$). The improved instructions resulted in no different in patients knowing which bone they broke (0.3953), which DVT prophylaxis they were on ($p = 0.3994$), bone healing time ($p = 0.2075$) or what ROM was allowed ($p = 0.4434$). Patients who were more educated were more likely to answer the DVT prophylaxis and ROM questions correct ($p = 0.0197$ and 0.0032, respectively).

Conclusion

Our study shows improved understanding and retention of post-operative instructions in patients who receive enhanced instructions, which contain illustrations and clear explanations of their post-operative course. With patients having a better understanding of their post-operative instructions, namely their weight-bearing status and what surgery they underwent, we hope to decrease our non-compliance complications and improve patient satisfaction with their overall care.

Senior Abstract

Senior Bio Questionnaire

- Full Name: John David Jennings
- Birthdate: 10/17/1985
- Hometown: Allentown, PA
- Undergraduate University: Pennsylvania State University
- Undergraduate Degrees: Finance, Pre-med, Biology
- Medical School: Temple University SOM
- Fellowship: Rothman Institute, Hand & Upper Extremity
- Significant Other: Alexandra Jennings
- Children: John and Grayson
- Hobbies: Skiing, golf, reminiscing about when I had time to ski and golf

Debridement of Dorsal Hand Abscesses in the Operating Room Does Not Improve Outcomes

JOHN JENNINGS, MD

Hypothesis

The most common site for hand infections is over the dorsal surface and is secondary to some traumatic mechanism. There is, however, no evidence to date to support either formal debridement in the operating room or a simple bedside procedure. The benefits of bedside procedures include decreased hospital costs, decreased time and staff required, and, particularly for sick patients, the ability to avoid general anesthesia. We hypothesize that formal debridement in the operating room does not improve patient outcomes and, therefore, does not justify forgoing the aforementioned benefits of a bedside procedure.

Methods

After obtaining IRB approval, a retrospective chart review was conducted for patients presenting to our level-one trauma center with a dorsal hand abscess. Information obtained included demographics, whether the initial debridement was performed at the bedside or in the operating room, as well as the organism, number of trips to the operating room, and repeat hospitalizations.

Results

During the one-year retrospective collection period, 27 patients had a dorsal hand debridement in the operating room whereas 23 patients had undergone bedside debridement as their primary procedure and a paired t-test was used for comparisons. The number of trips to the operating room was significantly less in the bedside debridement group ($p = 0.03$), as was the average length of hospital stay ($p = 0.04$). *Staphylococcus aureus* was the most common organism in both groups, with no statistical difference in MRSA isolation. There was no difference in hospital readmissions, duration of symptoms prior to debridement, age, gender, or comorbidities. Size of abscess on presentation was not significant, although this was poorly documented in the records.

Summary

Bedside debridement of dorsal hand abscesses may result in less overall trips to the operating room and less overall hospital days. While selection bias may influence these results, an initial attempt at bedside debridement may be safe and cost-efficient as a first-line attempt at treating dorsal hand infections.

Senior Abstract

Senior Bio Questionnaire

- Full Name: William Richard Smith
- Birthdate: 4/3/1987
- Hometown: Havertown, PA
- Undergraduate University: Pennsylvania State University
- Undergraduate Degrees: Biology, Classical Studies
- Medical School: Jefferson Medical College
- Fellowship: University of Pittsburgh Medical Center (UPMC), Hand Surgery
- Significant Other: Stephanie Smith
- Children: Baby Smith due 7/2018
- Hobbies: Golf, travel, Lenny B. Smith
- Interesting Fact: I was also born and raised in West Philadelphia, and on the playground is where I spent most of my days, chilling out, maxing, relaxing all cool, and all shooting some b-ball outside of the school

Patient Satisfaction in the Preoperative Period: Preparing for Hand Surgery

William Smith, MD

Introduction

With healthcare incentives and reimbursement transitioning from volume- to value-based, the business and patient-centered care models of practice are becoming increasingly intertwined. Patient experience is now widely accepted as a healthcare measure and component of healthcare quality, often reported as patient satisfaction scores. The potential impact of the number and type of preoperative encounters on satisfaction rates prior to elective surgical procedures is unclear, specifically scheduling and medical clearance encounters.

Methods

Questionnaires investigating satisfaction with the preoperative process were collected for 200 patients presenting for elective hand surgery. The number of telephone, surgeon and medical clearance encounters were recorded and satisfaction was determined for each type based on a 4-category Likert scale. All patients 18 years or older were included, while only patients providing incomplete questionnaires were excluded. Outcome data was assessed for associations between different encounter totals or types and satisfaction rates.

Results

Among 200 patients, 197 completed the questionnaire and were included. Overall satisfaction with the preoperative process was 92.9%, with only 3% of patients dissatisfied. There was a significant association between satisfaction and the number of telephone and total encounters. Satisfaction fell below 90% after four or more telephone calls (66.6%, $p = 0.005$) and five or more total encounters (80%, $p = 0.008$). When considered individually, there was no significant association between satisfaction and the number of surgeon ($p = 0.267$) or medical office encounters ($p = 0.087$), or a patient's perceived health status ($p = 0.14$).

Conclusions

Greater than three telephone or four total encounters significantly decreases patient satisfaction, while surgeon and medical office visits are not significantly associated with satisfaction rates when considered individually. This suggests the number, not the type, of preoperative encounters impact satisfaction and highlight the importance of efficient communication between patients and providers.

Table 1. Patient Satisfaction Rates for Telephone and Total Encounters

	Extremely Satisfied	Somewhat Satisfied	Averagely Satisfied	Somewhat or Very Dissatisfied	Total	p-Value
Number of Telephone Encounters						0.0050
0	51 (87.9%)	4 (6.9%)	2 (3.4%)	1 (1.7%)	58 (100.0%)	
1	69 (83.1%)	10 (12.0%)	3 (3.6%)	1 (1.2%)	83 (100.0%)	
2	29 (82.9%)	2 (5.7%)	3 (8.6%)	1 (2.9%)	35 (100.0%)	
3	9 (75.0%)	3 (25.0%)	0 (0.0%)	0 (0.0%)	12 (100.0%)	
4+	3 (33.3%)	3 (33.3%)	0 (0.0%)	3 (33.3%)	9 (100.0%)	
Total	161 (81.7%)	22 (11.2%)	8 (4.1%)	6 (3.0%)	197 (100.0%)	
Number of Total Encounters						0.0082
1	25 (92.6%)	1 (3.7%)	1 (3.7%)	0 (0.0%)	27 (100.0%)	
2	40 (85.1%)	4 (8.5%)	2 (4.3%)	1 (2.1%)	47 (100.0%)	
3	54 (85.7%)	7 (11.1%)	1 (1.6%)	1 (1.6%)	63 (100.0%)	
4	22 (88.0%)	2 (8.0%)	1 (4.0%)	0 (0.0%)	25 (100.0%)	
5	13 (65.0%)	3 (15.0%)	3 (15.0%)	1 (5.0%)	20 (100.0%)	
6+	7 (46.7%)	5 (33.3%)	0 (0.0%)	3 (20.0%)	15 (100.0%)	
Total	161 (81.7%)	22 (11.2%)	8 (4.1%)	6 (3.0%)	197 (100.0%)	

Special Event

Resident Research Day

April 15, 2017

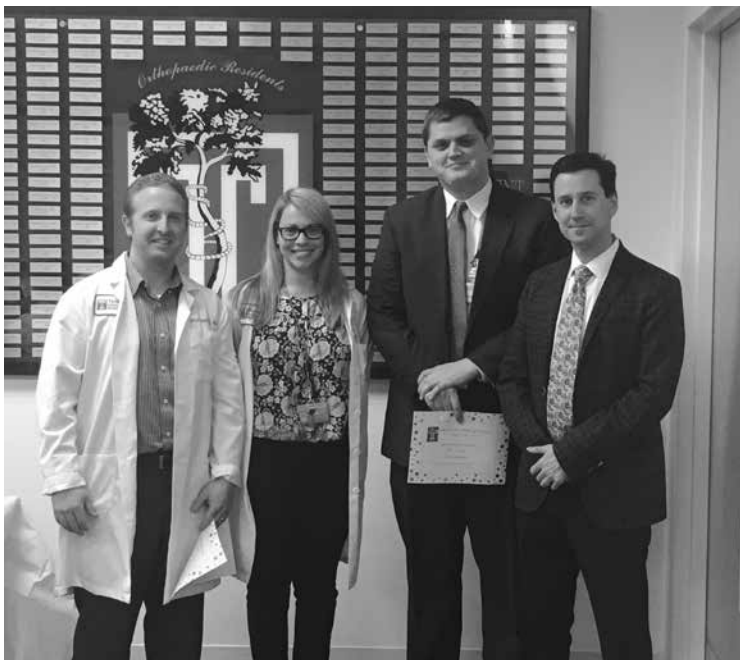
On April 15, 2017, the Temple University Department of Orthopaedic Surgery held its annual Resident Research Day. This event allows current Temple orthopaedic surgery residents to showcase their ongoing and published research endeavors. Greg Della Rocca, MD, PhD, FACS, Chief of Orthopaedic Trauma at Duke University, was our keynote speaker and guest judge. Dr. Della Rocca presented an insightful lecture entitled "Prevalence of Intimate Partner Violence in Orthopaedic Fracture Clinics."

Jim Lachman, MD (PGY-5) won first place for his paper "Going Rogue with Perioperative Antibiotics in Ankle Fracture Surgery: Whom Are We Protecting?" Dr. Lachman's study questioned the use of post-operative antibiotics after ankle fracture surgery. His results revealed no difference in the incidence of draining wounds, cellulitis, or return to OR for infection between patients who received intravenous antibiotics, oral antibiotics, or no antibiotics. He concluded that there was no justification for antibiotic use in patient's undergoing outpatient ankle fracture surgery.

Katharine Harper, MD (PGY-4) took second place for her work entitled "A Consistent Anatomical Landmark for Identifying the Lateral Femoral Circumflex Artery in a Direct Anterior Approach." Dr. Harper's retrospective study confirmed that the LFCA is found approximately 2/3 of the way between the lesser and greater trochanters along the femur's anatomical axis. Using this method, even surgeons unfamiliar with the approach will be able to reliably identify the LFCA and ligate the bundle.

Third place went to Dustin Greenhill, MD (PGY-5) for his work entitled "Inadequate Helmet Fit Increases Concussion Severity in American High School Football Players." Among the many conclusions Dr. Greenhill's study was able to reveal, he found that an improperly-fitted football helmet is a risk factor for more symptomatic concussions as well as those of longer duration. In order to decrease concussion severity and duration, he believes team physicians, athletic trainers, coaches, and high school officials should play a more important role in ensuring proper helmet fit.

Dayna Phillips, MD



Special Event

Temple-Shriners Alumni Day 2017

The Temple University Hospital Department of Orthopaedics and Sports Medicine held its annual Temple-Shriners Alumni Day at the Blue Bell Country Club this past May 2017. Despite the rainy weather and soggy conditions, many alumni, current residents and faculty gathered for a morning academic conference, afternoon of golf and an evening of celebration.

The event began with a vigorous academic discussion including current challenges in pain management and opioid use, obstacles in the execution of basic science research and an update on the orthopedic humanitarian response. Distinguished speakers included Temple Alumnus Asif Ilyas, MD and Christopher Born, MD visiting from the Weiss Center for Orthopedic Trauma Research in Rhode Island.

Next, several alumni, faculty and resident attendees donned their golfing attire and took to the green for a lively round prior to the final events of the day. Joined by colleagues, friends and loved ones, the evening concluded with a celebration dedicated to Dr. Joseph J. Thoder. Recognizing his enormous contribution to the education of Temple residents and the care of our community, Dr. Thoder's portrait was commissioned and revealed. Today, Dr. Thoder's portrait hangs in the Rock Pavilion amongst many of Temple's other prestigious and honored faculty members.

Dana Cruz, MD

Special Event

9th Annual Philadelphia Orthopaedic Trauma Symposium

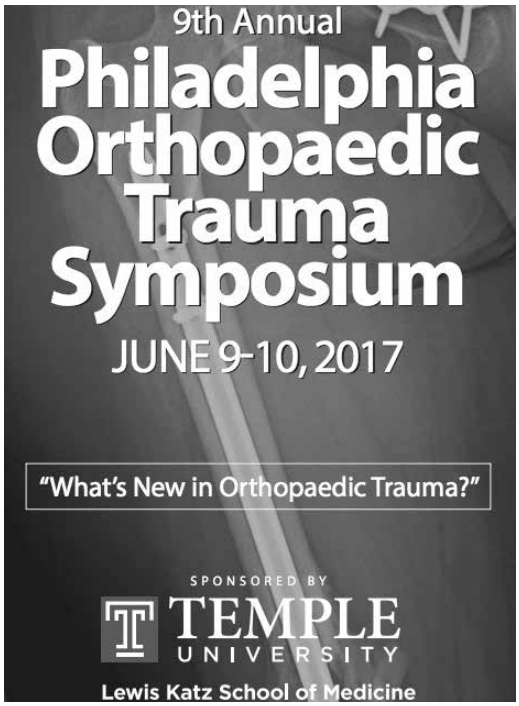
June 9–10, 2017

The 9th annual Philadelphia Orthopaedic Trauma Symposium was held at Temple University's Medical Education and Research Building from June 9–10, 2017. The event's chairman was Temple's own Dr. Saqib Rehman who organized and led the event. The course faculty included 25 orthopaedic surgeons from Philadelphia and surrounding area 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.

Dr. Melvin Rosenwasser, MD, Director of Hand Fellowship at Columbia University Medical Center, gave the keynote lecture. His thought-provoking lecture titled "Distal Radius Fractures: Are We Operating Too Much?" demonstrated that not all distal radius fractures should undergo open reduction and internal fixation including some intra-articular fractures. He stressed the importance of an adequate closed reduction and the important structures to assess in order to yield positive and predictable outcomes. Participants were then able to apply these concepts in the skills lab that followed.

This year's symposium touched on many topics such as post-traumatic deformity and non-union as well as where the treatment pendulum was now swinging toward in reference to clavicle shaft fractures. Current controversies and previously debated issues were discussed during the orthopaedic trauma debates segment of the program. In continuation of Dr. Rosenwasser's distal radius lecture, distinguished surgeons presented their stance on the use of volar plating versus fragment-specific fixation. Several other topics were discussed including non-operative versus operative management of proximal humerus fractures in the elderly population. Despite some differences in opinions, this segment of the program not only allowed insight into the thought process behind certain treatments but also new, innovative ways of treating certain fractures.

Dayna Phillips, MD



Special Event

Ponderosa Bowl 2017

Sunday, December 3rd, marked the 7th annual Ponderosa Bowl in the friendly confines of Dr. Thoder's backyard. The participants were welcomed with cool, crisp air and fresh frost that covered the field. Former Temple Resident, Dr. John Fowler, marked his return this year by lining the field with a fresh coat of spray paint.

The Cherry Team was comprised of attendings Dr. Min Lu and Dr. Hesham Abdelfattah, esteemed alumnus Dr. John Fowler, and residents Dr. Courtney Quinn and Dr. Alex Johnson. The White Team consisted of Dr. Macelroy Vroome, Dr. Jeff Wera, Dr. Peter Eyvazzadeh, Dr. Megan Reilly, and Dr. Justin Kistler.

The first half was highlighted by the Cherry Team's high-octane offense, which scored on every possession. The unorthodox quarterback play of Peter Eyvazzadeh kept the White Team within striking distance with a couple of crucial fourth down touchdowns. The game was tied at halftime, but the Cherry Team's offense proved too much to handle in the second half. A late second half defensive stop, followed by a pick six sealed the win for the Cherry Team.

Following the game, festivities continued in the Ponderosa basement with NFL football on three separate televisions. Along with the provisions provided by Dr. Thoder, Alex Johnson brought some of his favorite Italian roast pork from the Collegeville Bakery. The victorious Cherry squad enjoyed a celebratory drink from the Ponderosa Cup and will enjoy bragging rights until the next installment of the Ponderosa Bowl.

Jeff Wera, MD

Special Event

The "How to Be a Gentleman and a Lady" Party: 2017 Edition

The 2017 iteration of the annual "How to Be a Gentleman and Gentle Lady" was again sponsored by Dr. Thoder at the Ponderosa. Along with his supporting cast of well-trained gentlemen and ladies (including one Navy officer), the annual attempt at educating the residents in important aspects of life outside of orthopaedics was again a great success in learning and fun. The classic course objectives, some of which some chief residents struggle with even after five years of attendance, include learning the basics of primary social skill sets, understanding the need to understand those skills, and understanding the need to incorporate those skills into practice. This year's activities included, but were not limited to, whisky tasting, fundamental cigar knowledge, how to tie a bow tie, appropriate dress (from casual to formal) and, of course, what purse and shoe combination is appropriate in any setting. Penalties for inappropriate dress or behavior, such as failure to mark your drinking cup with a Sharpie or to keep the darts on the dart board (and not the wall) included "time out" in the corner or ejection from the basement altogether, depending on the severity of the offense. The event was overall a great success, and we thank Dr. Thoder and his supporting cast for their continued hospitality and dedication to educating residents on how to respectfully function in society. See you next year!

Will Smith, MD

Departmental News

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
Saqib Rehman, MD, *Vice Chairman*
Joseph Torg, MD

Associate Professors

Eric Gokcen, MD
J. Milo Sewards, MD
Bruce Vanett, MD

Assistant Professors

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

Adjunct Faculty — Philadelphia Shriners Hospital for Children

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 Report

Division of Adult Reconstruction

Matthew Lorei, MD
Division Chief

Min Lu, MD

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 advanced reconstruction. We are currently crafting an electronic comprehensive care plan for perioperative joint replacement patients. This expands on (and fine tunes) our well-received post-op electronic order set. This will be a "soup to nuts" care plan, taking patients from surgical scheduling through PATs, preop clearances, joint class, preop preparation as well as intraop and postop care. This should help to continue to streamline the preop and postop processes for the joint replacement patient. Ultimately, we hope it not only improves the patient experience, but builds on our success at reducing length of stay, reducing the need for SNF admission and reducing readmission. This will be critical as we transition away from a multi-day inpatient stay following joint replacement surgery.

Dr. Mooar is currently involved in the Novacart trial comparing MACI cartilage transplantation vs. microfracture of femoral condylar articular cartilage defects. This past year, he also served on the American College of Radiology Appropriate Use Criteria Committee and the AAOS Committee on Evidence-Based Quality and Value. In addition, he was an editor for McKesson InterQual® on Care Planning Criteria for TKA.

In late summer of 2018, we will be welcoming Julie Shaner as a new member of our staff. Julie is currently an Adult Reconstruction Fellow at the Brigham and Women's Harvard Combined program and is a graduate of the Jefferson Orthopaedic residency.

Publications

1. Quinn RH, Mooar PA, Murray JN, Pezold R, Sevarino KS. Treatment of Hip Fractures in the Elderly. *J Am Acad Orthop Surg.* 2017 May;25(5):e102–e104. doi: 10.5435/JAAOS-D-16-00431.
2. Quinn RH, Mooar PA, Murray JN, Pezold R, Sevarino KS. Postoperative Rehabilitation of Low Energy Hip Fractures in the Elderly. *J Am Acad Orthop Surg.* 2017 Jan;25(1):e11–e14. doi: 10.5435/JAAOS-D-16-00472.
3. Ibrahim SA, Blum M, Lee GC3, Mooar PA, Medvedeva E, Collier A, Richardson D. 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 Jan 18;152(1):e164225. doi: 10.1001/jamasurg.2016.4225. Epub 2017 Jan 18.
4. Mooar PA, Doherty WJ, Murray JN, Pezold R, Sevarino KS. Management of Carpal Tunnel Syndrome. *J Am Acad Orthop Surg.* 2018 Feb 7. doi: 10.5435/JAAOS-D-17-00451. [Epub ahead of print.]

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 continues to mature since Eric Gokcen, MD was appointed as the Division Head last year. As a follow-up to last year's Grand Rounds presentation of "Global Orthopaedics," PGY-4 resident Megan Reilly joined Dr. Gokcen on a short-term trip to Kijabe, Kenya, where they were able to perform many surgeries and provide teaching to the local staff and residents. During the trip, discussions began about the possibility of partnering with the Kenyan hospital for teaching and research projects. The trip was a resounding success, and plans are in the making to return later this year.

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 November 17th followed by a Grand Rounds presentation on November 18th on "Adult Flatfoot." The sessions were well received and provided further educational opportunity for our residents.

Research is progressing well and several foot and ankle research projects are ongoing, including studying alternative techniques to metatarsophalangeal plantar plate repair, driving after foot surgery, impact of reaming on ankle fusion surgery, and others.

The Division initiated the start of the Philly Orthopaedic Foot Club, established to encourage Philadelphia foot and ankle orthopaedic surgeons to cooperate in networking in order to provide the best care possible to our patients. The first meeting was in January and was well received, with plans to continue meeting regularly.

Division Report

Division of Hand Surgery

Joseph Thoder, MD
Division Chief

Hesham Abdelfattah, MD

Mark Solarz, MD

Bruce Vanett, MD

General

The division of Hand Surgery at Temple continues to grow. We have added another "new" faculty member in 2018. Mark Solarz, MD (residency class of 2017) has joined the staff having completed his fellowship at the University of Florida-Shands Hospital. We now have a full team of fellowship trained hand and upper extremity surgeons, all of whom are dedicated to resident education and scholarly activity.

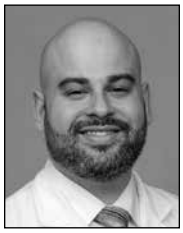
Over the past 27 years, Temple Orthopaedics has produced a significant number of graduates who have pursued fellowships and careers in hand surgery, many of whom are now leaders in the field. This year's graduating class has both John Jennings and Will Smith going on to hand fellowships at the Rothman Institute and UPMC respectively, where their faculty will include former Temple residents Asif Ilyas, MD, Robert Kaufmann, MD and John Fowler, MD.

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 and Mark are welcome additions to the program, contributing to our clinical, educational and research efforts.

Division Report

Division of Orthopaedic Trauma

Saqib Rehman, MD, MBA
Division Chief



Christopher Haydel, MD

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. 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.

The 9th 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 hosting the 10th Annual Meeting on June 8–9th with a lot of new changes to the program this year.

Resident and student didactic educational efforts have continued to evolve over the past year, with increasing use of online resources and flipped classroom teaching methods and strong emphasis on the "active learning" approach. The addition of our YouTube channel with over 1500 subscribers and viewers in over 200 countries has allowed us to reach a truly global audience.

The ortho trauma faculty continue 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), and AO Trauma. In addition, we have taught at local and regional courses, and given grand rounds lectures at other teaching programs. In addition, we have been actively serving many of these societies, chair committees and serve on Executive Boards in national organizations in our specialty, and serve as manuscript reviewers for multiple scientific journals. Back home at Temple, the ortho trauma faculty actively serve and chair numerous committees and project teams at the university, hospital, and departmental levels.

Research Activity

The Division of Orthopaedic Trauma, as Principal and Sub-Investigators, have been involved in the following clinical trials:

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

Scientific Publications in Peer Reviewed Journals

1. 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.
2. Solarz MK, Kistler JM, Rehman S. Obturator artery injury resulting in massive hemorrhage from a low energy pubic ramus fracture. *Orthopedics.* 2017 May 1; 40(3):e546–e548.
3. Gangavalli A, Malige A, Terre G, Rehman S, Nwachuku C. Misuse of opioids in orthopaedic postoperative patients. *J Orthop Trauma.* 2017 Apr;31(4):e103–e109.
4. Bosse MJ, Murray CK, Carlini AR, Firoozabadi R, Manson T, Scharfstein DO, Wenke JC, Zadnik M, Castillo RC; METRC. Assessment of severe extremity wound bioburden at the time of definitive wound closure or coverage: correlation with subsequent postclosure deep wound infection (Bioburden Study). *J Orthop Trauma.* 2017 Apr;31 Suppl 1:S3–S9. Doi: 10/1097/BOT.0000000000000805.
5. O'Toole RV, Joshi M, Carlini AR, Murray CK, Allen LE, Scharfstein DO, Gary JL, Bosse MJ, Castillo RC; METRC. Local antibiotic therapy to reduce infection after operative treatment of fractures at high risk of

infection: A multicenter, randomized, controlled trial (VANCO study). *J Orthop Trauma.* 2017 Apr; 31 Suppl 1:S3–S9. Doi: 10/1097/BOT.0000000000000801.

6. Gangavalli AK, Malige A, Rehman S, Nwachuku CO. Patient comprehension and compliance survey to assess postoperative pain regimens in the orthopaedic trauma population. *J Orthop Trauma.* 2017 Jun;31(6):e190–194. Doi: 10.1097/BOT.0000000000000822.
7. Amer K, Rehman S, Haydel C. Efficacy and safety of tranexamic acid in orthopaedic fracture surgery: A meta analysis and systematic literature review. *J Orthop Trauma.* 2017 Oct;31(10):520–525.
8. Mansfield C, Ali S, Komperda K, Zhao H, Rehman S. Optimizing radiation dose in computed tomography of articular fractures. *J Orthop Trauma.* 2017 Aug;31(8): 401–406.
9. Harper KD, Navo P, Ramsey F, Jallow S, Rehman S. "Hidden" Preoperative Blood Loss With Extracapsular Versus Intracapsular Hip Fractures: What Is the Difference? *Geriatr Orthop Surg Rehabil.* 2017 Dec;8(4): 202–207.
10. Harper K, Li S, Jennings R, Amer K, Haydel C, Ali S The Relative Effect of Exposure Control on Radiation Dose Vital Organs in Patients Undergoing Total Hip Arthroplasty. *J Am Acad Orthop Surg.* 2017 Nov 20. PMID: 29176493.

Scientific Podium and Poster Presentations

1. 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.
2. Harper K, Quinn C, Rodriguez E, Krause P, Born C, Rehman S. Mass casualty in orthopaedics: from planning to management. Is your department ready? *American Academy of Orthopaedic Surgeons Annual Meeting,* San Diego, CA, March 2017 (Scientific Exhibit) — Award Winner, Best Scientific Exhibit.
3. Jennings J, Quinn C, Rehman S. Orthopaedic surgery resident financial literacy: an assessment of knowledge in debt, investment, and retirement savings. *American Academy of Orthopaedic Surgeons Annual Meeting,* San Diego, CA. March 2017 — Award Winner, Best Poster in Practice Management category.
4. Greenhill D, Haydel C, Rehman S. Thigh compartment syndrome — a retrospective chart review. *Pennsylvania Orthopaedic Society Spring Meeting,* Erie, PA, April 2017.
5. Harper K, Li S, Jennings R, Amer K, Ali S. The relative effect of exposure control on radiation dose of vital organs in patients undergoing total hip arthiation dose of vital organs in patients undergoing total hip arthroplasty. *Pennsylvania Orthopaedic Society Spring Meeting,* Erie, PA, April 2017.
6. Harper K, Jallow S, Rehman S. "Hidden" pre-operative blood loss with extracapsular vs. intracapsular hip fractures — What is the difference? *Pennsylvania Orthopaedic Society Spring Meeting,* Erie, PA, April 2017.
7. Lachman J, Elkrief J, Pipitone P, Haydel C. Going Rogue With Perioperative Antibiotics in Ankle Fracture Surgery: Who Are We Protecting? *Philadelphia Orthopaedic Trauma Symposium,* June 2018.
8. Jennings J, Quinn C, Rehman S. Orthopaedic surgery resident financial literacy: an assessment of knowledge in debt, investment, and retirement savings. *American Orthopaedic Association Annual Meeting,* Charlotte, NC, June 2017.
9. Lachman J, Elkrief J, Pipitone P, Haydel C. Going Rogue With Perioperative Antibiotics in Ankle Fracture Surgery: Who Are We Protecting? *Annual Meeting of the Orthopaedic Trauma Association,* Vancouver, BC, October 2017
10. Vroome CM, Gonzalez MN, Haydel C. Regional Anesthesia Techniques in a Patient Undergoing Surgical Repair of a Tibial Plateau Fracture. *Pennsylvania Orthopaedic Society Fall Scientific Meeting,* State College, PA, October 2017.
11. Vroome C, Jones E, Rehman S. Pain Control in Orthopedic Trauma Inpatients. *Pennsylvania Orthopedic Society Fall Scientific Meeting,* State College, PA, Oct. 26, 2017.
12. Quinn C, McKinney R, Rehman S. Incidence of infection in civilian gunshot arthrotomies: does formal joint washout make a difference? *Pennsylvania Orthopedic Society Fall Scientific Meeting,* State College, PA, Oct. 26, 2017.
13. Harper K, Wera J, Jordan H, Kakalecik J, Ramsey F, Rehman S. Are we informing our patients properly about their care? A prospective study on patient education following traumatic orthopaedic injury. *Pennsylvania Orthopedic Society Fall Scientific Meeting,* State College, PA, Oct. 26, 2017.

Educational Presentations

1. Lecture, lab moderator. *Foundation for Orthopaedic Trauma Upper Extremity Surgical Approaches Course,* Las Vegas NV, February 2017 (Haydel).
2. Tranexamic acid: when should we be using it? *Foundation for Orthopaedic Trauma Annual Meeting,* Las Vegas, NV, February 2017 (Haydel).
3. Fractures of the proximal femur: ICL#185. At the *Annual Meeting of the American Academy of Orthopaedic Surgery,* San Diego, CA, March 2017 (Haydel).
4. Old and hip: Improving outcomes in geriatric fracture patients. *Grand Rounds, Department of Surgery, Temple University Hospital,* March 2017 (Haydel).
5. Old and hip: Improving outcomes in geriatric fracture patients. *Grand Rounds, Department of Nursing, Temple University Hospital,* June 2017 (Haydel).

6. ORIF trimalleolar ankle fracture with posterior fixation (lab moderator). At the *9th Annual Philadelphia Orthopaedic Trauma Symposium,* June 9, 2017 (Haydel).
7. Hip fractures (moderator). At the *9th Annual Philadelphia Orthopaedic Trauma Symposium,* June 9, 2017 (Haydel).
8. Managing open tibia fractures: Tips and techniques. At the *9th Annual Philadelphia Orthopaedic Trauma Symposium,* June 10, 2017 (Haydel).
9. Clavicle fractures (moderator). At the *9th Annual Philadelphia Orthopaedic Trauma Symposium,* June 9, 2017 (Rehman).
10. Orthopaedic trauma debates (moderator). At the *9th Annual Philadelphia Orthopaedic Trauma Symposium,* June 9, 2017 (Rehman).
11. Decision making for humeral shaft fractures. How to best treat them. At the *9th Annual Philadelphia Orthopaedic Trauma Symposium,* June 9, 2017 (Rehman).
12. Lab moderator: ORIF proximal tibia fractures. At the *9th Annual Philadelphia Orthopaedic Trauma Symposium,* June 9, 2017 (Rehman).
13. Splinting workshop for emergency medicine interns. *TUH,* August 2017 (Haydel).
14. Distal humerus fractures — This ain't tennis elbow surgery (panel). At the *6th Annual Mid Atlantic Shoulder and Elbow Society Annual Meeting,* Washington DC, Sept. 8, 2017 (Rehman).
15. Applied anatomy and approaches to the proximal tibia. At the *Foundation for Orthopaedic Trauma lower extremity dissection course,* September 2017 (Haydel)
16. Bone healing. At the *Orthopaedic Trauma Association Comprehensive Fracture Course for Residents,* Vancouver BC, October 2017 (Haydel).
17. Getting through the night: fractures with vascular injury. At the *OTA Annual Meeting Boot Camp,* Vancouver, BC, Canada, Oct. 11, 2017 (Rehman).
18. Malreduction and malrotation with proximal femur fractures. At the *10th Annual Delaware Orthopaedic Symposium,* Newark, DE, Oct. 28, 2017 (Rehman).
19. Online education in orthopaedic surgery. At the *10th Annual Martin Cohen, MD Memorial Lecture at St. Luke's Health System,* Dec. 6, 2017 (Rehman).
20. Distal radius fractures. *AO Principles of Fracture Management,* Atlanta, GA, Dec. 2017 (Haydel).
21. Lower extremity module (moderator). *AO Principles of Fracture Management,* Atlanta, GA, Dec. 2017 (Haydel).
22. Orthopaedic infections. *AO Principles of Fracture Management*, Atlanta, GA, Dec. 2017 (Haydel).
23. Extracapsular hip fractures. *AO Principles of Fracture Management,* Atlanta, GA, Dec. 2017 (Rehman).
24. Diaphyseal management (Moderator). *AO Principles of Fracture Management,* Atlanta, GA, Dec. 2017 (Rehman).
25. Online education in orthopaedic surgery. *Grand Rounds at LSU Orthopaedic Surgery Residency Program,* New Orleans, LA, Jan. 26, 2018 (Rehman).
26. Malreduction and malrotation with proximal femur fractures. *LSU Orthopaedic Surgery Residency Program,* New Orleans, LA, Jan. 26, 2018 (Rehman).
27. Fractures of the proximal femur: ICL#388. At the *Annual Meeting of the American Academy of Orthopaedic Surgery,* New Orleans, LA, March 8, 2018 (Rehman).
28. Extreme nailing: Tips and tricks from the experts. At the *Annual Meeting of the American Academy of Orthopaedic Surgery*, New Orleans, LA, March 9, 2018 (Rehman).

Division Report

Division of Spine Surgery

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

The spine service has undergone some changes over the past year. Dr. F. Todd Wetzel left the spine division at Temple University in November to join Bassett Healthcare in Cooperstown, NY, as the Chairman of Orthopaedics. To help manage the non-operative side of spine care at Temple, Jennifer Francis joined the spine service in March as a new Physician Assistant.

The spine service is steadily working to grow the clinical and educational aspects of the service. To improve upon residents' education, a combined spine conference between the Neurosurgery spine service and the Orthopaedic spine service now takes place every two weeks. In April, we began dedicating one full day of every rotation to train the spine service resident in a cadaver lab setting.

Some specific activities of the section are detailed below.

Educational

1. Annual Spine Anatomy lecture for the PMR residents.
2. Spine series lectures, *Physician Assistant Curriculum,* 2018.
3. Spine lectures, *Orthopaedic Residency Program.*
4. Saw bones lab for pedicle screw instrumentation of the spine. *Orthopaedic Residency Program.*
5. **Sardar ZM.** Osteotomies in Adult Spinal Deformity Management. *1st Combined North American Spine Society and Asia Pacific Spine Society Meeting,* March 2018.
6. **Sardar ZM.** Surgical Planning of Osteotomy in ASD. *1st Combined North American Spine Society and Asia Pacific Spine Society Meeting,* March 2018.

Publications

1. **Sardar ZM.** CORR Insights: Debridement and Reconstruction Improve Postoperative Sagittal Alignment in Kyphotic Cervical Spinal Tuberculosis. *Clinical Orthopaedics and Related Research,* 2017.
2. **Sardar ZM,** Ames RJ, Lenke LG. Scheuermann's Kyphosis. Under review for publication in *JAAOS.*

Book Chapters

1. Sardar ZM, Lehman R, Lenke LG. Adult Scoliosis. In: *Orthopaedic Knowledge Update: Spine 5.*
2. Sardar ZM, Lenke LG. Adolescent Idiopathic Scoliosis: Classification and Natural History. In: *AO Spine Master Series, Volume 9: Pediatric Spinal Deformity.*

External Activities

Sardar ZM:
Reviewer, *The Spine Journal*
Reviewer, *Global Spine Journal*
Member, *AOSpine*
Member, *Scoliosis Research Society (SRS)*
Member, *SRS Website Committee*
Member, *North American Spine Society*
Member, *American Association of Orthopaedic Surgeons*

Division Report

Division of Sports Medicine and Shoulder Surgery

Eric J. Kropf, MD
Director of Sports Medicine

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 23,000 patient visits a year and performs 1200+ procedures annually. A key area of recent growth has been through continued development of our Shoulder Reconstruction/Arthroplasty program led by Dr. Leslie Barnes.

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, physician assistant students, and Kinesiology undergraduate and graduate athletic training students. While orthopaedic residents remain our primary focus, the sports division also works with internal 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, Father Judge High School, Archbishop Wood HS, Archbishop Ryan HS and LaSalle College Preparatory. Members of the team have also developed affiliate relationships with Arcadia University Athletics and Drexel University's primary care sports medicine program.

Scientific Publications (Peer Reviewed)

1. Fink Barnes LA, Lombardi J, Gardner TR, Strauch RJ, Rosenwasser MP. Comparison of Exposure in the Kaplan versus the Kocher Approach in the Treatment of Radial Head Fractures. *Hand.* January 2018.
2. Shukla DR, Rubenstein WJ, Barnes LA, Klion MJ, Gladstone JN, Kim JM, Cleeman E, Forsh DA, Parsons BO. The Influence of Incision Type on Patient Satisfaction After Plate Fixation of Clavicle Fractures. *Orthop J Sports Med.* 2017 Jun 22;5(6):2325967117712235.
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*. 2017 June;18(2):57–61.
4. Jolstad C, Kropf EJ, Ramsey FV, Torg J. Joint Preservation Surgery for Secondary Osteonecrosis of the Knee: A Presentation of two cases and Literature Review. *Temple University Journal of Orthopaedic Surgery and Sports Medicine.* 2017;12:34–40.
5. Pandelidis A, Reilly R, Ly J, Ramsey FV, Kropf EJ. Utility of MRI to define anatomical features of the anterior inferior iliac spine. *Temple University Journal of Orthopaedic Surgery and Sports Medicine.* 2017;12:49–53.
6. Vaysburg D, Jennings J, Kropf EJ. Seizure-associate anterior shoulder instability: Review of the literature and operative case series. *Temple University Journal of Orthopaedic Surgery and Sports Medicine.* 2017;12: 54–62.
7. 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.* Feb 2017;99-B(2):245–249.
8. Amoako, AO, Nassim, A, Keller, C. Body Mass Index as a Predictor of Injuries in Athletics. *Current Sports Medicine Reports.* July/August 2017.

Scientific Presentations
(Podium, Poster, Invited Lecture)

1. Greenhill D, Navo P, Zhao H, Torg J, Comstock D, Boden B. Inadequate Helmet Fit Increases Concussion Severity in American High School Football Players. *American Orthopaedic Society for Sports Medicine (AOSSM) Annual Meeting,* Toronto, ON, Canada, July 2017. **Winner T. David Sisk Research Award — Best original research paper in SportsHealth.
2. Kropf EJ. Early Career Development: Challenge and Opportunity in Academic Practice. *Pennsylvania Orthopaedic Society Spring 2017 Scientific Meeting,* Erie, PA, May 11, 2017.
3. 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).
4. Coleman S, Poor A, Salvo J, Kropf EJ, Roedl J, Zoga A, Meyers WC. Combined surgery of concomitant femoroacetabular impingement (FAI) and core muscle injury (CMI) offers speedy return to play. *ISHA Annual Meeting,* Santiago, Chile, Feb. 9–11, 2017.
5. Kropf EJ. Proximal Hamstring Injuries: Evaluation, management and surgical indications. *MACRA-ACSM 2017 Annual Meeting,* Harrisburg, PA, Nov. 2017.
6. Kropf EJ. Femoroacetabular Impingement; Surgical Indications and Treatment Options. *PA Ortho Society Spring Meeting,* April 27, 2018, Charleston, SC.
7. Kropf EJ. Combined Hip and Core Muscle Injury. *PA Ortho Society Spring Meeting,* April 28, 2018, Charleston, SC.
8. Barnes LA. Radial head fractures: When to fix, when to replace. *Pennsylvania Orthopedic Society Annual Meeting,* State College, PA, Oct. 2017.
9. 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.
10. 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).
11. 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).
12. Keller CJ. Shoulder Assessment. *LKSOM Family Medicine Review Course,* March 2017.
13. Keller CJ. The Aging Athlete. *Reading Hospital Family Medicine Grand Rounds,* March 2017.
14. Keller CJ. Medical Assessment of Lumbar Pain. *Arcadia University Interdisciplinary Case-Based Approach to Medical Screening for the Physical Therapist,* March 2018.
15. Keller CJ. Orthopedic Cases. *LKSOM Family Medicine Review Course,* March 2018.
16. Keller CJ. Sudden Cardiac Death in Sports. *Reading Hospital DO Symposium,* November 2017.
17. Keller CJ. Assessment of Shoulder Pain. *LKSOM Family Medicine Review Course,* October 2017/March 2018.
18. Noreski M. Pelvic Injuries in Athletes, *Northeast Regional AOASM,* PCOM 2017.
19. Noreski M. Sports Medicine Panel. *American Women's Medical Association, Philadelphia College of Osteopathic Medicine,* 2017.
20. Schreiter R. Ankle Exam and Treatment. *Chestnut Hill Family Medicine Residency Grand Rounds*, 2017.
21. Schreiter R. Pancreatitis in College Football Student Athlete. *AMSSM 2018 Annual Meeting* (poster).

Clinical Trials (Ongoing)

1. 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. (Aesculap) Phase III (Sewards, Mooar, Kropf).

Temple University Hospital
Department of Orthopaedic Surgery and Sports Medicine
House Staff 2017–2018

Katherine Harper, MD

Hometown: London, Ontario, Canada

Undergraduate: McMaster University

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

Fellowship: Adult reconstruction, Houston Methodist Hospital

John Jennings, MD

Hometown: Allentown, PA

Undergraduate: Pennsylvania State University

Medical School: Temple University School of Medicine

Fellowship: Hand/upper extremity, Rothman Institute

James Bennett, MD

Hometown: Charlotte, VT

Undergraduate: Colby College

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

Fellowship: Pediatrics, Los Angeles Children's Hospital

William Smith, MD

Hometown: Havertown, PA

Undergraduate: Pennsylvania State University

Medical School: Jefferson Medical College

Fellowship: Hand/upper extremity, University of Pittsburgh

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

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

Temple University Hospital
Department of Orthopaedic Surgery and Sports Medicine
House Staff 2017–2018 *(cont.)*

Dayna Phillips, MD

Hometown: Rosenhayn, NJ

Undergraduate: University of the Sciences

Medical School: Rutgers – New Jersey Medical School

Interest: Pediatrics

Colin "Mac" Vroome, MD

Hometown: Havertown, PA

Undergraduate: Villanova

Medical School: Jefferson Medical College

Interests: Hand/upper extremity

Jeffrey Wera, MD

Hometown: Villa Hills, KY

Undergraduate: The College of William & Mary

Medical School: University of Louisville School of Medicine

Interests: Sports, hand/upper extremity

Robert Ames, MD

Hometown: Dallas, TX

Undergraduate: Rutgers University

Medical School: Temple University School of Medicine

Interests: Spine, pediatrics

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 Hospital
Department of Orthopaedic Surgery and Sports Medicine
House Staff 2017–2018 *(cont.)*

Colin Ackerman, MD

Hometown: Allentown, PA

Undergraduate: Pennsylvania State University

Medical School: Jefferson Medical College

Interest: Undecided

Joshua Luginbuhl, MD

Hometown: Denver, PA

Undergraduate: Muhlenberg College

Medical School: Drexel University

Interest: Undecided

Akul Patel, MD

Hometown: Ampthill, England

Undergraduate: Duke University

Medical School: University of North Carolina

Interest: Undecided

Andrew Porter, MD

Hometown: Chester, NH

Undergraduate: Boston University

Medical School: Temple University School of Medicine

Interest: Adult reconstruction

Temple University Department of Orthopaedic Surgery and Sports Medicine: Research Update July 2017–June 2018

Research Not Listed in Division Reports

Podium Presentations

1. Kistler J, Thoder J. MRSA Incidence and Antibiotic Trends in Urban Hand Infections: A Ten-Year Longitudinal Study. *American Association of Hand Surgery Annual Meeting,* Phoenix, AZ, January 2018.
2. Quinn C, McKinnley R, Ramsey F, Rehman S. Incidence of infection in civilian gunshot arthrotomies: does formal joint washout make a difference? Podium Presentation. *Pennsylvania Orthopedic Society Fall Meeting,* State College, PA, October 2017. *Awarded 3rd Place for Resident Papers at *POS Fall 2017 Meeting.*
3. Vroome C, Jones E, Ramsey F, Rehman S. Pain Control in Orthopedic Trauma Inpatients. Podium Presentation. *Pennsylvania Orthopedic Society Fall Meeting,* State College, PA, October 2017.
4. Greenhill D, Johnson A, Rehman S. Thigh Compartment Syndrome: When, Why, and How Long to Worry? *Eastern Orthopedic Society Annual Meeting,* Miami, FL, October 2017.

Poster Presentations

1. Harper K, Wera J, Jordan H, Kakalicek J, Ramsey F, Rehman S. Are we informing our patients properly about their care? A prospective study on patient education following traumatic orthopaedic injury. *American Orthopaedic Association (AOA) Annual Leadership Meeting,* Boston, MA, June 2018.
2. Harper K, Wera J, Jordan H, Kakalicek J, Ramsey F, Rehman S. Are we informing our patients properly about their care? A prospective study on patient education following traumatic orthopaedic injury. *American Academy of Orthopaedic Surgeons (AAOS) Annual Meeting,* New Orleans, LA, March 2018.
3. Quinn C, McKinnley R, Ramsey F, Rehman S. Incidence of infection in civilian gunshot arthrotomies: does formal joint washout make a difference? Poster Presentation. *American Academy of Orthopaedic Surgeons (AAOS) Annual Meeting,* New Orleans, LA, March 2018.
4. Smith WR, Wera J, Ramsey FV, Takei R, Gallant G, Liss F, Beredjiklian P, Kwok M. Patient Satisfaction in the Preoperative Period: Preparing for Hand Surgery. *American Association of Hand Surgery Annual Meeting,* Phoenix, AZ, January 2018. *Poster was presented by J. Wera.
5. Harper K, Wera J, Jordan H, Kakalicek J, Ramsey F, Rehman S. Are we informing our patients properly about their care? A prospective study on patient education following traumatic orthopaedic injury. *Pennsylvania Orthopedic Society Fall Meeting,* State College, PA, October 2017.
6. Vroome C, Starks V, Gargya, A, Gonzalez M, Haydel C. Regional Anesthesia Techniques in a Patient Undergoing Surgical Repair of a Tibial Plateau Fracture. *Pennsylvania Orthopedic Society Fall Meeting,* State College, PA, October 2017.
7. Jennings J, Vroome CM, Ghandi S, Thoder JJ. Does Debridement of Dorsal Hand Abscesses in the Operating Room Improve Outcomes? *American Society for Surgery of the Hand Annual Meeting,* San Francisco, FL, September 2017.

Publications in Peer-Reviewed Journals

1. Harper KD, Navo P, Jallow S, Ramsey F, Rehman S. "Hidden" pre-operative blood loss with extracapsular vs. intracapsular hip fractures — What is the difference? *Geriatric Orthopaedic Surgery & Rehabilitation* (in press).
2. Harper KD, Li S, Jennings R, Amer K, Haydel C, Ali S. The Relative Effect of Automatic Exposure Control on Radiation Dose to Vital Organs in Patients Undergoing Total Hip Arthroplasty. *Journal of the American Academy of Orthopaedic Surgeons* (in press), January 2018.

Textbook Chapters

1. Reilly M, Rehman S. Metatarsal Fractures Fixed with Plates or Wires. In: Tejwani N. (eds): *Fractures of the Foot and Ankle.* Springer, Cham., 2018.

Joseph J. Thoder
Orthopaedic Excellence Award

"Awarded 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 of recognition.

This year, **Colin "Mac" Vroome** (Class of 2020) was selected by chief residents Dustin Greenhill, James Lachman, Anastassia Newbury, and Arianna Trionfo (Class of 2017).

Previous Winners:
2016 — Courtney Quinn, MD
2015 — Katharine Harper, MD
2014 — Arianna Trionfo, MD
2013 — Rupam Das, MD
2012 — Matthew Kleiner, MD
2011 — Richard Han, MD
2010 — John Fowler, MD

Colin "Mac" Vroome, MD

Snapshots from 2017–2018

Dr. Howard Steel and Temple PGY3 residents Colin Vroome, Dayna Phillips, and Jeffrey Wera at the Philadelphia Orthopaedic Society September meeting

Colin Vroome, Katharine Harper, and Courtney Quinn at the fall POS meeting

Temple Orthopaedics at the Philadelphia Flyers game

Snapshots from 2017–2018

Handpod love!!

Congratulations to Justin and Megan Kistler on the birth of their son Nathan Michael on 12/21/17!

Justin Kistler presenting at the AAHS Annual Meeting in January

Jack Reynolds…in typical corner fashion

Snapshots from 2017–2018

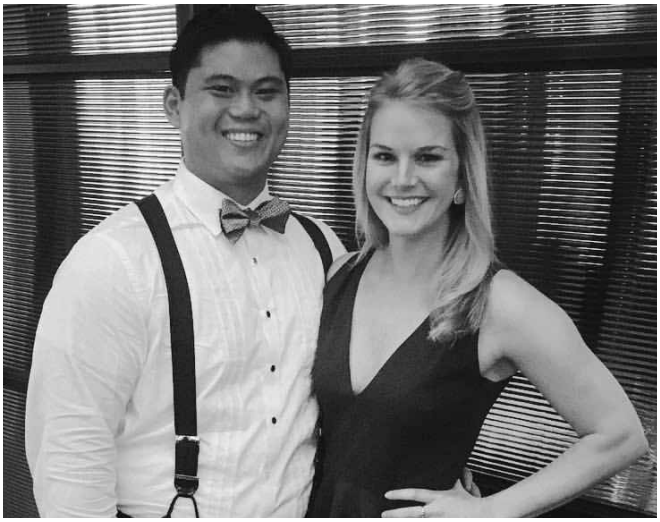
Our attendings do it all

Dr. Sewards cutting his farewell cake at the 2017 Gentlemen and Ladies Event

As per usual, Kate is working and Will seems distracted

Congratulations to John Jennings and Ali Jennings on their twins John Lawrence Jennings, Jr. and Grayson Michael Jennings on 4/21/17!

Snapshots from 2017–2018



Congratulations to Courtney Quinn, Megan Reilly, Katharine Harper, and Dayna Phillips on their engagements last year!!! #theyputaringonit

Dr. Howard Steele and Robert Ames at the Scoliosis Research Society annual meeting in fall 2017

Snapshots from 2017–2018

Dr. Sardar teaching Temple interns how to place Gardner-Wells tongs

The future of hand surgery could lie in the hands of these three interns . . . good luck world

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.**

Notes

Notes

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.

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Orthopaedics & Sports Medicine
TEMPLE HEALTH

Temple Health refers to the health, education and research activities carried out by the affiliates of Temple University Health System (TUHS) and by the Lewis Katz School of Medicine at Temple University. TUHS neither provides nor controls the provision of health care. All health care is provided by its member organizations or independent health care providers affiliated with TUHS member organizations. Each TUHS member organization is owned and operated pursuant to its governing documents.

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