# CAMPBELL ORTHOPAEDIC JOURNAL

2018

VOLUME 4

Campbell Clinic® ORTHOPAEDICS

CAMPBELL FOUNDATION ESTABLISHED 1946

# When You Treat Sports Injuries . . .

FibuLock® Nail with TightRope® XP Implant*

*Pending FDA clearance

Distal Biceps Repair using the BicepsButton™ and Tension-Slide Technique

BTB TightRope ACL Graft Fixation

Hip Labral Repair with Knotless SutureTak® Anchors

Instability Repair with 2.9 mm BioComposite PushLock® Anchors and LabralTape™ Sutures

Volar Distal Radius Plating

## Think Arthrex.

Global registry validation with:

Surgical Outcomes System

www.surgicaloutcomesystem.com

Arthrex®

www.Arthrex.com



AD1-00227-EN_B

# CAMPBELL ORTHOPAEDIC JOURNAL

Volume 4, May 2018

A JOINT PUBLICATION OF

**Campbell Clinic Orthopaedics • The Campbell Foundation**

**University of Tennessee-Campbell Clinic Department of Orthopaedic Surgery & Biomedical Engineering**



# TABLE OF CONTENTS

# DUROLANE®

hyaluronic acid, stabilized single injection

## The Power of One is Here.


## Pain Relief in a Single Injection

DUROLANE is a single-injection hyaluronic acid (HA) treatment that has proven:

- Greater reduction in knee pain vs. Synvisc-One® (hylan G-F 20)[1*]
- Longer-lasting knee pain relief vs. steroid[2]
- Clinically equivalent performance to five-injection HA therapy[3,4]

*Some patients were treated with a three-injection Synvisc® regimen. A three-injection Synvisc regimen is equivalent to one injection of Synvisc-One.

**Summary of Indications for Use:** DUROLANE is indicated for the treatment of pain in osteoarthritis (OA) of the knee in patients who have failed to respond adequately to conservative non-pharmacological therapy or simple analgesics, e.g. acetaminophen.

Do not inject DUROLANE in patients with knee joint infections, skin diseases, or other infections in the area of the injection site. Do not administer to patients with known hypersensitivity or allergy to sodium hyaluronate preparations. Risks can include transient pain or swelling at the injection site.

DUROLANE has not been tested in pregnant or lactating women, or children. Full prescribing information can be found in product labeling, at www.DUROLANE.com, or by contacting Bioventus Customer Service at 1-800-836-4080.

**References: 1.** McGrath AF, McGrath AM, Jessop ZM, et al. A comparison of intra-articular hyaluronic acid competitors in the treatment of mild to moderate knee osteoarthritis. *J Arthritis*. 2013;2(1):108. doi:10.4172/2167-7921.1000108. **2.** Leighton R, Åkermark C, Therrien R, et. al. NASHA hyaluronic acid vs methylprednisolone for knee osteoarthritis: a prospective, multi-centre, randomized, non-inferiority trial. *Osteoarthritis Cartilage*. 2014;22(1):17-25. **3.** Zhang H, Zhang K, Zhang X, et al. Comparison of two hyaluronic acid formulations for safety and efficacy (CHASE) study in knee osteoarthritis: a multicenter, randomized, double-blind, 26-week non-inferiority trial comparing Durolane to *Artz*. *Arthritis Res Ther*. 2015;17:51. doi: 10.1186/s13075-015-0557-x. **4.** DUROLANE [package insert]. Durham, NC: Bioventus LLC; 2017.

bioventus®

*Active Healing Through Orthobiologics*

# CLINICAL & SCIENTIFIC ARTICLES

## Graduating Resident Research



## Adult Reconstruction

djosurgical®

# AltiVate® | Reverse®

## Two Stems, One Platform

In addition to reverse total shoulder arthroplasty, the AltiVate Reverse® stems are indicated for anatomic total shoulder arthroplasty and hemiarthroplasty, making this one platform to treat your arthroplasty patients.


*Standard Shell Diameter 42mm*

*Small Shell Diameter 36mm*

*Standard Shell Diameter 42mm*

## Reaching Higher by Design

The anatomically-based, data-driven AltiVate Reverse system incorporates two metaphyseal sizes, enhanced fixation technologies, and precision instrumentation for exceptional fit in more of your patients*.

DJO®

T 800.456.8696 D 512.832.9500 F 512.834.6300
9800 Metric Blvd. | Austin, TX 78758 | U.S.A.
DJOGlobal.com/surgical


MKT00-30210-002 Rev A

**References**
*Data on file at DJO Surgical.

## Foot & Ankle



## Pediatrics



## Spine



## Sports



# FOUNDATION AND EDUCATION NEWS

# PIONEERING ROBOTIC NAVIGATION


# ExcelsiusGPS®

REVOLUTIONARY ROBOTIC NAVIGATION

*Designing innnovations to revolutionize minimally invasive spine surgery and optimize patient care.*

DELIVERING INNOVATION · EXCEPTIONAL RESPONSE · ADVANCING PATIENT CARE

**Learn more at Excelsius-GPS.com**

GLOBUS MEDICAL

*Life moves us*

# Letter from the Editor-in-Chief


## S. Terry Canale, M.D.

Department Chair, Emeritus
UT-Campbell Clinic Department of Orthopaedic Surgery and Biomedical Engineering
University of Tennessee Health Science Center


May, 2018

Dear Colleagues,

I am honored to present the 4th volume of the *Campbell Orthopaedic Journal* (COJ). It is the result of a great deal of collaborative work, and several of the abstracts in these pages describe results of interim projects that are part of a larger body of clinical investigations. Occasionally, there is a "Eureka!" moment in clinical research, but more often discoveries in orthopaedic medicine are iterative and evolutionary, rather than revolutionary. Breaking the question into sub-parts allows evidence to be analyzed and, with time, a collective image emerges. Insights are gained, changes are made in treatment, and better results for patients are achieved.

This iterative process came to mind as I read of Sir Roger Bannister's death earlier this year. Bannister is known for his record-breaking 4-minute mile, a feat thought unattainable when he achieved it in May of 1954. He was an amateur, but well-known in the running scene, having come close to the 4-minute barrier several times in the months leading up to his pivotal race. As I read more about his accomplishment, I was struck by how unlikely it was that Bannister achieved the mark. He was in training to become a neurologist and had worked a shift at a London hospital the evening before the race. He finished his night shift, sharpened the spikes of his running shoes on graphite, and then took a train from Paddington Station to Oxford, where the race would be held. Conditions at the Iffley Road Track were rainy and windy, and Bannister considered not competing, but his friends, Chris Chataway and Chris Brasher, were also competing in the race and they encouraged him not to drop out. At 6:00 pm on the evening of May 6th, 1954, the starter's pistol sounded. Brasher immediately took the lead, followed by Bannister, with Chataway a stride behind. After the second lap, Chataway moved to the lead followed by Bannister until the last half-lap when Bannister started a finishing kick that propelled him to run the last lap in just under 59 seconds. Bannister divided the race into smaller parts, and Brasher and Chattaway served as pacers to ensure that progress was made toward the goal. Bannister crossed the finish line in a time of 3 minutes, 59.4 seconds, and the roar of the crowd was deafening.

This concept of pace-setters who keep things moving along, as well as breaking down larger goals into smaller elements - both tactics used by Bannister in his record-breaking effort - are equally beneficial strategies for clinical orthopaedic research. One must set a goal, break it into iterative steps, and work with "pacesetters" who help move the work along to accomplish the goal. Then, once the discovery is made, the cycle begins again with a new question.

As a postscript to the Bannister story, it is worth noting that Bannister's record was broken just 46 days later by one of his rivals, Australian John Landy, in a race in Finland. So it is with clinical research—studies completed today will likely be questioned or surpassed by the researchers of tomorrow, the pacesetters who will ensure the pursuit for answers to our most challenging questions.

As you enjoy the 2018 edition, I hope that you are inspired to chase your own '4-minute mile' and to look around for your very own pacesetters. They are there, waiting to work with you. You simply have to sharpen your spikes and get on the train.

Sincerely,
S. Terrence Canale, MD, Editor-in-Chief
Campbell Foundation President

Isto BIOLOGICS & ARTERIOCYTE Helping Patients Heal Faster™

**Isto Biologics** has a complete medicine portfolio with revolutionary cartilage regenerating technologies to meet all of your clinical needs.

## Osteoconductive

### InQu® BONE GRAFT EXTENDER & SUBSTITUTE

InQu is a novel biosynthetic that provides a more direct and rapid path to new bone formation when compared with traditional ceramic-based synthetics.

## Osteoinductive

### Influx®

TRABECULAR BONE GRAFT

Influx provides a natural complement of bone growth factors for osteoinductivity while maintaining an interconnected pore structure ideal for cellular ingrowth and bone formation.

## Osteogenic

### cellpoint®

CONCENTRATED BONE MARROW ASPIRATE SYSTEM

CellPoint is an automated, closed-loop system that delivers a high concentration of marrow-derived progenitor cells at the point-of-care.*


***References**

**1.** Pittinger MF, MacKay AM, Beck SC, et al. Science. 1999.
**2.** Lu J, Pompili VJ, Das H. Cell Biochem Biophys. 2013.
**3.** Lubrowska A, Dolegowska B, Banfi G. J Biol Regul Homeost Agents. 2012.

## Osteogenic & Soft Tissue Regenerative

### MAGELLAN®

Autologous Platelet Separator

The Magellan Autologous Platelet Separator System is a fully automated, Dual spin centrifuge designed to fractionate and concentrate blood and bone marrow at the point-of-care.

Isto Biologics • 1155 Olivette Exec Pkwy. St. Louis MO, 63123 • 1-888-705-Isto (4786)

# Departmental Update from the Chairman


## James H. Beaty, M.D.

Department Chairman, Harold B. Boyd, M.D. Professor
UT-Campbell Clinic Department of Orthopaedic Surgery and Biomedical Engineering
University of Tennessee Health Science Center


The UT-Campbell Clinic Department of Orthopaedic Surgery and Biomedical Engineering is committed to significant improvements in musculoskeletal health through the dedicated efforts of devoted faculty, researchers and scientists, and health care providers devoted to the pursuit of new discoveries. There is considerable breadth and depth of experience in the Department, with our scientists making genuine progress in both translational and basic science pursuits related to the genetic, individualized and cellular influences on bone and soft tissue mechanisms of injury, and healing. Their work offers the promise of discoveries that clinicians will be able to provide for their patients who are limited by musculoskeletal diseases, disorders, and conditions.

## RESEARCH

As we near the end of the 2017-2018 academic year, the department consists of nine full-time basic science researchers: Hongsik Cho, PhD, Denis DiAngelo, PhD, Weikuan Gu, PhD, Karen Hasty, PhD, Yan Jiao, MD, Susan Miranda, PhD, Richard Smith, PhD, and Brooke Sanford, PhD; along with clinician scientist, Bill Mihalko, MD, PhD. This includes three Chairs of Excellence:

- George Wilhelm, Chair of Excellence,
- Harold Boyd Chair of Excellence and,
- Hyde Chair of Excellence.

Our scientists have robust extramural funding, including NIH R01 grants, and support from multiple other sources.

On the clinical side, our research effort has been equally impressive, with 84 scientific articles published in peer-reviewed publications, along with 60 podium presentations, and 22 posters highlighting our research presented at national and international meetings last year. We are expanding our participation in higher order Level 1 and Level 2 clinic trials to truly provide comparative evidence of therapeutic treatments. There is considerable breadth and variety in our work, examining the safety and efficacy of surgical procedures performed in an outpatient surgical setting, alternative methods of pain management (particularly timely in light of the opioid epidemic in the United States), and results with a number of operative interventions to build an impressive array of clinical evidence. Our work crosses all orthopaedic subspecialties in patients of all ages and races, and both genders. Notably, we have doubled our industry- and government-sponsored clinical research studies and grants over the prior year. In support of the additional work, our team expanded last year with the addition of a sixth research coordinator.

## EDUCATION

Musculoskeletal education from the department occurs at all post-graduate levels, including medical students, orthopaedic residents and fellows, engineers, clinical and research fellows, scientists and PhD candidates. On the scientific side, the Department oversees a joint MA and PhD program with the University of Tennessee and the University of Memphis. Drs. William Mihalko (University of Tennessee) and Gene Eckstein (University of Memphis) serve as Co-Directors.

Our orthopaedic surgical residency program is ranked in the top 10% nationally, with eight residents per class, in a five-year program. We are accredited through the Accreditation Council for Graduate Medical Education (ACGME), and present our students with a greater than 1:1 ratio of faculty to students. Instruction is provided in all orthopaedic subspecialties by fellowship-trained orthopaedic surgeons. Dr. Thomas W. 'Quin' Throckmorton and Dr. Derek M. Kelly ably serve as Program Director and Assistant Program Director, and do an outstanding job in supervising and advising the resi-

dents. Fellowships in the subspecialties are available, and we trained seven clinical fellows this year, and have one additional spine research fellow working with the team this year on an interesting project funded by the Scoliosis Research Society.

Monday night continues as our traditional 2½ hour interactive didactic educational meeting sprinkled with case presentations. Weekly subspecialty conferences are held as well as a monthly journal club. The Visiting Professors Program is designed for distinguished orthopaedic surgeons to give "Grand Rounds" four times a year with our premier CME meeting, known as the Alvin J. Ingram Memorial Lecture held in the spring. Since the fall of 2015, we have sustained a Visiting Professor Lecture Series, funded with donor support. This important series, which is open to area orthopaedic surgeons, nurses, physicians assistants, engineers and researchers, allows us to supplement the educational experience since it brings prominent thought leaders in each orthopaedic subspecialty to Memphis for engaging discussions about important and challenging issues in orthopaedic subspecialties, and culminates in a lecture on a prominent topic within the subspecialty.

We take pride in the latest (13th) edition of Campbell's Operative Orthopaedics, published in November 2016, noting that it is the leading orthopaedic textbook in the world, with worldwide sales in the first year that surpassed sales of all prior editions.

The department continues to make strong progress in education, research and innovation. We are well-positioned to advance toward the centennial anniversary of our residency training program in 2024. Dr. Campbell would be proud.

# News from Campbell Clinic


## Frederick M. Azar, M.D.

Chief of Staff, Campbell Clinic Orthopaedics
Professor and Sports Medicine Fellowship Director


As the practice of orthopaedics and musculoskeletal medicine continues to evolve, the physicians at Campbell Clinic have remained at the forefront of innovative research while delivering compassionate patient care.

2017 was a busy but exciting year for our practice as we welcomed new physicians, offered additional surgical procedures in our market, and created a sports performance program. Years of thoughtful strategic planning also began to pay off as we unveiled renderings for a new $30 million, 120,000-square foot expansion at our Germantown campus set to open in late 2019.

Through all of these changes, we have maintained an unwavering resolve to offer unparalleled patient access, unique approaches to orthopaedic surgery, and programs that promote optimal patient outcomes and satisfaction.

Our new facility in Germantown will truly be a world-class showplace for outpatient orthopaedic care. Our physicians and administration have spent the last five years reviewing market trends and analyzing potential future demand for our services. After considering several options, we partnered with Rendina Healthcare Real Estate – a nationally renowned developer of medical office space – to create plans for a multipurpose facility immediately east of our existing outpatient clinic in Germantown, TN.

The new facility will serve patients seeking care across all orthopaedic specialties, house a new sports performance and physical therapy floor, and allow for an expanded ambulatory surgery center. Campbell Clinic will double its on-site outpatient surgery suites from four to eight, giving us a total of 12 in the region. We will maintain our existing outpatient clinic on the Germantown campus, and upon occupancy of the new building, our current facility will undergo a transformative renovation. It will truly be a national destination for bone and joint care.

Our physicians have also participated in several interesting clinical trials over the past year. Notably, we are leading the way in seeking solutions for the national opioid crisis. Our doctors have examined alternative methods of pain control for patients undergoing elective rotator cuff surgery in a randomized, controlled study, measuring patients' post-operative pain and comparing two unique alternatives. We have also studied alternative methods of pain control for patients undergoing total knee replacement by utilizing a cryonucleolysis method – freezing the nerves – to provide a temporary interruption in localized nerve signals.

These studies come on the heels of another trial with similar goals which utilized periarticular injections to reduce pain signals in the hours and days immediately following major surgery. We are even exploring alternative methods for decreasing patient anxiety in pediatric patients after spinal surgery through the use of all-natural supplements like essential oils. The cumulative effect of this research will hopefully help us offer real-world alternatives to medications such as narcotics and opiods as we manage post-operative pain more effectively.

Collectively, these studies are blazing a path toward more responsible pain management plans in the future. It's important that we contribute to a reasonable, sustainable solution when so much is at stake for our patients.

We added three new physicians to the Campbell Clinic family over the past year. Dr. Tyler Brolin (shoulder and elbow), Dr. Marcus Ford (total joint replacement), and Dr. Benjamin Sheffer (pediatrics) joined us last August. Adding three young surgeons of their caliber further enhanced the reputation of our practice and will have far-reaching positive impacts on patients in the Mid-South for years to come.

Drew Graham also joined our group in 2017 to direct our growing sports performance program. Drew is a former NBA Trainer of the Year and works with athletes of

all ages to help them reach their goals. His program integrates functional movement screens with specially-designed home exercise programs to enable school athletes and weekend warriors to develop their skills, eliminate movement deficiencies, and improve overall strength and stability. With concussions and sports "overuse injuries" becoming and even larger issue in the youth sports community, Campbell Clinic expanded its outpatient concussion management program and added a new event last summer geared toward educating parents and coaches on concussion and other relevant sports medicine trends.

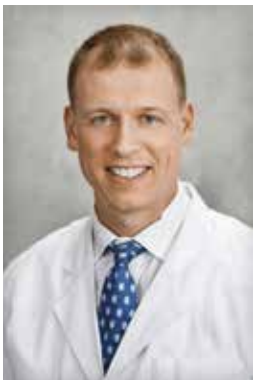
Finally, we launched a new version of our website (www.campbellclinic.com) late last year. The new site enables patients to book, review and change appointments online, cross-reference physicians from different specialties at specific locations, and identify the most appropriate avenue for care across our region depending on when they visit the site. It has truly been a game-changer for us in an environment where patients are more informed about their problems when they arrive in our office than ever before. Opening up access to patients and placing them with the right provider, at the right place, at the right time is critical in the operation of an efficient, full-service orthopaedic practice like ours.

# State of the Residency


## Thomas W. 'Quin' Throckmorton, M.D.

Orthopaedic Residency Director, Professor

UT-Campbell Clinic Department of Orthopaedic Surgery and Biomedical Engineering

For nearly 100 years, the Campbell Clinic, in conjunction with the University of Tennessee-Campbell Clinic Department of Orthopaedic Surgery and Biomedical Engineering, has been proud to train orthopaedic surgeons from all over the country and, indeed, all over the globe. Over 570 orthopaedic surgeons have trained at our institution and our graduates include 8 presidents of the American Academy of Orthopaedic Surgeons (AAOS), 9 directors of the American Board of Orthopaedic Surgery (ABOS), 4 presidents of the American Orthopaedic Association (AOA), and numerous presidents of subspecialty societies. Surgeon education is a hallmark of our program, and the staff, in addition to our responsibilities for teaching our residents, continue to author Campbell's Operative Orthopaedics, now in its 13th edition. While orthopaedic knowledge continues to expand, our educational goal has remained constant: to produce excellent, well-rounded orthopaedic surgeons who have the opportunity to pursue the subspecialty training of their choice.

Our residents train in each orthopaedic subspecialtie, both as junior and senior residents, and our rotations combine an exposure to the academic/tertiary medical center environment as well as the private practice setting. This comprehensive approach offers the ability to see all subspecialties from different angles and maximizes true understanding of orthopaedic principles and their application. Our training program is designed to prepare residents for the Orthopaedic Inservice Training Examination (OITE) and Step I of the American Board of Orthopaedic Surgery examination, through a combination of Core Curriculum training combined with subspecialty conferences in trauma, pediatric orthopaedics, sports medicine and shoulder/ elbow surgery, hand surgery, foot and ankle surgery, and spine surgery. And in this era where medicine and business often intersect, we have augmented our curriculum with business training and an awareness of value as it pertains to orthopaedic care.

Additionally, we have focused on strengthening and building our clinical and biomechanical research infrastructure, which includes multiple research nurse coordinators, database access to track patient outcomes, a biomechanics laboratory and an extensive orthopaedic library staffed by a full-time librarian. We currently are conducting over 150 active clinical and biomechanical research projects. Investigators have been awarded funding from both internal and external sources to conduct these studies, in addition to additional extramural (NIH, NSF, etc.) awards among our basic science research staff. We remain committed to sharing our research at regional, national, and international meetings, and in academic and scientific publications. In short, orthopaedic research has never been stronger at the Campbell Clinic.Our international elective medical mission program continues, with sponsorship of an international community service medical mission. Our residents have served in Nicaragua, Guatemala, Honduras, Tanzania, and Uganda. In this way, we imbue a commitment to community service within our residents.

This year, we will celebrate the graduation of our 93rd residency class, whose members are profiled within this publication. We are very proud of these eight orthopaedic surgeons. Their senior research efforts are depicted within these pages, and thousands of patients will benefit from the clinical discoveries these projects have yielded. Simultaneously, I am pleased to recognize the incoming Class of 2023 which will begin training in July. We are confident these exceptional young physicians will continue the tradition set forth by their predecessors.

In summary, we are proud of our heritage at the Campbell Clinic, but we are equally proud of our present and we look forward to our future. With our comprehensive, diverse, high-volume brand of training, we will continue to strive for excellence in the training of orthopaedic surgeons.


Alvin J. Ingram, MD

Dedicated Lectureship Series:

# Alvin J. Ingram, MD Memorial Lecture

Each year, the Campbell Foundation is privileged to host a Distinguished Professor in memory of a fine surgeon. The annual Alvin J. Ingram, MD Memorial Lecture was initiated in memory of former Campbell Clinic Chief of Staff and Department Chairman Alvin J. Ingram, M.D., through a gift from members of his family, to honor his commitment to education. Dr. Ingram was a graduate of our residency program, was a world authority on the treatment of polio.

The lecture series highlights achievements in surgeon education, and features a Keynote Address by a Distinguished Professor, followed by presentations from the Campbell Foundation graduating residents. Beginning in 2014, under the guidance of course director Derek M. Kelly, M.D., the Ingram Lecture was expanded considerably and included not only lectures by our Distinguished Professor, faculty and the residents, but also an Expert Panel and technical exhibits. This year will be our second year to also display posters that highlight research from our Residents and Fellows. The Ingram Lecture is open to the public, with continuing education credits available for physicians and other allied health professionals. The Ingram Lecture regularly attracts an audience of more than 150 surgeons, engineers, scientists, and others dedicated to excellence in orthopaedics.

## 2017 Alvin J. Ingram, MD Memorial Lecture • May 19, 2017

### Distinguished Professor: David A. Halsey, M.D.

Professor, University of Vermont School of Medicine
Attending, Martha's Vineyard Hospital
Oak Bluffs, Massachusetts


David A. Halsey, MD

David A. Halsey M.D. is a Professor in the Department of Orthopedics and Rehabilitation at the University of Vermont School of Medicine in Burlington, Vermont where he has been honored twice as "Teacher of the Year". He attended undergraduate school at Middlebury College, received a medical degree from Robert Wood Johnson Medical School, and trained in orthopaedic surgery at University of Vermont.

Dr. Halsey has over 25 years of experience in the treatment of hip and knee problems and is dedicated to helping patients "get back in the game." His caregiver team combines leading edge techniques with proven traditional methods to provide the best orthopaedic care possible, emphasizing a partnership with the patient.

Dr. Halsey is recognized as an expert in many non-medical issues that impact a physician's practice such as economic and value indicators of medical care, financial barriers, professional compliance, group purchasing, and orthopaedic advocacy. His expertise is frequently shared in professional forums and peer reviewed publications. Dr. Halsey's Keynote Address, "Orthopaedic Advocacy at the National Level," described the initiatives that the American Academy of Orthopaedic Surgeons (AAOS) is advancing with regulatory bodies, payers and legislators to ensure that patient access to highly skilled and well-trained orthopaedic specialists remained strong and unencumbered by regulation. He added to the discussions of the day by providing a further update on "Medical-Legal Matters in Orthopaedics" during the Expert Panel on the business side of orthopaedic medicine.

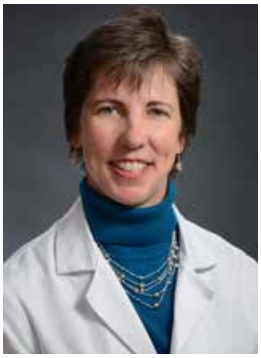
Dr. Halsey, now President of the American Academy of Orthopedic Surgeons (AAOS), was First Vice President at the time of the 2017 Ingram Lecture. In addition, he is a fellow in the American Orthopaedic Association, the American Academy of Orthopaedic Surgeons, and the American Association of Hip and Knee Surgeons.

Another highlight of the 2017 Ingram Lecture was the presentation of the research of our graduating class of residents. Resident research at the Campbell Foundation is only possible through donor support. These financial gifts offset the costs of research, including supplies, testing equipment

and support personnel. In addition, through a gift from the family of Dr. Hugh Smith, the Hugh Smith Research Award is presented each year to the best research project, judged by a panel from the Ingram Lecture. Dr. Hugh Smith, a former Campbell Clinic Chief of Staff, and one of the founders of the Campbell Foundation, believed strongly in the power of innovation to unlock solutions to challenging clinical programs. Dr. Smith recognized the significant role that research can play in developing new surgical techniques and implants that will lead to a better quality of life for patients, and his family wanted to formally celebrate and recognize the importance of ongoing research. The panel of judges evaluated each presentation based upon the design, content, and originality of the research, clinical significance and potential for publication in a peer-reviewed journal. The 2017 Hugh Smith Presentation Award was presented to Dr. Andrew 'Drew' J. Wodowski, for "Ambulatory Surgery Center Hip Arthroplasty is a Safe and More Cost Effective Alternative to the Hospital."

## 2018 Alvin J. Ingram, MD Memorial Lecture • May 18, 2018

Distinguished Professor: Kristy L. Weber, M.D.
Professor and Vice-Chair of Faculty Affairs
Chief - Division of Orthopaedic Oncology
Abramson Family Professor in Sarcoma Excellence
University of Pennsylvania Department of Orthopaedic Surgery
Director - Sarcoma Program at the Abramson Cancer Center
Philadelphia, Pennsylvania


Kristy L. Weber, MD

Kristy L. Weber, MD, is an attending surgeon with the Cancer Center and Division of Orthopaedics at Children's Hospital of Philadelphia (CHOP). She specializes in treating children, adolescents and adults with bone and soft tissue tumors.

Along with her work at CHOP, Dr. Weber is the Abramson Family Professor in Sarcoma Excellence in the Department of Orthopaedic Surgery at the University of Pennsylvania. She was recruited to Penn in 2013 to serve as Vice-chair of Faculty Affairs in the Department of Orthopaedic Surgery and Director of the Sarcoma Program in the Abramson Cancer Center.

Dr. Weber was named the first Vice President of the American Academy of Orthopaedic Surgeons (AAOS) in 2018. Now in her second year in a four-year term of volunteer service, Dr. Weber will serve as the first female president of the Academy in 2019-20.

Originally from St. Louis, MO, Dr. Weber attended college at the University of Missouri-Columbia. She earned her M.D. from Johns Hopkins School of Medicine, Baltimore, MD. Dr. Weber completed her orthopedic residency training at the University of Iowa, Iowa City, IA, and a two-year research/clinical fellowship in orthopaedic oncology at the Mayo Clinic, Rochester, MN. Dr. Weber joined the faculty at University of Texas/M.D. Anderson Cancer Center where she developed a large clinical practice in orthopedic oncology and developed a basic science research program related to osteosarcoma metastasis to lung and renal cell carcinoma metastasis to bone.

In 2003, Dr. Weber jointed the staff at Johns Hopkins as Chief of the Division of Orthopedic Oncology and director of the Sarcoma Program. She was promoted to professor in 2009. Dr. Weber received the Kappa Delta national orthopedic research award for her work at Johns Hopkins in 2006. Her laboratory was funded by private foundations, the Orthopaedic Research and Education Foundation (OREF), and the National Institutes of Health (NIH).

Dr. Weber has served on the boards of directors of many national orthopaedic and cancer organizations including the American Academy of Orthopaedic Surgeons (AAOS), American Orthopaedic Association (AOA), and the Connective Tissue Oncology Society. She spent four years as chair of the AAOS Council on Research and Quality where she oversaw initiatives related to clinical practice guidelines, evidence-based medicine, appropriate-use criteria, patient safety, biomedical engineering, biological implants and the development of orthopaedic clinician-scientists.

Currently, Dr. Weber is serving as President of the Musculoskeletal Tumor Society, vice president of the Ruth Jackson Orthopaedic Society (RJOS), and secretary-elect of the Orthopaedic Research Society.

Dr. Weber's Keynote Address will be "*AAOS: What's New and How to Get Involved,*" and she will also provide a short lecture entitled, "*Tips and Tricks for Evaluation/Treatment of Soft Tissue Masses.*"

# 2018
# Campbell Foundation & UT-Campbell Clinic
# Department of Orthopaedic Surgery & Biomedical Engineering

## Visiting Professor Lecture Series
## Schedules of Lectureships and Conferences

**Richard M. Schwend, MD**

***"Differential Rod Contouring and Other Techniques for 3-D Correction of Adolescent Idiopathic Scoliosis"***

*Director of Clinical Research and*
*Professor of Orthopaedics and Pediatrics*
University of Missouri, Kansas City
and University of Kansas

*Chief of Service, Division of Orthopaedics*
Children's Mercy Hospital
Kansas City, Missouri

January 11, 2018
Le Bonheur Children's Hospital
Community Room
Memphis, TN 38103

**John C. Clohisy, MD**

***"Radiographic Interpretation of the Young Adult Hip"***

***"Borderline Dysplasia: Arthroscopic or Open?"***

*Chief*, Adult Reconstructive Surgery &
Daniel C. & Betty B. Viehmann

*Distinguished Professor in Orthopaedic Surgery*
Washington University Medical School
St. Louis, Missouri

April 9, 2018
Campbell Foundation Classroom
1211 Union Avenue, Suite 510
Memphis, TN 38103

**Alvin J. Ingram, M.D. Memorial Lecture**

**Kristy L. Weber, MD - Keynote Speaker**

*"AAOS: What's New and How to Get Involved"*

Professor & Vice-Chair of Faculty Affairs
Chief - Division of Orthopaedic Oncology
Abramson Family Professor in Sarcoma Excellence
University of Pennsylvania Department of Orthopaedic Surgery
Director - Sarcoma Program at the Abramson Cancer Center
Philadelphia, PA

***PLUS***

Presentations by the Class of 2018 Residents
And an Expert Panel on Orthopaedic Oncology

May 18, 2018
The Zone, FedEx Institute of Technology
Memphis, TN

# EXPAREL®

(bupivacaine liposome injectable suspension)

OPIOID FREE

## Used in more than

## 3.5 MILLION PATIENTS

## since 2012


Learn more at EXPAREL.com

**Reference:** Data on File, 4051. Parsippany, NJ: Pacira Pharmaceuticals, Inc.; December 2017.

For full Prescribing Information, please visit **www.EXPAREL.com** or call 1-855-RX-EXPAREL (793-9727).

PACIRA PHARMACEUTICALS, INC.



PP-EX-US-3544 04/18

# Hell, I don't know! Ask Kay!!

*by* S. Terry Canale, M.D.

When I first came on the staff of Campbell Clinic forty-four years ago, *Campbell's Operative Orthopaedics* textbooks were the "bible" of orthopaedics, the envy of all other specialty texts. I was extremely proud that we "wrote the book" on orthopaedic surgery and care. But, what I couldn't believe about the publication was how disorganized it was and how difficult it was to get the "bible" to press. We missed deadlines and were under constant threat from the publisher of the textbook. Dr. Hoyt Crenshaw, who edited several of the earliest editions and Dr. Allen Edmonson, who served as co-editor with Dr. Crenshaw for the 6th edition, had to take time off from their clinic responsibilities to complete their editions and still we were tardy. But in 1978 things began to change for the better. We hired a young librarian with expertise in public education named Mrs. Kay Daugherty. Suddenly the "book" began to be organized, deadlines began to be met; and now, 40 years and eight editions later, the "book" is still going strong, thanks to Mrs. Daugherty; the same young lady most people know only as 'Kay.'

Several facts you need to know about Kay, and I will swear they are correct even if they are not all completely true:

1) Kay knows more about orthopaedics because of her 40 years of reviewing orthopaedics literature than any orthopaedic surgeon I know.
2) Kay has given more writing help and advice to orthopaedists than any surgeon I know.
3) Kay has written more papers, edited more manuscripts, and prepared more CME lectures and talks than any orthopaedist I ever knew.
4) Finally, Kay has helped and counseled more orthopaedic residents, fellows, students, and international visitors to the clinic than any orthopaedist I know.

There are over 5,000 pages in Campbell's Operative with over 1,500 illustrations. Can you imagine how much effort and work it takes just to insert or delete or change any one sentence in the book? To insert a sentence or quote you have put it in the text, take the old sentence out, check the validity of the new sentence, check the inserted new material, and check any illustrations, x-rays or images for accuracy. With the new insertion of an illustration you must get permission for its use from the previous publication. Finally, the corrected bibliography must be inserted and placed in order. Kay has edited every sentence in eight editions.

How would you like to edit a 5,000-page book eight times?

I feel tired and overworked every time I think about this mammoth job. So you can see why, at one time or another, and on many occasions, I have said, "Hell, I don't know! Ask Kay!" Nearly every day it can actually go something like, "Hell, I don't know who wrote that or what journal it was in. Ask Kay, she'll know!"

Thanks, Kay from all of us at the Campbell Clinic and the Campbell Foundation, and from hundreds everywhere who have benefited from your knowledge. We are eternally grateful!

ZipLine® medical

ZIP® Surgical skin closure

## Clinically superior, non-invasive alternative to staples and sutures.

# CLOSE WITH CONFIDENCE

- **Better economics***
- **Better clinical outcomes***
  - Closure consistency
  - High tissue perfusion
  - Better uniform closure
  - Better wound protection
  - 16 clinical performance studies
- **Better patient satisfaction***

POD 10 | POD 90

POD 1

POD 14 | POD 90

Please contact ZipLine for your local sales representative
TEL 1-888-326-8999 EMAIL customerservice@ziplinemedical.com

www.ziplinemedical.com | Follow us on

*Data on file

# "SO, WHAT'S IN THE WATER IN MEMPHIS?"

*by* S. Terry Canale, M.D.

Why are so many leaders from the "Big M"? It has often been said that all roads to the AAOS must go through Memphis. Seven Campbell Clinic staff members and one alumnus have served as president of the AAOS since its first elected president, Willis C. Campbell, in 1933. In addition, four have been presidents of the AOA and eight have been directors of the ABOS.

So, what's in the water in Memphis that continues to produce leaders? Volunteerism, that's what's in the water. At the Campbell Clinic we have always encouraged volunteerism in all forms and fashions to promote orthopaedics. As a large part of the culture of Campbell Clinic, volunteerism becomes embedded in our staff and fellows and residents. This has occurred because of hard work and promotion by our staff and the results of "big names" in orthopaedics, such as Campbell, Speed, Boyd, Ingram, Sage, Smith, Crenshaw, Calandruccio, Sisk, Milford, and Edmondson. It is by hard work and sheer volume that the fruits of their labor have paid off.

In the present generation, we are determined not to rest on our laurels but to continue to promote volunteerism by our staff and alumni. We continue to encourage and support our staff and alumni so that they may serve in positions at the highest level, nationally, regionally, and locally. We continue to be involved in the leadership of AAOS, AOA, ABOS, OREF, POSNA, SRS, and other orthopaedic sub-specialty societies. Some of our staff and alumni are more comfortable serving at the local or state level than in the national spotlight and volunteer in local medical societies, community orthopaedic societies, various charitable organizations, and churches or schools. Regardless, in Memphis at the Campbell Clinic, we encourage volunteerism from our staff and also from our alumni. We hope the volunteer spirit will continue and will send the message that volunteering is a proud reminder of our Campbell heritage. So, you see it is not just what's in the water in Memphis, but what's embedded in the training program in Memphis, and thus a part of the "DNA" of all alumni from Memphis.

# The Most Comprehensive Products for Pediatric Trauma & Deformity Correction

**PICTURED**
Complete Locking Cannulated Blade and Locking Proximal Femur Plate systems

- The OrthoPediatrics PediLoc® Infant Locking Proximal Femur Plate was designed for the smallest of patients.
- With converging 3.5mm screws, this stronger plate can accommodate unique infant anatomy.
- The PediLoc® Locking Proximal Femur System features the most expansive and comprehensive array of plate angles, offsets and lengths to address the needs of each individual patient.

**PICTURED**
Infant Locking Proximal Femur Plates

OrthoPediatrics®
TRAUMA & DEFORMITY CORRECTION

**Our hip portfolio is getting bigger, while our pediatric specific plates are getting smaller!** OrthoPediatrics is proud to introduce the Infant Locking Proximal Femur. Learn more about our entire Trauma & Deformity Correction portfolio, including the wide range of PediLoc® pediatric specific plates at OrthoPediatrics.com.

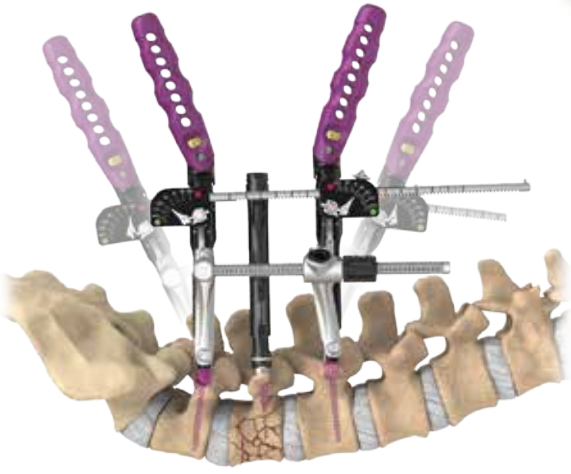
Distributed by: SURGICAL SOLUTIONS
*For Surgeons & Patients*

**PHONE**:901.517.1076
**ADDRESS**:5100 Poplar, Memphis, TN 38137
**WEB**:www.surgical-solutions.net

PHONE 574.268.6379 ADDRESS 2850 Frontier Drive, Warsaw, IN 46582 WEB OrthoPediatrics.com

RELINE®

# Surgical Efficiency Meets Reliable Versatility



Visit the **NuVasive® exhibit table** at the 2018 Alvin J. Ingram Memorial Lecture to learn more.



NUVASIVE

# The Russell-Taylor Intramedullary Nail System: Origins and Achievements

*by* Thomas A. (Toney) Russell MD

Invented in 1983, the Russell-Taylor (RT) Interlocking Intramedullary Nail system was the first closed-section interlocking intramedullary nail system. It was designed to optimize the structural environment for fracture healing while permitting adequate fatigue life of the implant to allow immediate weight-bearing post-operatively. The original system included a femoral nail designed by the author as a length and rotationally stable load-bearing device in conjunction with a unique kinematic targeting system attachable to the nail to assist with distal interlocking designed and prototyped by Dr. Charles Taylor and his brother, Harold Taylor **(Figure 1)**. In 1983, I was a first year faculty member and Charlie was a resident in training at the University of Tennessee-Campbell Clinic Department of Orthopaedic Surgery in Memphis, Tennessee.

**Figure 1:** Russell-Taylor Intramedullary Nail System: Early prototype designs

All advances in medicine are the result of our teachers and our predecessors, and the RT story is no different. Historically, there were previous attempts to treat diaphyseal fractures with intramedullary devices for over a century, with the most successful foundation laid by G. Küntscher in conjunction with the Pohl manufacturing company in Germany in the late 1930s and early 1940s. After WWII, however, acceptance of closed intramedullary nailing as advocated by Küntscher was unpopular because of the relationship of E. Pohl and his company, The Pohl Manufacturing Company, to the Nazi party. The Allied Powers blacklisted the company.

Advancements in fracture fixation attributable to intramedullary nails included the use of medical grade high-strength stainless steel alloy implants, improvement in image intensification C-arm technology, and know-how developed by Küntscher during the war as to clinical indications and techniques. However, in 1950, an article by Watson-Jones et al. in *The Journal of Bone and Joint Surgery-British* discouraged the intramedullary technique, resulting in a delay in the availability of these technological advances by Küntscher and Pohl in the U.K. and U.S.A until 30 years after the war. There were, however, friends and supporters of Küntscher's concepts, including Dr. Hugh Smith at the Campbell Clinic, who contributed to the 1950 article and befriended Küntscher. Dr. Smith wrote the forward to the 2nd edition of Küntscher's textbook "*Practice of Intramedullary Nailing*" (English translation), published in 1967.

When I was in training in the late 1970's, the standard of care for an adult femoral fracture was skeletal traction in the hospital for 8 to 12 weeks and then a body cast for 4 to 6 weeks. Although the union rate was 80% to 90%, malunion was common, and most patients experienced some type of residual handicap. Typically, there were at least 80 patients in traction at all times on the university service.

I became attracted to intramedullary nailing when I was a medical student after observing several open nailing cases and closed nailing attempts by some of the younger staff, including Drs. Greer Richardson and

George Wood. C-arm availability was just beginning in Memphis, and the instruments and implants were quite crude. We would saw 52-cm long straight Küntscher nails to the required length and try to insert them without opening the fracture site, but we often failed and resorted to open reduction. There were real opportunities for improved instrumentation and implants. I was encouraged and supported during my residency training at the Campbell Clinic by my professors, in particular Drs. David Sisk, R. A. Calandruccio (The Chief), Fred Sage, and Hugh Smith, despite frequent constructive criticism by the more conservative members of the Campbell Clinic staff. I also was encouraged by my fellow residents, for which I will always be thankful. The staff encouraged my homemade "tools," which they let me use and perfect on almost every femoral nail case I could attend. I became convinced that the instruments could be improved and that the open cloverleaf nail design used at the time was too weak and rotationally unstable to permit weight-bearing. I presented my concepts in 1982 to Professor Dietrich Hempel of the Küntscher Kreis society, while he was visiting the USA, and he encouraged me to pursue my concepts (With the support of Mr. B. Lotz, President of OEC International, the successor of the Pohl Manufacturing Company, Professor Hempel had written a book on intramedullary nailing techniques in 1982, which was the first technical guide to intramedullary nailing available in English).

I had initially contacted the Zimmer Company about presenting the nail concepts, but they declined my offer. At a scientific meeting in Germany in 1983, I was asked by Mr. Pete Read of the Richards Manufacturing Company (RMC) in Memphis what I thought about intramedullary nailing. I presented my concepts and included Dr. Taylor's targeting device concepts, and we arranged a meeting when we returned to Memphis. The targeting system was the first component presented to Richards, and then the nail design was disclosed at a meeting at the Campbell Clinic on a Monday night to Frank Lewis and David Brumfield, engineers with Richards. They were initially quite skeptical of the concept of an I-beam design for right/left nail selection with oblique interlocking holes and a closed-section design, and were concerned as to how it might be manufactured. Fortuitously, RMC was acquiring Küntscher-style femoral nails from a Swiss company, OSTEO, that were fabricated from cylindrical nail stock in which the slot was secondarily created. They were able to fabricate test samples and initial clinical material by welding a threaded attachment to the closed section nail and drilling the interlocking hole patterns we had suggested. The instrumentation was designed to be efficient and simple to assemble with the first commercial intramedullary manipulation tool for reduction of the fracture.

The first clinical use of the invention occurred in Memphis in the summer of 1983 when a size 13 X 38 cm nail was inserted to repair a comminuted femoral fracture, and the nail was then statically locked distally. After 3 successful surgeries, Mr. Ron Pickard, then President of RMC, decided to release the system at the annual meeting of the American Academy of Orthopaedic Surgeons (AAOS) the following year (1984). Mr. Read proposed that the system be named after Dr. Taylor and me as there was a precedent for naming interlocking nail systems (e.g., Klemm-Schellman, Grosse-Kempf) and Mr. Pickard agreed. The Russell-Taylor (RT) nail was thus named.

At that time, the primary interlocking nail system in the USA was the Grosse-Kempf system from Strasbourg, France, marketed by Howmedica, which had been introduced in 1982. The Grosse-Kempf (GK) system used a welded, proximally threaded design that was prone to failure in mobilized patients. In light of our observations of the GK clinical experience, and following the first RT weld failure, the R&D engineering team, Dr. Taylor, and I agreed that all welds must be removed from our design. The concept of gun-drilling of the nails was advanced by the engineering and manufacturing teams, and Mr. Pickard committed the resources to purchase and develop the first gun-drilling facilities for medical implants. Glen Durham, and later Neal Beals, joined Dave Brumfield on the engineering team . The engineers observed surgery, and the surgeons engaged the engineers and manufacturing teams on the shop floor giving the team essential and mutual understanding of both the constraints and opportunities in the operating room and on the manufacturing floor.

The technological challenges associated with the development of the RT nail design cannot be overstated! The goal was to ensure structural implant function of a 36- to 44-cm long nail manufactured of cold-forged steel with a nail wall thickness of only 1 mm, fabricated to very tight tolerances. The brilliance and tenacity of the R&D and the manufacturing teams in Memphis led to their recognition by NASA, among others, as the premier gun-drilling experts in the USA in the 1980s.

The precise design formula for the nails is proprietary, but was designed such that the nail's bending strength was matched to the respective bone diaphysis to yield a bending stiffness of 90% to 95% of an intact femur with approximately 50% of the bone's rotational stiffness **(Figure 2)**.

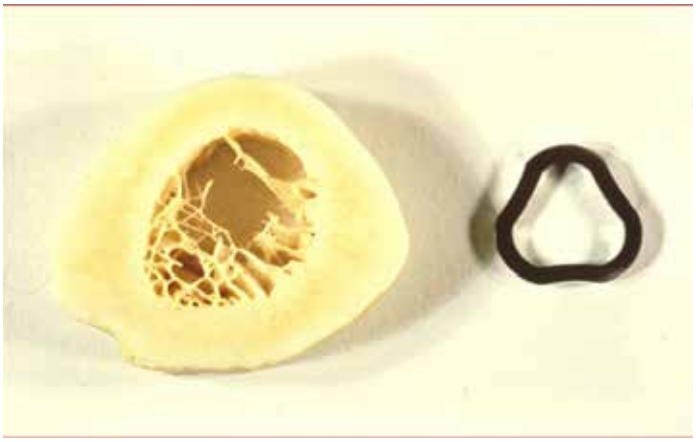


**Figure 2:** Cross-sections: Diaphyseal bone and closed-section intramedullary nail

In the proximal attachment region of the nail, the diameter and wall thickness were increased to give better fatigue resistance for the proximal locking section. The holes for the interlocking screws were placed to optimize material around the hole and aligned in a slightly oblique manner to allow some axial give at the fracture site for loading the fracture callus. The locking screws used were 6.4 mm diameter (to increase fatigue strength) fully-threaded screws **(Figure 3)**. In subsequent design iterations, the design philosophy mandated three principles:

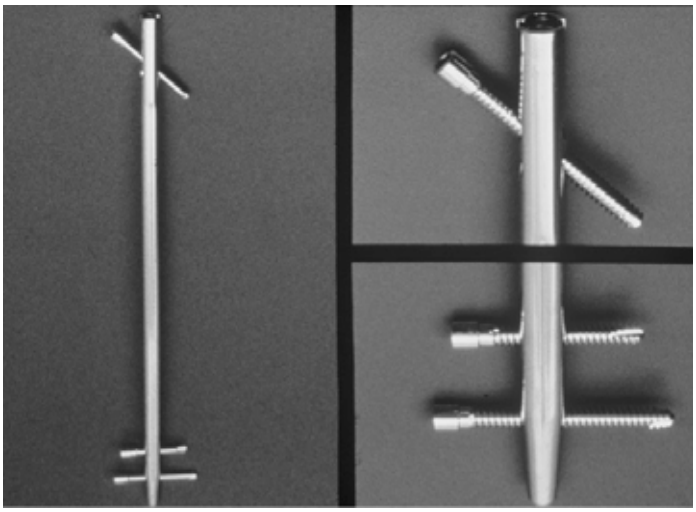


**Figure 3:** Bone and nail cross-sections.

1. Surgical efficiency in instrumentation and technique.
2. Structural criteria for load bearing to prevent deformation and to minimize implant failure while supporting the development of rapid callus formation.
3. Improvement in functional recovery capabilities of the injured extremity during fracture healing

The success of the RT system proved the concept of close integration of a team consisting of design surgeons with a high degree of clinical know-how, trauma engineering specialists with testing and manufacturing expertise, tool and dye machining experts, and marketing personnel (responsible for development of surgical education materials), all with an intimate knowledge of the implant design and history and the potential benefits to the patient and surgeon **(Figure 4)**. Marketing managers Frank Navarra, Danny Crittenden, and Bob Heinrich at RMC provided the educational tools and marketing documentation required for training orthopaedic surgeons on these new techniques. Dr. David Lavelle joined the surgeon design team in 1986 and later implanted the first RT interlocking humeral nail in 1989.

**Figure 4:** Multidisciplinary Russell-Taylor Nail team at the annual AAOS meeting.

A pivotal year for intramedullary nailing using Kuntscher's closed technique principles was 1984: it included publication of the Harborview series of 520 femoral nailings in the *Journal of Bone & Joint Surgery* (JBJS) by Winquist et al., the first American report (also in

JBJS) by Ken Johnson et al. of interlocking nailing that showed superiority to traction and open nailing, and the release of the American Russell-Taylor femoral interlocking nail system. The controversial nature of these fundamental innovations in nail design and technique led to initial criticism and disbelief. It was thought that rotational instability was required for fracture healing and that static locking of an intramedullary nail would increase implant failure and nonunion rates. However, mechanical testing and clinical studies around the world validated the results of closed interlocking nailing and, specifically the RT nail closed-section design. Many of the initial reports and publications came from the staff and residents of the Campbell Clinic. The RT femoral nail system was documented to have the lowest failure rate, even with postoperative weight-bearing, with union rates of 98%. By 1988, the RT system became the market-leading interlocking femoral nail system. From 1983 to 1990, the RT system was expanded with development of the Reconstruction Nail for subtrochanteric fractures, pathologic fractures, and selected ipsilateral femoral neck shaft fractures, along with the Delta Tibial Nail, the first nonreamed static interlocking treatment for open tibial fractures. In addition, the RT system expanded with interlocking humeral nails and smaller diameter nails for use in adolescents and Asian populations. Success with these smaller diameter nails in other applications proved that downsized reaming (from 13 to 18 mm to 10 to 12 mm in femurs and from 11 to 14 mm to 9 to 10 mm in tibias), along with the insertion of smaller diameter nails for both femoral and tibial fractures, could still deliver high union rates while maintaining low failure rates . Today, the closed section modulus design is the intramedullary nail standard adopted by every modern medical manufacturer.

The RT nail remained a gold standard for nail design until medical design innovation and manufacturing techniques permitted the development the next generation of titanium alloy nail and screw interlocking systems in 2000-2010. Titanium alloy materials provide implant systems with even lower fatigue rates and the option of more multiplanar interlocking holes; however, the closed section design made possible with advances in precision manufacturing is still the gold standard for interlocking nails. The RT intramedullary nail system's achievement of the goals of immediate weight bearing and rapid mobilization with the highest rates of fracture healing and lowest rates of implant failure make it a benchmark in the history of surgical implant design.

## SELECTED BIBLIOGRAPHY


1. **Watson-Jones R, Bonnin J, King T, Palmer I, Smith H, et al.** Medullary nailing of fractures after fifty years. J Bone Joint Surg 1950;32B(4):694-729.
2. **Winquist RA, Hansen ST, Clawson DK.** Closed intramedullary nailing of femoral fractures. J Bone Joint Surg Am 1984; 66:529- 39.
3. **Johnson KD, Johnston DW, Parker B.** Comminuted femoral-shaft fractures: treatment by roller traction, cerclage wires and an intramedullary nail, or an interlocking intramedullary nail. J Bone Joint Surg Am 1984; 66(8):1222-35.
4. **Russell TA.** Biomechanics of intramedullary nailing of the femur: current concepts. Seminars in Orthopaedics 1986; 1(4)
5. **Taylor JC, Russell TA, LaVelle DG, Calandruccio RA.** Clinical results of 100 femoral shaft fractures treated with Russell-Taylor interlocking nail system. [Abstract] Orthop Trans 1987;11:491.
6. **Brumback RJ, Uwagie-Ero S, Lakatos RP, Poka A, Bathon GH, Burgess AR.** Intramedullary nailing of femoral shaft fractures. Part II: Fracture-healing with static interlocking fixation. J Bone Joint Surg Am 1988;70(10):1453-62.
7. **Russell TA: Biomechanics of intramedullary femoral nails.** J Int Orthop Trauma 1991;1(1):35-51.
8. **Russell TA.** Management of ipsilateral femoral neck and shaft fractures. Op Tech Orthop 1991;1(4):292-302.
9. **Blumberg KD, Foster WC, Blumberg JF, Adelaar RS, Deblois ME, Hussey RW, Loughran TP, Cardea JA.** A comparison of the Brooker-Wills and Russell-Taylor nails for treatment of patients who have fractures of the femoral shaft. J Bone Joint Surg Am 1990;72(7):1019-24.
10. **Russell TA, Taylor JC, Lavelle DG, Beals N, Brumfield D, Durham G.** Mechanical characterization of femoral interlocking intramedullary nailing systems. J Orthop Trauma 1991;5:332-40.
11. **Whittle P, Russell TA, Taylor JC, Lavelle DG.** Treatment of open fractures of the tibial shaft with the use of interlocking nailing without reaming. J Bone Joint Surg Am 1992;74(8):1162-71.
12. **Slater JC, Russell TA, Walker BC.** Intramedullary nailing of complex subtrochanteric fracture of the femur. American Academy of Orthopedic Surgeons Orthopaedic Transactions, 1992.
13. **Russell TA, Taylor, JC.** Subtrochanteric fractures of the femur. In Browner BD, Jupiter JB, Levine AM, Trafton PG, (Eds.). Skeletal Trauma. 2nd edition. WB Saunders, Philadelphia, PA; 1992:1832-78.
14. **Beaty JH, Austin SM, Warner WC, Canale ST, Nichols L.** Interlocking intramedullary nailing of femoral-shaft fractures in adolescents: preliminary results and complications. J Pediatr Orthop 1994;14(2):178-83.
15. **Whittle AP, Wester W, Russell TA.** Fatigue failure in small diameter interlocking tibial nails. Clin. Orthop Relat Res 1995;315:119-28.
16. **Kyle RF, Cabanella ME, Russell TA, Swiontkowski MF, Winquist RA, Zuckerman JD, Schmidt AH, Koval KJ.** Fractures of the proximal part of the femur. J Bone Joint Surg Am 1995;77(44):227-53.
17. **French BG, Tornetta P III.** Use of interlocked cephalomedullary nail for subtrochanteric fracture stabilization. Clin Orthop Relat Res 1998;348:95–100.
18. **Roberts C, Nawab A, Wang M, Voor M, Seligson D.** Second-generation intramedullary nailing of subtrochanteric femur fractures: a biomechanical study of fracture site motion. J Orthop Trauma 2002;16:231–238.
19. **Russell TA.** Intramedullary nailing: evolutions of femoral intramedullary nailing: first to fourth generations. J Orthop Trauma 2012;25:S135-S138.

X4™ × mi™

DONJOY®

# Monitor patients.

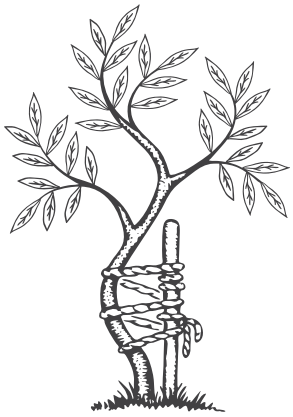
## Stay connected. From anywhere.

Introducing the cloud-based remote patient monitoring solution: X4™ Smart Brace with Motion Intelligence™. A post-op knee brace that stabilizes and supports while monitoring rehabilitation in real time. Visit www.djoglobal.com/mi to experience the future of connected medicine.


*patient app*

*physician portal*

DJO®
T 800.336.6569 D 760.727.1280 F 800.936.6569
1430 Decision Street | Vista, CA 92081-8553 | U.S.A.
DJOGlobal.com/donjoy



# CLASS OF 2018 RESIDENT RESEARCH

# A Quantitative Analysis of Deltoid Lengthening on Associated Complications Following Reverse Total Shoulder Arthroplasty


## ABSTRACT

**BACKGROUND:** Reverse total shoulder arthroplasty (RTSA) reduces pain and improves function for a number of rotator cuff deficient conditions. Inferior glenosphere positioning and medialization of the center of rotation act to increase the deltoid lever arm to restore forward elevation. However, overtensioning of the deltoid can have negative clinical consequences, including acromion fractures, deltoid dehiscence, and prolonged pain. We proposed to compare deltoid length in a 1:2 matched cohort of patients with and without deltoid tension-related complications following RTSA.

**MATERIALS AND METHODS:** We retrospectively identified 13 patients who developed post-operative complications following RTSA including 9 patients with acromion fractures or deltoid dehiscence, and 4 patients with persistent (>2 years postoperative) deltoid pain. These were compared with a cohort of 26 patients (1:2 matching) without post-operative deltoid complications that were matched according to age and operative indication. Component lateralization was also standardized between groups. Minimum follow-up was 2 years for all patients. We excluded cases of revision arthroplasty or prior history of deltoid dysfunction. Average deltoid lengthening was measured radiographically from preoperative and postoperative radiographs using established techniques. One-way ANOVA with post-hoc testing was used to identify differences in deltoid length between cohorts. Nonparametric analyses (Pearson chi-square analysis, Kendall's tau coefficient) were used to examine all nominal variables for association. Differences with $p<0.05$ were considered statistically significant.

**RESULTS:** The experimental cohort of 13 patients included 6 patients with acromion fractures, 3 with deltoid dehiscence, and 4 with persistent deltoid pain. The control group was composed of 26 patients without deltoid related complications. The average age for the overall cohort was 71 years and there were no significant differences between groups regarding age, sex, operative indication, the use of bone graft, or duration of follow-up. Average deltoid lengthening was found to be 21 mm. Patients with deltoid-related complications had significantly greater deltoid lengthening (acromion fracture or deltoid dehiscence 29 mm [range 17-41 mm]; persistent deltoid pain 26 mm [range 18-36 mm]) compared to those without complications (17 mm [range 5-30 mm]; $p=0.002$).

**CONCLUSION:** Patients with post-operative acromion fractures, deltoid dehiscence, or persistent deltoid pain had significantly greater deltoid lengthening than a control group without complications. Further, this degree of lengthening corresponds to previously published biomechanical data regarding the degree to which the deltoid can tolerate elongation. Surgeons should be cognizant that lengthening the deltoid more than 25mm during RTSA increases the risk of post-operative tension-related complications.



**Thomas R. Acott, MD[1]**
**Tyler J. Brolin, MD[1]**
**Frederick M. Azar, MD[1]**
**Richard A. Smith, PhD[1]**
**Thomas W. Throckmorton, MD[1]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery
& Biomedical Engineering
Memphis, Tennessee

**Corresponding author:**

Thomas W. Throckmorton, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
tthrockmorton@campbellclinic.com

## REFERENCES


1. **Ackland DC, Roshan-Zamir S, Richardson M, Pandy MG.** Moment Arms of the Shoulder Musculature After Reverse Total Shoulder Arthroplasty. J Bone Joint Surg Am. 2010;92:1221-30.
2. **Boileau P, Watkinson DJ, Hatzidakis AM, Balg F.** Grammont reverse prosthesis: Design, rationale, and biomechanics. J Shoulder Elbow Surg. 2005 Jan-Feb;14:147S-161S.
3. **Crosby LA, Hamilton A, Twiss T.** Scapula Fractures After Reverse Total Shoulder Arthroplasty: Classification and Treatment. Clin Orthop Relat Res. 2011;469:2544-2549.
4. **Cuff D, Pupello D, Virani N, Levy J, Frankle M.** Reverse Shoulder Arthroplasty for the Treatment of Rotator Cuff Deficiency. J Bone Joint Surg Am. 2008;90:1244-1251.
5. **De Wilde L, Audenaert E, Barbaix E, Audenaert A, Soudan K.** Consequences of deltoid muscle elongation on deltoid muscle performance: a computerised study. Clinical Biomechanics. 2002;17:499-505.
6. **Dubrow S, Streit JJ, Muh S, Shishani Y, Gobezie R.** Acromial Stress Fractures: Correlation with Acromioclavicular Osteoarthritis and Acromiohumeral Distance. Orthopedics. 2014;37:1074-9.
7. **Frankle M, Siegal S, Pupello D, Saleem A, Mighell M, Vasey M.** The Reverse Shoulder Prosthesis for Glenohumeral Arthritis Associated with Severe Rotator Cuff Deficiency: A Minimum Two-Year Follow-up Study of Sixty Patients. J Bone Joint Surg Am. 2005;87:1697-705.
8. **Greiner SH, Back DA, Herrmann S, Perka C, Asbach P.** Degenerative changes of the deltoid muscle have impact on clinical outcome after reversed total shoulder arthroplasty. Arch Orthop Trauma Surg. 2010;130:177-183.
9. **Gruber G, Bernhardt GA, Clar H, Zacherl M, Glehr M, Wurnig C.** Measurement of the acromiohumeral interval on standardized anteroposterior radiographs: A prospective study of observer variability. J Shoulder Elbow Surg. 2010;19:10-3.
10. **Hamid N, Connor PM, Fleischli JF, D'Alessandro DF.** Acromial Fracture After Reverse Shoulder Arthroplasty. Am J Orthop. 2011;40(7):E125-E129.
11. **Hattrup SJ.** The Influence of Postoperative Acromial and Scapular Spine Fractures on the Results of Reverse Shoulder Arthroplasty. Orthopedics. 2010;33.
12. **Henninger HB, Barg A, Anderson AE, Bachus KN, Tashjian RZ, Burks RT.** Effect of deltoid tension and humeral version in reverse total shoulder arthroplasty: a biomechanical study. J Shoulder Elbow Surg. 2012;21:483-490.
13. **Jobin CM, Brown GD, Bahu MJ, Gardner TR, Bigliani LU, Levine WN, Ahmad CS.** Reverse total shoulder arthroplasty for cuff tear arthropathy: the clinical effect of deltoid lengthening and center of rotation medialization. J Shoulder Elbow Surg. 2012;21:1269-1277.
14. **Katzer A, Sickelmann F, Seemann K, Loehr JF.** Two-Year Results After Exchange Shoulder Arthroplasty Using Inverse Implans. Orthopedics. 2004;27:1165-7.
15. **Ladermann A, Williams MD, Melis B, Hoffmeyer P, Walch G.** Objective evaluation of lengthening in reverse shoulder arthroplasty. J Shoulder Elbow Surg. 2009;18:588-95.
16. **Ladermann A, Edwards TB, Walch G.** Arm lengthening after reverse shoulder arthroplasty: a review. International Orthopaedics. 2014;38:991-1000.
17. **Ladermann A, Walch G, Lubbeke A, Drake GN, Melis B, Bacle G, Collin P, Edwards TB, Sirveaux F.** Influence of arm lengthening in reverse shoulder arthroplasty. J Shoulder Elbow Surg. 2012;21:336-341.
18. **Ladermann A, Lubbeke A, Melis B, Stern R, Christofilopoulos P, Bacle G, Walch G.** Prevalence of Neurologic Lesions After Total Shoulder Arthroplasty. J Bone Joint Surg Am. 2011;93:1288-93.
19. **Levy JC, Anderson C, Samson A.** Classification of Postoperative Acromial Fractures Following Reverse Shoulder Arthroplasty. J Bone Joint Surg Am. 2013;95:e104(1-7).
20. **Otto RJ, Virani NA, Levy JC, Nigro PT, Cuff DJ, Frankle MA.** Scapular fractures after reverse shoulder arthroplasty: evaluation of risk factors and the reliability of a proposed classification. J Shoulder Elbow Surg. 2013;22:1514-21.
21. **Russo R, Rotonda GD, Ciccarelli M, Cautiero F.** Analysis of complications of reverse total shoulder arthroplasty. Joints. 2015;3:62-6.
22. **Sabesan VJ, Lombardo D, Josserand D, Buzas D, Jelsema T, Petersen-Fitts GR, Wiater JM.** The effect of deltoid lengthening on functional outcome for reverse shoulder arthroplasty. Musculoskelet Surg. 2016;100:127-132.
23. **Scarlat MM.** Complications with reverse total shoulder arthroplasty and recent evolutions. International Orthopaedics. 2013;37:843-851.
24. **Schwartz DG, Kang SH, Lynch TS, Edwards S, Nuber G, Zhang LQ, Saltzman M.** The anterior deltoid's importance in reverse shoulder arthroplasty: a cadaveric biomechanical study. J Shoulder Elbow Surg. 2013;22:357-64.
25. **Walch G.** Mottier F, Wall B, Boileau P, Mole D, Favard L. Acromial insufficiency in reverse shoulder arthroplasties. J Shoulder Elbow Surg. 2009;18:495-502.
26. **Werner BS, Daggett M, Carrillon Y, Walch G.** Evaluation of lengthening in reverse shoulder arthroplasty comparing X-rays and computerised tomography. International Orthopaedics. 2015;39:2389-2394.
27. **Werner BS, Jacquot A, Molé D, Walch G.** Is radiographic measurement of acromiohumeral distance on anteroposterior view after reverse shoulder arthroplasty reliable? J Shoulder Elbow Surg. 2016;25:e276-80.
28. **Werner CM, Conrad SJ, Meyer DC, Keller A, Hodler J, Gerber C.** Intermethod agreement and interobserver correlation of radiologic acromiohumeral distance measurements. J Shoulder Elbow Surg. 2008;17:237-240.
29. **Werner CM, Steinmann PA, Gilbart M, Gerber C.** Treatment of Painful Pseudoparesis Due to Irreparable Rotator Cuff Dysfunction with the Delta III Reverse-Ball-and-Socket Total Shoulder Prosthesis. J Bone Joint Surg Am. 2005;87:1476-86.
30. **Whatley AN, Fowler RL, Warner JJ, Higgins LD.** Postoperative rupture of the anterolateral deltoid muscle following reverse total shoulder arthroplasty in patients who have undergone open rotator cuff repair. J Shoulder Elbow Surg. 2011;20:114-122.
31. **Wong MT, Langohr DG, Athwal GS, Johnson JA.** Implant positioning in reverse shoulder arthroplasty has an impact on acromial stresses. J Shoulder Elbow Surg. 2016;25:1889-1895.
32. **Wright J, Potts C, Smyth MP, Ferrara L, Sperling JW, Throckmorton TW.** A quantitative analysis of the effect of baseplate and glenosphere position on deltoid lengthening in reverse total shoulder arthroplasty. Int J Shoulder Surg 2015;9:33-37. doi: 10.4103/0973-6042.154752.

# The Worst of the Worst: High Energy Comminuted Proximal Femur Fractures in Young Patients Treated with a Fixed Angle Reconstruction Nail


## ABSTRACT

**Background:** High-energy comminuted proximal femur fractures can be difficult to manage. These fractures commonly occur in young patients and are associated with atypical fracture patterns that often have significant comminution and soft tissue stripping. Fixation with intramedullary nails has not been well described, whereas fixation with proximal femoral locking plates is associated with nonunion and failure rates of up to 70%. The purpose of this study is to evaluate clinical outcomes of a cohort of young patients with high-energy comminuted proximal femur fractures treated with a locked fixed angle reconstruction nail. This novel approach incorporates a nail that statically fixes the proximal reconstruction screws to the shaft of the nail to prevent collapse and shortening. We hypothesize that this fixation will allow for anatomic alignment with a low rate of postoperative complications.

**Methods:** This was a retrospective study performed at a regional level I trauma center. Eighteen skeletally mature patients age <65 years with high-energy comminuted proximal femur fractures (OTA/OA 31-A2.3 and 31-A3.3) treated with a locked piriformis entry cephalomedullary nail were included. The main outcome measure was malalignment <5 degrees on the postoperative anteroposterior (AP) pelvis radiograph. Follow-up data was available on 15 patients at an average of 18.9 weeks.

**Results:** The study population included 14 male and 4 female patients with an average age of 39.5 years. The mean immediate post-operative neck-shaft angle for the operative extremity was 131.0 degrees, whereas the contralateral (control) neck-shaft angle averaged 130.6 degrees. The average neck-shaft angle at final follow-up was 130.3 degrees. All patients were fixed in <5 degrees of varus. One patient developed nonunion requiring secondary surgery for exchange nailing. A second patient required secondary operation for revision of the proximal reconstruction screws but went on to union. There were no other known complications in any of the study patients.

**Conclusion:** High energy comminuted proximal femur fractures can be treated successfully with a fixed angle reconstruction nail with low rates of malalignment and nonunion hardware complications.

**Level of Evidence:** Level IV, case series



**Source of Funding:** no external funding source



**David C. Carver, MD[1]**

**Eric A. Barcak, DO[2]**

**Edward A. Perez, MD[1]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery
& Biomedical Engineering
Memphis, Tennessee

[2] John Peter Smith Hospital
1400 S. Main St.
Houston, Texas 76104

**Corresponding author:**

Edward A. Perez, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3224
F: 901-759-3195
eperez@campbellclinic.com


## REFERENCES


1. **Russell, TA.** Intertrochanteric Fractures of the Hip. In: Court-Brown CM, Heckman JD, McQueen MM, et al, eds. Rockwood and Green's Fractures in Adults. 8th ed. Philadelphia, PA: Wolters Kluwer; 2015:2017-2129.
2. **Streubel PN, Moustoukas M, Obremskey WT.** Locked plating versus cephalomedullary nailing of unstable intertrochanteric femur fractures. Eur J Orthop Surg Traumatol 2016;26:385-390.
3. **Kregor PJ, Obremskey WT, Kreder HJ, et al.** Unstable Pertrochanteric Femoral Fractures. J Orthop Trauma 2005;19:63-33.
4. **Amini MH, Feldman JJ, Weinlein JC.** High Complication Rate in Young Patients with High-Energy Intertrochanteric Femoral Fractures. Orthopedics 2017;40:e293-e299.
5. **Sadowski C, Lübbeke A, Saudan M, et al.** Treatment of Reverse Oblique and Transverse Intertrochanteric Fractures with Use of an Intramedullary Nail or a 95° Screw-Plate. JBJS 2002;84-A:372-381.
6. **Lin SJ, Huang KC, Chuang PY, et al.** The outcome of unstable proximal femoral fracture treated with reverse LISS plates. Injury 2016;47:2161-2168.

7. **Collinge CA, Hymes R, Archdeacon M, et al.** Unstable Proximal Femur Fractures Treated With Proximal Femoral Locking Plates: A retrospective, Multicenter Study of 111 Cases. J Orthop Trauma 2016;30:489-495.
8. **Floyd MW, France JC, Hubbard DF.** Early experience with the proximal femoral locking plate. Orthopedics 2013;36:e1488-1494.
9. **Johnson B, Stevenson J, Chamma R, et al.** Short-term follow-up of pertrochanteric fractures treated using the proximal femoral locking plate. J Orthop Trauma 2014;28:283-287.
10. **Barbosa de Toledo Lourenço PR, Pires RES.** Subtrochanteric fractures of the femur: update. Revista Brasileira de Ortopedia. 2016;51(3):246-253.
11. **Starr AJ, Hay MT, Reinert CM, et al.** Cephalomedullary Nails in the Treatment of High-energy Proximal Femur Fractures in Young Patients: A Prospective, Randomized Comparison of Trochanteric Versus Piriformis Fossa Entry Portal. J Orthop Trauma 2006;20:240-246.
12. **Barquet A, Francescoli L, Rienzi D.** Intertrochanteric-subtrochanteric fractures: treatment with the long Gamma nail. J Orthop Trauma 2000;14:324-328.
13. **Kovalak E, Ermutlu C, Atay T, et al.** Management of unstable pertrochanteric fractures with proximal femoral locking compression plates and affect of neck-shaft angle on functional outcomes. J Clin Orthop Trauma 2017;8:209-14.
14. **Zha GC, Chen ZL, Qi XB, et al.** Treatment of pertrochanteric fractures with a proximal femur locking compression plate. Injury 2011;42:1294-9.
15. **Glassner PJ, Tejwani NC.** Failure of proximal femoral locking compression plate: a case series. J Orthop trauma 2011;25:76-83.
16. **Streubel PN, Moustoukas MJ, Obremskey WT.** Mechanical failure after locking plate fixation of unstable intertrochanteric femur fractures. J Orthop Trauma 2013;27:22-28.
17. **Forward DP, Doro CJ, O'Toole RV, et al.** A biomechanical comparison of a locking plate, a nail, and a 95° angled blade plate for fixation of subtrochanteric femoral fractures. J Orthop Trauma 2012;26:344-40.
18. **Winquist RA.** Locked femoral nailing. J Am Acad Orthop Surg 1993;1:95-105.
19. **Bose WJ, Corces A, Anderson LD.** A Preliminary Experience with the Russell-Taylor Reconstruction Nail for Complex Femoral Fractures. J Trauma 1992;32:71-76.
20. **Kang S, McAndrew MP, Johnson KD.** The reconstruction locked nail for complex fractures of the proximal femur. J Orthop Trauma 1995;9:453-463.

# Genetic Relationship in a Group of Metal on Metal Total Hip Bearing Failures


## ABSTRACT

**BACKGROUND:** Since the recall of some metal on metal (MoM) total hip replacement (THR) bearings, surgeons have seen patients with pain, elevated Co and Cr levels and adverse local tissue reactions (ALTR). While many variables may contribute to THR MoM failures, many times these variables are not present in patients who present with symptoms. We investigate the possible genetic predilection of a group of patients who were revised after MoM THR surgery for pain, high Co/Cr levels and ALTR.

**METHODS:** IRB approval was obtained prior to our study. We have analyzed 19 control (asymptomatic) MoM THR patients > 6 years after surgery and 19 disease (revised) MoM THR for high metal ions and ALTR). The 38 sample intensity files were subject to sample Quality Control (QC) using Contrast QC (< 0.4) with an Affymetrix Genotyping Console. The resulting 38 sample files with genotype calls were loaded and further analyzed using the Association Workflow in Partek Genomics Suite 6.6 (Partek, Missouri). Hardy-Weinberg equilibrium test was performed on the single nucleotide polymorphism (SNP) level. The difference between the observed and expected frequencies of each allele at each locus were tested by Fisher's exact test and $\chi^2$ test. To get the working SNP list, two filters were used: (1) a SNP no-call rate should be less than 5%, and (2) minor allele frequency of a SNP should be greater than 5%.

After filtering, association analysis of the SNPs with disease was done using $\chi^2$ Test. In this study, $\chi^2$ statistic was used to assess the difference in allele frequencies between the control and disease samples. The value of $\chi^2$ statistic, degrees of freedom, and the associated p-value for each SNP were calculated. Dot Plot was used to visualize the genotypes of all samples.

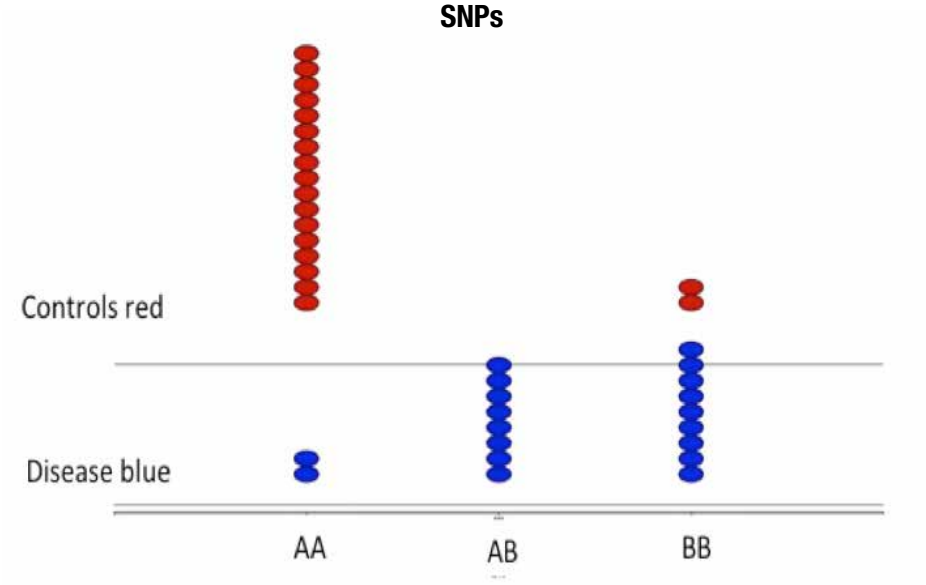




**Figure 1:** MS-1 genotypes with AA homozygous dominant isoform, AB heterozygous isoform, BB homozygous recessive isoform. Red are control subjects and blue are disease subjects who underwent MoM THR revision.


**Justin D. Hallock, MD[1]**
**Weikuan Gu, PhD[1,2]**
**Anita Kerkhof, RN, MSN[1]**
**Yan Jiao, PhD[1]**
**Jan Wan, PhD[1]**
**William M. Mihalko, MD, PhD[1]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery
& Biomedical Engineering
Memphis, Tennessee

[2] College of Medicine
University of Tennessee Health Science Center
Memphis, Tennessee

**Corresponding author:**

William M.Mihalko, MD, PhD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
wmihalko@campbellclinic.com

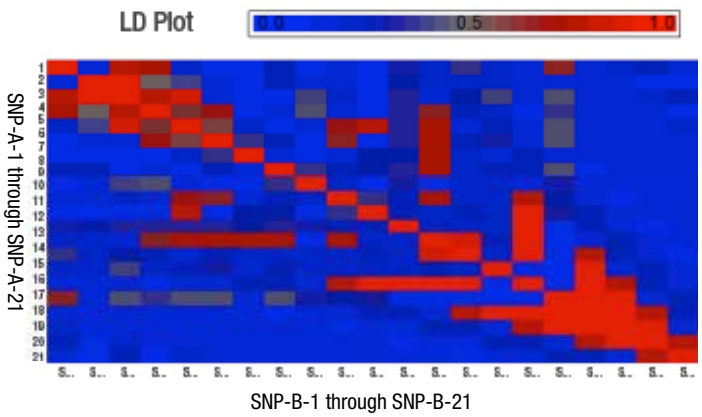



**Figure 2:** SNP LD Dot plot showing strong correlation of several identified SNPs in the disease cohort who has high metal serum ion levels and or ALTR and had their MoM THR revised. Blue show low correlation and red high correlation.

To measure the non-random association of alleles at different loci, Linkage Disequilibrium analysis was performed using the neighborhood size of 20 and statistic $r^2$. The resulting correlations show the value of $r^2$ for SNPs. The $r^2 = 1$ means that two SNPs are tightly associated.

**RESULTS:** We found that several SNPs are linked to the revision disease group that showed evidence of metal sensitivity. Among them, a strong association in the disease group was found in an SNP for a gene we refer to as MS1. In the disease group 17/19 patients were either heterozygous or homozygous recessive for MS1, while 17/19 asymptomatic patients were of the homozygous dominant MS1 isoform. Based on the Linkage Disequilibrium analysis results, several other SNPs were also found to be strongly correlated with the disease group. The controls had an average Co level of 2.4 and Cr level of 1.3 while the disease group 18 and 10.4 respectively.

**CONCLUSIONS:** This study found a strong genetic relationship in a gene we designate as MS1 where the homozygous recessive and heterozygous isoform genotypes were found in the disease group of revised MoM THRs. A strong correlation of several other SNPs were also found. This may be a good predictor of failures and an avenue for choice of personalized implants in the future.

## REFERENCES


1. **National Hospital Discharge Survey.** Table, procedures by selected patient characteristics—number by procedure category and age. Centers for Disease Control and Prevention Web site 2010 http://www.cdc.gov/nchs/fastats/inpatient-surgery. htm [Page last updated April 29, 2015. Accessed March 3, 2016].
2. **Perino G, Ricciardi BF, et.** al. Implant based differences in adverse local tissue reaction in failed total hip arthroplasties: a morphological and immunohistochemical study. BMC Clinical Pathology. 2014 Sep 5;14:39. doi: 10.1186/1472-6890-14-39.
3. **Sands D, Schemitsch EH.** The role of metal-on-metal bearings in total hip arthroplasty and hip resurfacing: Review Article. HSS Journal. 2017 Feb: 13(1):2-6.
4. **Innmann MM, Gotterbarm T, Kretzer JP, et al.** Minimum ten-year results of a 28-mm metal-on-metal bearing in cementless total hip arthroplasty in patients fifty years of age and younger. Int Orthop. 2014; 38(5): 929-934.
5. **Dowson D, Jin ZM.** Metal-on-metal hip joint tribology. Proc Inst Mech Eng H. 2006; 220(2): 107-118.
6. **Smith AJ, Dieppe P, Vernon K, Porter M, Blom AW.** National Joint Registry of England and Wales. Failure rates of stemmed metal-on-metal hip replacements: analysis of data from the National Joint Registry of England and Wales. Lancet. 2012; 379(9822): 1199-1204.
7. **Caicedo, M.**S., et al., Females with Unexplained Joint Pain Following Total Joint Arthroplasty Exhibit a Higher Rate and Severity of Hypersensitivity to Implant Metals Compared with Males: Implications of Sex-Based Bioreactivity Differences. J Bone Joint Surg Am, 2017. 99(8): p. 621-628.
8. **Mitchelson, A.**J., et al. Biomaterial hypersensitivity: is it real? Supportive evidence and approach considerations for metal allergic patients following total knee arthroplasty. Biomed Res Int, 2015. 2015: p. 137287.
9. **Kurtz S, Ong K, Lau E, Mowat F, Halpern M.** Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am. 2007 Apr;89(4):780-5.
10. **Inacio MC, Ake CF, Paxton EW, Khatod M, Wang C, Gross TP, Kaczmarek RG, Marinac- Dabic D, Sedrakyan A.** Sex and risk of hip implant failure: assessing total hip arthroplasty outcomes in the United States. JAMA Intern Med. 2013 Mar 25;173(6):435-41.
11. **Haughom BD, Erickson BJ, Hellman MD, Jacobs JJ.** Do Complication rates differ by gender after metal-on-metal hip resurfacing arthroplasty? A systematic review. Clin Orthop Relat Res. 2015 Aug;473(8):2521-9.
12. **Lachiewicz, P.**F., Watters T.S., Jacobs J. Metal Hypersensitivity and Total Knee Arthroplasty. J Am Acad Orthop Surg, 2016. 24(2): p. 106-12.
13. **Carossino A.**M., et al. Hypersensitivity reactions to metal implants: laboratory options. BMC Musculoskelet Disord, 2016. 17(1): p. 486.
14. **Lohmann C.**H., Hameister R, Singh G. Allergies in orthopaedic and trauma surgery. Orthop Traumatol Surg Res, 2017. 103(1s): p. S75-s81.
15. **Bozic KJ, Kurtz SM, Lau E, Ong K, Vail RP, Berry DJ.** The epidemiology of revision total hip arthroplasty in the United States. J Bone Joint Surg Am 2009;91(1):128–33.
16. **Baker PN, van der Meulen JH, Lewsey J, Gregg PJ.** National Joint Registry for Eng- land and Wales. The role of pain and function in determining patient satisfaction after total knee replacement: data from the National Joint Registry for England and Wales. J Bone Joint Surg Br. 2007; 89(7):893-900.
17. **Weber M1, Craiovan B1, Woerner ML1, Schwarz T1, Grifka J1, Renkawitz TF1.** Predictors of Outcome After Primary Total Joint Replacement. J Arthroplasty. 2017 Sep 7. pii: S0883-5403(17)30783-0. doi: 10.1016/j.arth.2017.08.044. [Epub ahead of print]
18. **Anakwe RE, Jenkins PJ, Moran M.** Predicting dissatisfaction after total hip arthroplasty: a study of 850 patients. J Arthroplasty. 2011;26(2):209–213. [PubMed]
19. **Yu S, Garvin KL, Healy WL, et al.** Preventing hospital readmissions and limiting the complications associated with total joint arthroplasty. J Am Acad Orthop Surg 2015;23(11):e60.
20. **Fournier MN, Hallock J, Mihalko WM.** Preoperative optimization of total joint arthroplasty surgical risk: Obesity. J Arthroplasty. 2016 Aug;31(8):1620-4. doi: 10.1016/j.arth.2016.02.085. Epub 2016 Mar
21. **Hallab N, Merritt K, Jacobs JJ.** Metal sensitivity in patients with orthopaedic implants. J Bone Joint Surg Am. 2001; 83(3):428–436. [PubMed: 11263649]
22. **Granchi D, Cenni E, Tigani D, et al.** Sensitivity to implant materials in patients with total knee arthroplasties. Biomaterials 2008;29:1494.
23. **Bravo D.**, et al., No Increased Risk of Knee Arthroplasty Failure in Patients With Positive Skin Patch Testing for Metal Hypersensitivity: A Matched Cohort Study. J Arthroplasty, 2016. 31(8): p. 1717-21.
24. **Amini M, Mayes WH, Tzeng A, Tzeng TH, Saleh KJ, Mihalko WM.** Evaluation and management of metal hypersensitivity in total joint arthroplasty: a systematic review. J Long Term Eff Med Implants. 2014;24(1):25-36. Review.
25. **Wang C, Gui Q, Zhang K.** Functional polymorphisms in CD86 gene are associated with susceptibility to pneumonia-induced sepsis. APMIS. 2015 May;123(5):433-8. doi: 10.1111/apm.12364.

# Total Knee Arthroplasty (TKA) In the Ambulatory Surgery Center is as Safe as and Less Costly than in an Inpatient Hospital Setting: A Matched-Cohort Comparison


## ABSTRACT

**Background:** To determine the safety, efficacy, and expense associated with both locations, we compared a matched cohort of outpatient TKAs done in a free-standing ambulatory surgery center (ASC) with those done in a standard inpatient hospital setting.

**Methods:** Retrospective review identified 82 patients who had a TKA, 41 at an ASC and 41 in an inpatient hospital. The cohorts were matched according to age and American Society of Anesthesiologists physical status classification (ASA score). Primary outcomes included episode-of-care measures and cost. Ninety-day episode-of-care measures included complications, hospital readmissions, and reoperations.

**Results:** The cohorts demonstrated no statistically significant differences in age ($p = 0.55$), gender ($p = 0.40$), body mass index (BMI) ($p = 0.29$), and ASA scores ($p = 0.15$). There were no readmissions or major complications, including deep infection, periprosthetic fracture, or venous thromboembolism, in either cohort. Minor wound issues occurred in four (9.8%) hospital patients and in one (2.4%) ASC patient (p=0.36). All ASC patients were discharged the same day of surgery without an overnight stay. The average length of stay for the hospital group was 2.5 days.

**Conclusion:** Our results demonstrate that TKA can be done safely, reliably, and cost effectively in the ASC. Patient selection, pre-operative screening/counseling, and the use of a multimodal pain regimen are critical to minimizing complications and reducing costs. With the increasing emphasis on lower costs and higher patient satisfaction as measures of outcomes, TKA in the ASC is an attractive alternative to traditional in-hospital TKA.



**Travis W. Littleton, MD[1]**
**Thomas W. Throckmorton, MD[1]**
**William M. Mihalko, MD, PhD[1]**
**Patrick C. Toy, MD[1]**
**Anthony A. Mascioli, MD[1]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery
& Biomedical Engineering
Memphis, Tennessee

**Corresponding author:**

Anthony A. Mascioli, MD
7545 Airways Blvd.
Southaven, MS 38671
P: 901-759-3211
F: 901-435-5783
amascioli@campbellclinic.com


## REFERENCES


1. **Berger RA, Kusuma SK, Sanders SA, Thill ES, Sporer SMS.** The feasibility and perioperative complications of outpatient knee arthroplasty. Clin Orthop Relat Res 2009;467:1443-9. doi: 10.1007/s11999-009-0736-7.
2. **Cross MB, Berger R.** Feasibility and safety of performing outpatient unicompartmental knee arthroplasty. Int Orthop 2014;38:443-7.
3. **Lovald ST, Ong KL, Malkani AL, Manley MT, Lau EC, Schmier JK, et al.** Complications, mortality, and costs for outpatient and short-stay total knee arthroplasty patients in comparison to standard-stay patients. J Arthroplasty 2014;29:510-5. doi: 10.1016/j.arth.2013.07.020.
4. **Pollock M, Somerville L, Firth A, Lanting B.** Outpatient total hip arthroplasty, total knee arthroplasty, and unicompartmental knee arthroplasty: a systematic review of the literature. JBJS Rev 2016 Dec 27;4(12). pii: 01874474-201612000-00004. doi: 10.2106/JBJS.RVW.16.00002.
5. **Richter DL, Diduch DR.** Cost comparison of outpatient versus inpatient unicompartmental knee arthroplasty. Orthop J Sports Med 2017;5:2325967117694352. doi: 10.1177/2325967117694352.
6. **Bovonratwet P, Ondeck NT, Nelson SJ, Cui JJ, Webb ML, Grauer JN.** Comparison of outpatient vs inpatient total knee arthroplasty: An ACS-NSQIP analysis. J Arthroplasty 2017;32:1773-8. doi: 10.1016/j.arth.2017.01.043.
7. **Meneghini RM, Ziemba-Davis M, Ishmael MK, Kuzma AL, Caccavallo P.** Safe selection of outpatient joint arthroplasty patients with medical risk stratification: the "Outpatient Arthroplasty Risk Assessment Score". J Arthroplasty 2017;32:2325-31. doi: 10.1016/j.arth.2017.03.004.
8. **A study of cost variations for knee and hip replacement surgeries in the U.**S. Blue Cross Blue Shield: The Health of America Report, January 21,2015.
9. **Berger RA, Sanders SA, Thill ES, Sporer SM, Della Valle C.** Newer anesthesia and rehabilitation protocols enable outpatient hip replacement in selected patients. Clin Orthop Relat Res 2009;467:1424-30. doi: 10.1007/s11999-009-0741-x.
10. **Dorr LD, Thomas DJ, Zhu J, Long WT, et al.** Outpatient total hip arthroplasty. J Arthroplasty 2010;25:501-6. doi: 10.1016/j.arth.2009.06.005.
11. **Kolisek FR, McGrath MS, Jessup NM, Monesmith EA, Mont MA.** Comparison of outpatient vs inpatient total knee arthroplasty. Clin Orthop Relat Res 2009;467:1438-42. doi: 10.1007/s11999-009-0730-0.
12. **Bovonratwet P, Webb ML, Ondeck NT, Lukasiewicz AM, Cui JJ, McLynn RP, et al.** Definitional differences of 'outpatient' versus 'inpatient' THA and TKA can affect study outcomes. Clin Orthop Relat Res 2017 Jan 12. doi: 10.1007/s11999-017-5236-6. [Epub ahead of print]

13. **Klingenstein GG, Schoifet SD, Jain RK, Reid JJ, Porat MD, Otegbeye MK.** Rapid discharge to home after total knee arthroplasty is safe in eligible Medicare patients. J Arthroplasty 2017 Jun 27. doi:10.1016/j.arth.2017.06.034. [Epub ahead of print]

14. **Courtney PM, Boniello AJ, Berger RA.** Complications following outpatient total joint arthroplasty: an analysis of a national database. J Arthroplasty 2017;32:1426-30. doi: 10.1016/j.arth.2016.11.055.

15. **Parcells BW, Giacobbe D, Macknet D, Smith A, Schottenfeld M, Harwood DA, et al.** Total joint arthroplasty in a stand-alone ambulatory surgical center: short-term outcomes. Orthopedics 2016;39:223-8. doi: 10.3928/01477447-20160419-06.

16. **Rozell JC, Courtney PM, Dattilo JR, Wu CH, Lee GC.** Late complications following elective primary total hip and knee arthroplasty: who, when, and how? J Arthroplasty 2017;32:719-23. doi: 10.1016/j.arth.2016.08.037.

17. **Meneghini RM, Ziemba-Davis M.** Patient perceptions regarding outpatient hip and knee arthroplasties. J Arthroplasty 2017 Apr 13. doi: 10.1016/j.arth.2017.04.006. [Epub ahead of print]

18. **Argenson JN, Husted H, Lombardi A Jr, Booth RE, Thienpont E.** Global forum: An international perspective on outpatient surgical procedures for adult hip and knee reconstruction. J Bone Joint Surg Am 2016;98(13):e55. doi: 10.2106/JBJS.15.00998.

19. **Lovecchio F, Alvi H, Sahota S, Beal M, Manning D.** Is outpatient arthroplasty as safe as fast-track inpatient arthroplasty? A propensity score matched analysis. J Arthroplasty 2016;31(9 Suppl):197-201. doi: 10.1016/j.arth.2016.05.037.

# Mood Disorders Do Not Predict A More Difficult Post-Operative Course Following Primary Anatomic Total Shoulder Arthroplasty


## ABSTRACT

**BACKGROUND:** Mood disorders, including depression and anxiety, are present in up to 30% of the population undergoing arthroplasty procedures. Investigation into the effect of these disorders on outcomes following rotator cuff repair and primary arthroplasty of the hip and knee has been performed. However, information is lacking on their impact following shoulder arthroplasty. As risk stratification models for bundled payment programs develop for arthroplasty procedures, this information will be increasingly relevant as these plans are typically tied to a 90 day episode of care. We proposed to study the effect of mood disorders on pain, narcotic use, length of hospital stay, and complications following primary anatomic total shoulder arthroplasty (TSA) in the global post-operative period.

**METHODS:** After IRB approval, a database search of primary anatomic total shoulder arthroplasties was conducted. Patients in the mood disorders group were identified by the presence of depression and/or anxiety on intake forms or use of a prescription mood stabilizer. Visual analog pain scores (VAS) were recorded at the pre-operative visit and at 2, 6, and 12 week visits after surgery. Oral morphine equivalents (OME) were recorded for in hospital use, discharge medications, and prescriptions given at 2, 6, and 12 week visits. Length of stay and complications data were also recorded. Statistical analyses were performed using Fishers exact tests for dichotomous variables and students t-test for continuous variables. Differences with $p<0.05$ were considered statistically significant.

**RESULTS:** After database search, 132 primary anatomic total shoulder arthroplasties were identified. Thirty-one shoulders comprised the mood disorder group and the remaining 101 did not have a mood disorder. There were no significant differences between groups regarding age, operative indication, BMI, or comorbidities.

There were no significant differences in VAS scores at the pre op, 2, 6, or 12 week visits (mood disorder vs no mood disorder: 6.6 vs 6.2, $p = 0.52$; 4.4 vs 4.0 $p = 0.43$; 3.4 vs 2.6 $p = 0.13$; 1.5 vs 1.8 $p = 0.59$, respectively). There were also no significant differences between groups regarding OME narcotic use at any of the recorded time points **(Table 1)**. And no statistically significant differences were found between cohorts regarding length of hospital stay (1.3 days v 1.1 days, $p= 0.11$) or post-operative complication rates (3% vs 11%, $p=0.19$)

**CONCLUSIONS:** Patients with mood disorders did not demonstrate a more difficult post-operative course following primary anatomic total shoulder arthroplasty. We found no significant differences in VAS scores at any recorded time point. There were no significant differences in post-operative narcotic requirement, length of hospital stay, or complications. These results indicate that patients with a mood disorder undergoing total shoulder arthroplasty can expect a similar post-operative course as those without depression or anxiety. Further, this data suggests the presence of a mood disorder will not necessarily be a significant risk factor for bundled payment plans to consider when developing predictive modeling for primary anatomic total shoulder arthroplasty.



**Timothy M. Lonergan, MD[1]**
**Arturo D. Villarreal, MD[2]**
**Richard A. Smith, PhD[1]**
**Tyler J. Brolin, MD[1]**
**Frederick M. Azar, MD[1]**
**Thomas W. Throckmorton, MD[1]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery
& Biomedical Engineering
Memphis, Tennessee

[2] Sports Medicine
Oschner Health System
New Orleans, LA

**Corresponding author:**

Thomas W. Throckmorton, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
tthrockmorton@campbellclinic.com

| Result | Mood Disorder | Control | P value | Results | Mood Disorder | Control | P value | Results | Mood Disorder | Control | P Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VAS Pre-op | 6.55 | 6.16 | 0.52 | OME Hospital | 73.5 | 63.3 | 0.381 | | | | |
| VAS 2 weeks | 4.38 | 4.01 | 0.429 | OME D/C | 1137.8 | 1283 | 0.251 | 2 wk cummulative OME | 1478.9 | 1584.5 | 0.535 |
| VAS 6 weeks | 3.37 | 2.6 | 0.128 | OME 2 weeks | 285.1 | 245.4 | 0.597 | 6 wk cummulative OME | 1809.8 | 1762.4 | 0.746 |
| VAS 12 weeks | 1.52 | 1.77 | 0.586 | OME 6 weeks | 365.1 | 197.5 | 0.097 | 12 wk cummulative OME | 1912.9 | 1878.8 | 0.846 |
| | | | | OME 12 Weeks | 110 | 119.9 | 0.946 | | | | |

**Table 1:** Pain scores and post-operative narcotic use for patients with and without mood disorders.

## REFERENCES


1. **Ayers, D., Franklin, P., Ploutz-Snyder, R., & Boisvert, C.** (2005). Total Knee replacement outcome and coexisting physical and emotional illness. Clin Orthop Relat Res(440), 157-61.
2. **Blackburn, J., Qureshi, A., Amirfeyz, R., & Bannister, G.** (2012). Does preoperative anxiety and depression predict satisfaction after totla knee replacement? The Knee(19), 522-524.
3. **Bot, A., Menendez, M., Neuhaus, V., & Ring, D.** (2014). The influence of psychiatric comorbidity on perioperative outcomes after shoulder arthroplasty. J of Shoulder Elbow Surg, 23, 519-27.
4. **Browne, J., Sandberg, B., D'Apuzzo, M., & Novicoff, W.** (2014). Depression Is Associated With Early Postoperative Outcomes Following Toatal Joint Arthroplasty: A nationwide Database Study. The Journal of Arthroplasty, 481-83.
5. **Cho, C., Jung, S., Park, J., Song , K., & Yu, K. (**2013, Feb). Is Shoulder pain for three months or longer correlated with depression, anxiety, and sleep disturbance? J Shoulder Elbow Surg, 22(2), 222-8.
6. **Cho, C., Seo, H., Bae, K., & LEE, K.** (2013, Sep). The Impact of depression and anxiety on selfpassessed pain, disability, and quality of life in patients scheduled for rotator cuff repair. J Shoulder Elbow Surg, 22(9), 1160-6.
7. **Day, J., Lau, E., Ong, K., Williams, G., Ramsey, M., & Kurtz, S.** (2010). Prevalence and projections of total shoulder and elbow arthroplasty in the United States to 2015. J Shoulder Elbow Surg.
8. **Drewett, R., Minns, R., & Sibly, T.** (1992). Measuring outcome of total knee replacement using quality of life indicies. Ann R Coll Surg Engl, 74(7), 286-9.
9. **Faller, H., Kirschner, S., & Konig, A.** (2003). Psychological distress predicts functional outcomes at three and twelve months after total knee arthroplasty. Gen Hosp Psychiatry(25), 372-3.
10. **Fisher, D., Dierckman, B., Watts, M., & Davis, K.** (2007). Looks good but feels bad: factors that contribute to poor results after total knee arthroplasty. J Arthroplasty, 22, 39-42.
11. **Gold, H. T., Slover, J. D., & Joo, L.** (2016). Association of Depression With 90-Day Hospital Readmission After Total Joint Arthroplasty. The Journal of Arthroplasty, 2385-2388.
12. **Greene, M., Rolfson, O., Gordon, M., Annerbrink, K., Malchau, H., & Garellick, G.** (2016). Is the use of antidepressants associated with patient-reported outcomes following total hip replacement surgery? Acta Orthopaedica, 87(5), 444-451.
13. **Kim, S., Wise, B., Zhang, Y., & Szabo, R.** (2011). Increasing Incidence of Shoulder Arthroplasty in the United States. J Bone Joint Surg Am, 93(24), 2249-2254.
14. **Mohammad R. Rasouli, M. E.** (2016). Direct Cost and Complications Associated With Total Joint Arthroplasty in Patients With Preoperative Anxiety and Depression. The Journal of Arthroplasty, 533-536.
15. **Mollon, B., Mahure, S., Ding, D., & Zuckerman, J.** (2016). The Influence of a History of Clinical Depression on Peri-operative Outcomes in Elective Total Shoulder Arthroplasty. The Bone and Joint Journal.
16. **Morris, B., Laughlin, M., Elkousy, H., Gartsman, G., & Edwards, T.** (2015). Preoperative Opioid Use and Outcomes After Reverse Shoulder Arthroplasty. J Shoulder Elbow Surg, 24, 11-16.
17. **Padegimas, E., Maltenfort, M., Lazarus, M., Ramsey, M., Williams, G., & Namdari, S.** (2015). Future Patient Demand for Shoulder Arthroplasty by Younger Patients: national Prjections. Clin Orthop Relat Res, 473(6), 1860-1867.
18. **Perez-Prieto, D., Gil-Gonzalez, S., Pelfort, X., Leal-Blanquet, J., Puig-Verdie, L., & Hinarejos, P.** (2014). Influence of depression on Total Knee Arthroplasty Outcomes. The Journal of Arthroplasty, 29, 44-47.
19. **Riddle DL, W. J.** (2010). Major Depression, generalized anxiety disorder, and panic disorder in patients scheduled for knee arthroplasty. J Arthroplasty, 4, 581-8.
20. **Ring, D., Kadzielski, J., Fabian, L., Zurakowski, D., Malhotra, L., & Jupiter, J.** (2006). Self-reported upper extremity health status correlates with depression. J Bone Joint Surg Am, 88, 1983-8.
21. **Roberson TA, G. C.** (2017, Jun). Nonoperative management versus reverse shoulder arthroplasty for treatment of 3- and 4-part proximal humeral fractures in older adults. J Shoulder Elbow Surg, 26(6), 1017-1022.
22. **Roth, M., Tripp, D., Harrison, M., Sullivan, M., & Carson, P.** (2007). Demographic and psychosocial predictors of acute periopertive pain for total knee arthroplasty. Pain Res Manag, 12(3), 185-94.
23. **Singh, J., & Lewallen, D.** (2014). Depression in Primary TKA and higher medical comorbidities in revision TKA are associated with suboptimal subjective improvement in knee function. BMC Musculoskeletal Disorders.
24. **Stundner, O., Kirksey, M., Chiu, Y. L., Mazumdar, M., Poultsides, L., Gerner, P., & Memtsoudis, S.** (2012, November 29). Demographics and Perioperative Outcome in Patients with Depression and Anxiety Undergoing Total Joint Arthroplasty: A Population-Based Study. Psychosomatics.
25. **Weller, W., Azzam, M., Smith, R., Azar, F., & Throckmorton, T.** (2017). Liposomal Bupivacaine Mixture Has Similar Pain Relief and Significantly Fewer Complications at Less Cost Compared to Indwelling Interscalene Catheter in Total Shoulder Arthroplasty. Journal of Arthroplasty.
26. **Wells DB, H. A.** (2018, Jan). Tobacco use predicts a more difficult episode of care after anatomic total shoulder arthroplasty. J Shoulder Elbow Surg, 27(1), 23-28.
27. **Werner, B., Wong, A., Chang, B., Craig, E., Dines, D., Warren, R., & Gulotta, L.** (2017). Depression and Patient-Reported Outcomes Following Total Shoulder Arthroplasty. The Journal of Bone and Joint Surgery, 99, 688-95.

# 90 Day Outcomes of Reverse Total Shoulder Arthroplasty in Tobacco Users


## ABSTRACT

**BACKGROUND:** The current health care environment warrants growing awareness and recognition of patient specific risk factors that may affect postoperative outcomes. Tobacco use has been associated with increased perioperative complications; however, the effect of tobacco use on outcomes following reverse total shoulder arthroplasty (RTSA) is valuable additional information. To determine the potential impacts of tobacco use in this setting, we evaluated postoperative pain, narcotic use, reoperations, and complications in the global 90-day care period for patients undergoing RTSA who were non-tobacco users, current tobacco users, or former tobacco users.

**METHODS:** Retrospective review of clinical database identified 279 patients undergoing RTSA who were then divided into 3 groups: current tobacco users (23), nonusers (150), and former users (106). All surgeries were done with the same technique and implants. Preoperative VAS and ASES scores were compared to postoperative scores. Oral morphine equivalents (OME) were calculated for patients while in hospital and after discharge to comprise the 90 day global period. Complications, re-operations, and hospital re-admissions were also examined.

**RESULTS:** Patients in the current tobacco use group had higher visual analog scale scores preoperatively and at 12 weeks postoperatively than nonusers and former users. Mean improvement in visual analog scale scores was less in current tobacco users versus non-tobacco and former tobacco users. Mean improvement in ASES scores were highest in non-tobacco users. Cumulative OME use at 90 days was significantly higher in current tobacco users than in nonusers and former users. The average OME per day was also significantly higher in the current tobacco users than in nonusers and former users. There were no significant differences in complications or reoperations.

**CONCLUSIONS:** Tobacco users reported increased postoperative pain, reported less improvement in postoperative scores, and had increased narcotic use in the global period after RTSA. Taken together, these data indicate current tobacco users can expect a more difficult post-operative course following RTSA than non-users or former users of tobacco.



**Erin M. Meehan, MD[1]**
**Tyler J. Brolin, MD[1]**
**Jacob T. Hartline, BS[2]**
**Frederick M. Azar, MD[1]**
**Thomas W. Throckmorton, MD[1]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery
& Biomedical Engineering
Memphis, Tennessee

[2] College of Medicine
University of Tennessee Health Science Center
Memphis, Tennessee

**Corresponding author:**

Thomas W. Throckmorton, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
tthrockmorton@campbellclinic.com


## REFERENCES


1. **Bayley KB, London MR, Grunkemeier GL, Lansky DJ.** Measuring the success of treatment in patient terms. Med Care. 1995;33:AS226–AS235. [PubMed]
2. **Wright RW, Baumgarten KM.** Shoulder outcomes measures. J Am Acad Orthop Surg. 2010;18:436–444.[PubMed]
3. **Noble PC, Fuller-Lafreniere S, Meftah M, Dwyer MK.** Challenges in outcome measurement: discrepancies between patient and provider definitions of success. Clin Orthop Relat Res. 2013;471:3437–3445. [PubMed]
4. **Smith MV, Calfee RP, Baumgarten KM, Brophy RH, Wright RW.** Upper extremity-specific measures of disability and outcomes in orthopaedic surgery. J Bone Joint Surg Am. 2012;94:277–285.[PMC free article] [PubMed]
5. **Kirkley A, Griffin S, Dainty K.** Scoring systems for the functional assessment of the shoulder. Arthroscopy. 2003;19:1109–1120. [PubMed]
6. **Wylie, James D et al.** "Functional Outcomes Assessment in Shoulder Surgery." World Journal of Orthopedics 5.5 (2014): 623–633. PMC.
7. **Wells DB, Holt AM, Tobacco use predicts a more difficult episode of care after anatomic total shoulder arthroplasty.** J Shoulder Elbow Surg. 2018 Jan;27(1):23-28. [PubMed]

# Mood Disorders Do Not Have An Adverse Effect On Outcomes Following Reverse Total Shoulder Arthroplasty


## ABSTRACT

**Introduction:** Mood disorders such as depression and anxiety are highly prevalent in the general population. The effect of mental distress on patient outcomes undergoing other orthopaedic procedures has been extensively studied in recent years. While this data generally indicates mood disorders are deleterious to patient outcomes, there is a paucity of information on its effect in patients undergoing shoulder arthroplasty. Therefore, we proposed to study a patient population undergoing primary reverse total shoulder arthroplasty (RTSA) to determine if mood disorders adversely affected two-year patient outcomes.

**Methods:** After Institutional Review Board approval, 114 shoulders undergoing primary reverse total shoulder arthroplasty were included. Patients were classified as having a mood disorder by documentation of depression/anxiety and/or use of a prescription mood-stabilizing drug. Patients were evaluated preoperatively and postoperatively at a minimum of two years. Patients were clinically evaluated using American Shoulder and Elbow Society (ASES) scores, Visual Analog pain scores (VAS), Single Assessment Numeric Evaluation (SANE), active shoulder range of motion, and strength testing. Complications, re-operations, and re-admissions were compiled, and radiographs were assessed for evidence of loosening or component failure at most recent follow up.

Statistical analyses were performed using independent samples t-tests and Pearson chi-square tests. Differences with $p<0.05$ were considered statistically significant.

**Results:** Of the 114 shoulders analyzed, 31 shoulders were categorized as having mood disorders while 83 shoulders were in the non-mood disorder group. The average age for the mood disorder group was 67 years and for the non-mood disorder group was 70 years ($p=0.16$). The average duration of follow up was 29.3 months for the mood disorder group and 28.1 months for the non-mood disorder group ($p= 0.77$). Significantly more women than men comprised the mood disorder group (25 female, 6 male, $p=0.007$). However, there were no significant differences between the groups with respect to body mass index, laterality, race, or worker's compensation claims.

There were no statistical differences observed between the two groups with respect to ASES, VAS, SANE, or range of motion at any time point. There was a trend towards improved external rotation (ER) (4.5 vs 4.8, $p=0.08$) and internal (IR) strength (4.6 vs 4.8, $p=0.091$) in favor of the non-mood disorder group at 2 years. The degree of improvement in these functional outcomes and pain scores from preoperatively to two year follow-up was also evaluated and found not to be significantly different as well.

There were 16 complications in the non-mood disorder group compared to 3 complications in the mood disorder group ($p=0.34$). Two of the patients in the non-mood disorder group required reoperations secondary to radiographic evidence of component loosening; however, this finding was not significant ($p=0.45$). In regards to re-admissions, 2 patients with mood disorders were readmitted while only 1 patient without a mood disorder was readmitted ($p=0.38$).



**Ryves A. Moore, MD[1]**
**Tyler J. Brolin, MD[1]**
**Richard A. Smith, PhD[1]**
**Frederick M. Azar, MD[1]**
**Thomas W. Throckmorton, MD[1]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery
& Biomedical Engineering
Memphis, Tennessee

**Corresponding author:**

Thomas W. Throckmorton, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
tthrockmorton@campbellclinic.com

**Conclusion:** These results suggest that patients suffering from mood disorders can expect similar outcomes to those without mood disorders when undergoing primary reverse total shoulder arthroplasty. This is contrary to most current literature on the effects of mood disorders on outcomes of patients undergoing other orthopedic procedures. It is also contrary to the reported inferior results for patients with mood disorders undergoing anatomic total shoulder arthroplasty. While the reason for this difference remains unclear, these data indicate that patients with mood disorders are ultimately not at an increased risk of inferior outcomes.

## REFERENCES


1. **Bayley KB, London MR, Grunkemeier GL, Lansky DJ.** Measuring the success of treatment in patient terms. Med Care. 1995;33:AS226–AS235. [PubMed]
2. **Wright RW, Baumgarten KM.** Shoulder outcomes measures. J Am Acad Orthop Surg. 2010;18:436–444. [PubMed]
3. **Noble PC, Fuller-Lafreniere S, Meftah M, Dwyer MK.** Challenges in outcome measurement: discrepancies between patient and provider definitions of success. Clin Orthop Relat Res. 2013;471:3437–3445. [PubMed]
4. **Smith MV, Calfee RP, Baumgarten KM, Brophy RH, Wright RW.** Upper extremity-specific measures of disability and outcomes in orthopaedic surgery. J Bone Joint Surg Am. 2012;94:277–285.[PMC free article] [PubMed]
5. **Kirkley A, Griffin S, Dainty K.** Scoring systems for the functional assessment of the shoulder. Arthroscopy. 2003;19:1109–1120. [PubMed]
6. **Wylie, James D et al.** "Functional Outcomes Assessment in Shoulder Surgery." World Journal of Orthopedics 5.5 (2014): 623–633. PMC.
7. **Wells DB, Holt AM, Tobacco use predicts a more difficult episode of care after anatomic total shoulder arthroplasty.** J Shoulder Elbow Surg. 2018 Jan;27(1):23-28. [PubMed]

# Tobacco Use Predicts A More Difficult Episode of Care After Anatomic Total Shoulder Arthroplasty*


## ABSTRACT

**Background:** In the current health care environment, it is becoming increasingly important to recognize risks factors that may affect a patient's postoperative outcome. To determine the potential impact of tobacco as a risk factor, we evaluated postoperative pain, narcotic use, length of stay, reoperations, and compli-cations in the global 90-day episode of care for patients undergoing anatomic total shoulder arthroplasty (TSA) who were current tobacco users, former users, or nonusers.

**Methods:** Database search identified 163 patients with primary anatomic TSA done for glenohumeral ar-thritis; these were divided into 3 groups: current tobacco users (28), nonusers (88), and former users (47). All surgeries were done with the same technique and implants.

**Results:** Patients in the current tobacco use group had significantly higher visual analog scale scores pre-operatively and at 12 weeks postoperatively than nonusers and former users. Mean improvement in visual analog scale scores was significantly less in current tobacco users. Cumulative oral morphine equivalent use at 12 weeks was significantly higher in current tobacco users than in nonusers and former users. The average oral morphine equivalent per day was also significantly higher in the current tobacco users than in nonusers and former users. There were no significant differences in length of stay or complications.

**Conclusions:** Although length of stay, complication rates, hospital readmissions, and reoperation rates were not significantly different, tobacco users reported increased postoperative pain and narcotic use in the global period after TSA. Former tobacco users were found to have a postoperative course similar to that of nonusers, suggesting that discontinuation of tobacco use can improve a patient's episode of care performance after TSA.

**Level of evidence:** Level III; Retrospective Cohort Design; Treatment Study





**Keywords:** Total shoulder arthroplasty; 90-day episode of care; tobacco use; outcomes; complications; postoperative pain



**Daniel B. Wells, MD[1]**
**Andrew M. Holt, MD[1]**
**Richard A. Smith, PhD[1]**
**Tyler J. Brolin, MD[1]**
**Frederick M. Azar, MD[1]**
**Thomas W. Throckmorton, MD[1]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery
& Biomedical Engineering
Memphis, Tennessee

**Corresponding author:**

Thomas W. Throckmorton, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
tthrockmorton@campbellclinic.com


The demand for primary total shoulder arthroplasty (TSA) has been steadily increasing during the last decade, and projections based on the Nationwide Inpatient Sample suggest this trend is likely to continue.[8,17,25] TSA has been shown to provide predictable pain relief and postoperative outcomes, with reports of long-term survival and satisfaction rates ranging from 87% to 95%.[23,24] Whereas there is an abundance of data supporting the use of TSA in the treatment of advanced glenohumeral arthritis, studies investigating patient-specific risk factors, including tobacco use, that may predict early post-operative outcomes are lacking.

Tobacco use has been shown to be a major risk factor for the development of postoperative complications in elective orthopedic surgery.[22] In the total hip and knee arthroplasty literature, multiple studies have shown that patients who use tobacco are at an increased risk for both wound complications and deep infections.[9,18,19,30,31] Not only are patients undergoing elective joint surgery at an increased risk for wound complications and infections,


* Reprinted with permission, J. Shoulder Elbow Surg 2018 Jan;27(1):23 -28. doi: 10.1016/jse.2017.06.033. Epub 2017 Jul 24.

they also are at risk for adverse functional outcomes that require revision surgery.[30] Wound complications, infections, and revision surgery lead to decreased patient satisfaction and increased hospital readmissions.[5,29] Surgical complications after joint arthroplasty leading to hospital readmissions have been shown to significantly increase costs to the health systems, with a re-ported average of $36,038 for total hip arthroplasty readmissions and $27,979 for total knee arthroplasty readmissions.[5]

During the past decade, increased attention has been directed toward the economic aspects of patient care. In particular, emphasis has been placed on providing the best possible care for the least possible cost, the so-called value equation.[27,28] This is particularly relevant because rates of shoulder arthroplasty are increasing by approximately 9.4% per year.[8] In response, payors have shifted from the traditional fee-for-service model of medicine toward one of value-based care. This often takes the form of bundled payment plans, whereby 90-day global costs of care are covered by a single payment, with the increased cost burden associated with any adverse events leading to decreased value of the procedure. This protocol establishes incentives for surgeons to provide high-quality, cost-effective care. During this same time, some payors have begun to transition to a system that either financially rewards or penalizes health care providers on the basis of subjective patient-reported outcomes. Recognizing risk factors that have the potential to increase cost burden and to decrease the value of procedures is especially relevant in the evolution of these payment models.

In an effort to determine the effects of tobacco as a potential risk factor for both decreased patient-reported outcomes and increased cost burden, we evaluated postoperative pain, narcotic use, length of stay, reoperations, and complications in the global 90-day episode of care for patients who had an-atomic TSA and who were current tobacco users, former tobacco users, or nonusers.

## MATERIALS AND METHODS

A database search identified patients with a diagnosis of glenohumeral arthritis who were treated with primary anatomic TSA; those with hemiarthroplasties, reverse TSAs, and revision TSAs were excluded. Others excluded were patients lost to follow-up and patients with incomplete medical records. All patients had radiographic and clinical indications for TSA, and nonoperative management had failed to relieve their symptoms.

There were no differences in surgical technique among the current tobacco users, nonusers, and former tobacco users. All procedures were done with the patient in the beach chair position under general anesthesia. After a standard deltopectoral approach, a biceps tenodesis and subscapularis tenotomy were done before release of the inferior capsule and dislocation of the humeral head. After final implant insertion, all shoulders exhibited appropriate head height, version, motion, and stability. The subscapularis and rotator intervals were closed with heavy nonabsorbable suture.

Patients who had TSA before February 2014 received an interscalene nerve block for postoperative pain control; after that time, an intraoperative periarticular injection consisting of liposomal bupivacaine, bupivacaine with epinephrine, and ketorolac was used. This standardized injection was placed in the deltoid, pectoralis major, and soft tissues around the incision. These interventions were supplemented with intravenous and oral narcotic medications as needed.

A standardized postoperative rehabilitation protocol consisted of sling immobilization and passive range of motion for the first 6 weeks. During postoperative weeks 6 through 12, patients began using the extremity for gentle activities in front of the body and continued passive range of motion in physical therapy. Isometric strengthening was initiated at 10 weeks, with unrestricted use of the arm allowed at 12 weeks.

Patients were identified as current tobacco users, nonusers, or former users by health history on intake forms and clinical interview. Former tobacco users were defined as patients who reported cessation of tobacco use longer than 3 months before their initial surgical evaluation. Visual analog scale (VAS) scores for pain were recorded at the preoperative visit and at 2-, 6-, and 12-week visits after surgery. Oral morphine equivalents (OMEs) were recorded for in-hospital use, discharge medications, and prescriptions given at 2-, 6-, and 12-week visits. This was complemented by query of a statewide narcotic prescriptions database. Hospital and clinic medical records were reviewed retrospectively to collect data pertaining to patient-specific demographics, complications, reoperations, length of stay, and hospital readmissions.

Statistical analyses for preoperative and postoperative measurements were performed using Student t-tests and analysis of variance, with $p < .05$ considered statistically significant.

| Characteristic | Current tobacco users | Nonusers | Former users |
|---|---|---|---|
| Age (y) | 57.4 (37-77) | 61.8 (33-80) | 64.5 (33.94) |
| Sex | 11 M, 17 F | 49 M, 39 F | 22 M, 25 F |
| Extremity | 15 L, 13 R | 36 L, 52 R | 21 L, 26 R |
| Body mass index | 30.7 (20.9-50.1) | 34.2 (19-55.7) | 31 (19-42) |
| Diabetes | 5 | 18 | 7 |
| CVA | 3 | 5 | 1 |
| CAD | 4 | 12 | 6 |
| Mood disorder | 11 | 19 | 10 |
| Renal disease | 1 | 2 | 2 |
| OSA | 5 | 21 | 7 |
| **Operative indications** | | | |
| Osteoarthritis | 24 | 78 | 45 |
| Inflammatory arthritis | 3 | 4 | 1 |
| Post-traumatic arthritis | 1 | 4 | 0 |
| Postcapsulorrhaphy arthritis | 0 | 2 | 1 |

CAD, coronary artery disease; CVA, cerebrovascular accident; OSA, obstructive sleep apnea.

**Table 1:** Patient characteristics

## RESULTS

Of the 163 patients with primary TSAs identified, 28 were current tobacco users, 88 were nonusers, and 47 were former users. An interscalene nerve block was used in 18 current tobacco users, 56 nonusers, and 39 former users. An injected periarticular liposomal bupivacaine mixture was used in 10 current tobacco users, 32 nonusers, and 8 former users. There was no statistical difference in the percentage of patients receiving an interscalene block between the tobacco-use group and the no-use and former-use groups (p = 1.0 and p = .09, respectively), and there were no differences in VAS or OME use between patients who had interscalene blocks and those who had periarticular injections. There were also no statistically significant differences among the groups regarding sex, operative indication, comorbidities, laterality, or body mass index. Patients in the tobacco-use group were on average younger compared with the no-use and former-use groups **(Table 1)**.

Patients in the current-use group had significantly higher VAS scores both preoperatively and at 12 weeks postoperatively compared with the no-use and former-use cohorts (p < .001 and p < .001, respectively) **(Fig. 1)**. At 12 weeks postoperatively, VAS scores decreased from 7.1 to 4.3 (p < .001) in the tobacco-use group, 5.8 to 1.8 (p < .001) in the no-use group, and 5.8 to 1.5 (p < .001) in the former-use group. The mean improvement in VAS was significantly less in the current-use cohort as well (2.8 vs. 4 and 4.3; p < .02) compared with both the no-use and former-use groups.

Cumulative OME use at 12 weeks was significantly

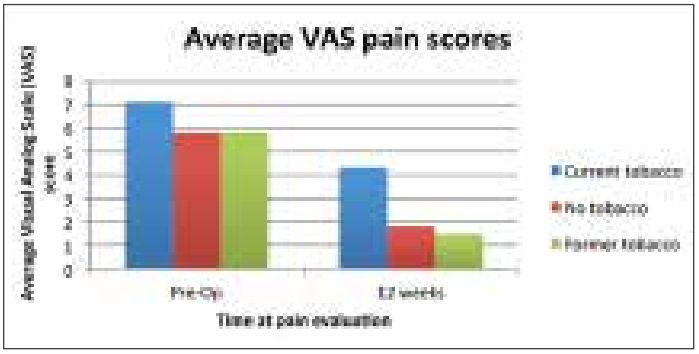



**Figure 1:** Comparison of visual analog scale (VAS) scores preoperatively and at 12 weeks.

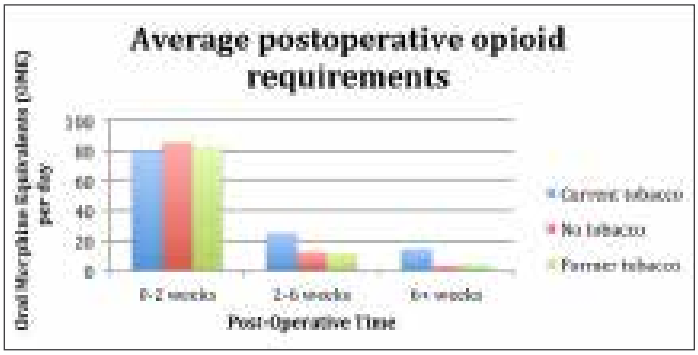



**Figure 2:** Comparison of postoperative opioid requirements.

higher in the current-use group compared with nonusers and former users (2348 mg vs. 1637 mg and 1623 mg; $p < .003$). The average OME per day also was significantly higher in the current-use group compared with the no-use and former-use groups ($p < .003$) **(Fig. 2)**.

Length of stay was not significantly different among the three groups; however, there was a trend toward longer length of stay for the current-use group compared with the former-use group (1.21 days vs. 0.95 days; $p = .08$). No statistically significant differences were found between the current-use group and the other two cohorts regarding complications (18% vs. 11% and 8%; $p = .35$ and $p = .28$). There were no complications requiring reoperations or hospital readmissions in the 90-day postoperative period in any group **(Table 2)**.

## DISCUSSION

In the United States, approximately 17% of the gross domestic product is derived from health care expenditures.[10,32] Not only do health care expenditures represent a larger portion of the gross domestic product in the United States than in any other developed nation, their rate of growth is increasing at a pace higher than the rate of inflation.[1,21,33] As a result, during the past several years, the U.S. Secretary of Health and Human Services has begun implementing a strategy to shift the health care industry toward a system in which providers are reimbursed on the basis of quality vs. quantity, placing an increased interest in value-based care.[34]

With total joint arthroplasty accounting for 5.7% of yearly Medicare expenditures, it represents the single largest outlay among Medicare beneficiaries and, as such, has been an early target for this shift toward value-based care.[6,7] In 2013, the Centers for Medicare and Medicaid Services implemented the Bundled Payments for Care Improvement initiative.[3] The Bundled Payments for Care Improvement initiative was designed to improve health care delivery and to decrease costs by allowing providers to enter into prenegotiated payment arrangements that include financial and performance account-ability for a clinical episode in which a risk-and-reward calculus must be determined.[10] As alternative payment structures, such as bundled payment models, continue to develop, it is becoming increasingly more important to recognize risk factors that could lead to higher cost episodes of care.

We evaluated patients in a 90-day period, which corresponds to the Centers for Medicare and Medicaid Services timeline of an episode of care.[4] Patients who used tobacco experienced significant increases in both VAS scores and OME use at 2-week, 6-week, and 12-week intervals compared with nonusers and previous users of tobacco. There also was a trend toward longer length of stay for the tobacco-use group compared with former users. Whereas the financial impact of such measures is beyond the scope of this study, their implications should be considered in examining the overall impact on the health care delivery system.

In this study, former tobacco users were found to have postoperative outcomes similar to those of nonusers. This finding is of particular interest in that it identified a risk factor that is modifiable. Previous studies have identified risk factors such as diabetes, obstructive sleep apnea, congestive heart failure, renal failure, age, female sex, and chronic pulmonary disease that lead to increased hospital stays, readmissions, complications, and thus an increased cost burden.[2,11,12,20,26,35] Recognizing tobacco use as a modifiable risk factor is important because it allows improved preoperative counseling. It is possible that through smoking cessation, patients may achieve decreased perceived pain as well as decreased consumption of narcotic pain medication postoperatively.

Overall, tobacco use appears to create a more difficult episode of care. Although there were no statistically significant differences in length of stay or complications, these were both higher in current tobacco users, suggesting that they consume more perioperative resources than nonusers and former users. Recognizing risk factors that can potentially contribute to more difficult episodes of care is important not only for the potential direct financial implications associated with increased perioperative resource consumption but also because, in the future, payment structures could be directly tied to subjective patient outcomes as measured by satisfaction scores and perceived pain. This is highlighted in multiple studies that have shown a direct correlation between increased pain and decreased patient satisfaction.[13-16] VAS scores and OME use were significantly higher in current tobacco users, indicating a more painful postoperative course that required more postoperative resources and may have adversely affected patient satisfaction.

Whereas it is important to recognize risk factors such as tobacco use that create a more difficult episode of care, this information should not be used to discourage patients from undergoing elective TSA. Although pain

| Complication | Current tobacco users | Nonusers | Former users |
|---|---|---|---|
| Total complications | 5 (18%) | 10 (11%) | 4 (8%) |
| Infection | 0 | 0 | 0 |
| Subscapularis failure | 0 | 2 | 0 |
| Rotator cuff tear | 0 | 1 | 0 |
| Arthrofibrosis | 1 | 0 | 1 |
| Greater tuberosity fracture | 1 | 0 | 0 |
| Incisional neuroma | 1 | 2 | 0 |
| Biceps tear | 0 | 0 | 1 |
| Brachial plexopathy | 0 | 0 | 1 |
| Suture abscess | 2 | 1 | 1 |
| Glenohumeral dislocation | 0 | 1 | 0 |
| Superficial venous thrombosis | 0 | 1 | 0 |
| Biceps tendinitis | 0 | 1 | 0 |
| Superficial radial neuritis | 0 | 1 | 0 |
| Readmissions | 0 | 0 | 0 |
| Reoperations | 0 | 0 | 0 |
| Length of stay (d) | 1.21 | 1.07 | 0.95 |
| None of the differences were statistically significant. | | | |

**Table 2:** Complications

scores were higher and decreased at a lower rate in the tobacco-use group, all groups improved significantly. As these risk stratification models evolve, we believe physicians and health care systems should not be penalized financially for certain subsets of patients simply because they report lower subjective scores. At the same time, we also believe that orthopedic surgeons should not deny treatment to these patients because they may have a more difficult episode of care.

There were several limitations of this study. This study was retrospective and conducted at a single institution where all procedures were performed by a single, fellowship-trained surgeon; therefore, the results may not be generalizable to all patient populations and surgeons. The numbers, specifically in the tobacco-use group, were relatively small, and it is possible that the results may be different with a larger sample size. Another limitation is that patients were grouped into tobacco use categories based on patient-reported health questionnaires. It is possible that patients who either use tobacco currently or have previously used tobacco under-reported their use. Also, this study provided no long-term outcomes as the stated goal was to examine the episode of care metrics relevant to most bundled payment programs.

## CONCLUSION

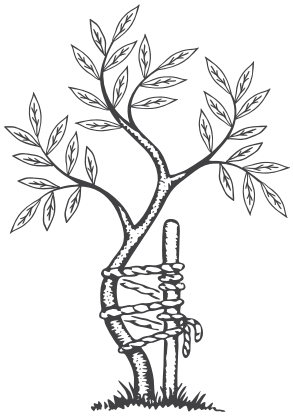
Current tobacco use is a significant predictor of increased postoperative pain and narcotic use in the global period after TSA. Although length of stay, complication rates, hospital readmissions, and reoperation rates were not significantly different, tobacco users in general re-quired more perioperative resources than nonusers or former users. As risk stratification models evolve for bundled payment plans, current tobacco use should be identified as a predictor of a more difficult postoperative course. Former tobacco users were found to have a postoperative course similar to that of nonusers, suggesting that discontinuation of tobacco use can improve a patient's episode of care performance after TSA.

## DISCLAIMER

The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

## REFERENCES


1. **Andrawis JP, Chenok KE, Bozic KJ.** Health policy implications of outcomes measurement in orthopaedics. Clin Orthop Relat Res 2013;471:3475-81. http://dx.doi.org/10.1007/s11999-013-3014-7.
2. **Belmont PJ Jr, Kusnezov NA, Dunn JC, Bader JO, Kilcoyne K, Waterman BR.** Predictors of hospital readmission after total shoulder arthroplasty. Orthopedics 2017;40:31-310. http://dx.doi.org/10.3928/ 01477447-20160915-06.
3. **Centers for Medicare and Medicaid Services.** Bundled payments for care improvement (BPCI) initiative: general information. http://innovation .cms.gov/initiatives/bundled-payments/. Accessed November 28, 2016.
4. **Centers for Medicare and Medicaid Services.** Comprehensive care for joint replacement model. https://innovation.cms.gov/initiatives/CJR. Accessed November 28, 2016.
5. **Clair AJ, Evangelista PJ, Lajam CM, Slover JD, Bosco JA, Iorio R.** Cost analysis of total joint arthroplasty readmissions in a bundled payment care improvement initiative. J Arthroplasty 2016;31:1862-5. http://dx .doi.org/10.1016/j.arth.2016.02.029
6. **Clement RC, Kheir MM, Soo AE, Derman PB, Levin LS, Fleisher LA.** What financial incentives will be created by Medicare bundled payments for total hip arthroplasty? J Arthroplasty 2016;31:1885-9. http://dx .doi.org/10.1016/j.arth.2016.02.047
7. **Cutler DM, Ghosh KN.** The potential for cost savings through bundled episode payments. N Engl J Med 2012;366:1075-7. http://dx.doi.org/ 10.1056/NEJMp1113361
8. **Day JS, Lau E, Ong KL, Williams GR, Ramsey ML, Kurtz SM.** Prevalence and projections of total shoulder and elbow arthroplasty in the United States to 2015. J Shoulder Elbow Surg 2010;19:1115-20. http://dx.doi.org/10.1016/j.jse.2010.02.009
9. **Espehaug B, Havelin LI, Engesaeter LB, Langeland N, Vollset SE.** Patient-related risk factors for early revision of total hip replacements. A population register-based case-control study of 674 revised hips. Acta Orthop Scand 1997;68:207-15.
10. **Greenwald AS, Bassano A, Wiggins S, Froimson MI.** Alternative reimbursement models: bundled payment and beyond: AOA critical issues. J Bone Joint Surg Am 2016;98:e45. http://dx.doi.org/10.2106/JBJS.15.01174
11. **Griffin JW, Hadeed MM, Novicoff WM, Browne JA, Brockmeier SF.** Patient age is a factor in early outcomes after shoulder arthroplasty. J Shoulder Elbow Surg 2014;23:1867-71. http://dx.doi.org/10.1016/j. jse.2014.04.004
12. **Griffin JW, Novicoff WM, Browne JA, Brockmeier SF.** Obstructive sleep apnea as a risk factor after shoulder arthroplasty. J Shoulder Elbow Surg 2013;22:e6-9. http://dx.doi.org/10.1016/j.jse.2013.06.003
13. **Hamilton DF, Lane JV, Gaston P, Patton JT, Macdonald D, Simpson AH, et al.** What determines patient satisfaction with surgery? A prospective cohort study of 4709 patients following total joint replacement. BMJ Open 2013;3:http://dx.doi.org/10.1136/bmjopen-2012 -002525
14. **Hanna MN, González-Fernández M, Barrett AD, Williams KA, Pronovost P.** Does patient perception of pain control affect patient satisfaction across surgical units in a tertiary teaching hospital? Am J Med Qual 2012;27:411-6. http://dx.doi.org/10.1177/1062860611427769
15. **Jacobs CA, Morris BJ, Sciascia AD, Edwards TB.** Comparison of satisfied and dissatisfied patients 2 to 5 years after anatomic total shoulder arthroplasty. J Shoulder Elbow Surg 2016;25:1128-32. http://dx.doi.org/ 10.1016/j.jse.2015.12.001
16. **Jibodh SR, Kandil AO, Malchau H, Estok DM 2nd.** Do commonly reported outcome measures reflect patient satisfaction after revision hip arthroplasty? J Arthroplasty 2010;25:41-5. http://dx.doi.org/10.1016/j. arth.2008.10.016
17. **Kim SH, Wise BL, Zhang Y, Szabo RM.** Increasing incidence of shoulder arthroplasty in the United States. J Bone Joint Surg Am 2011;93:2249-54. http://dx.doi.org/10.2106/JBJS.J.01994
18. **Lübbeke A, Rothman KJ, Garavaglia G, Barea C, Christofilopoulos P, Stern R, et al.** Strong association between smoking and the risk of revision in a cohort study of patients with metal-on-metal total hip arthroplasty. Orthop Res 2014;32:762-8. http://dx.doi.org/10.1002/jor.22603
19. **Meldrum RD, Wurtz LD, Feinberg JR, Capello WN.** Does smoking affect implant survivorship in total hip arthroplasty? A preliminary retrospective case series. Iowa Orthop J 2005;25:17-24.
20. **Menendez ME, Baker DK, Fryberger CT, Ponce BA.** Predictors of extended length of stay after elective shoulder arthroplasty. J Shoulder Elbow Surg 2015;24:1527-33. http://dx.doi.org/10.1016/j.jse.2015.02.014
21. **Mitka M.** Growth in health care spending slows, but still outpaces rate of inflation. JAMA 2009;301:815-6. http://dx.doi.org/10.1001/jama .2009.85
22. **Møller AM, Pedersen T, Villebro N, Munksgaard A.** Effect of smoking on early complications after elective orthopaedic surgery. J Bone Joint Surg Br 2003;85:178-81. http://dx.doi.org/10.1302/0301-620X.85B2.13717
23. **Neer CS 2nd, Watson KC, Stanton FJ.** Recent experience in total shoulder replacement. J Bone Joint Surg Am 1982;64:319-37.
24. **Norris TR, Lannotti JP.** Functional outcome after shoulder arthroplasty for primary osteoarthritis: a multicenter study. J Shoulder Elbow Surg 2002;11:130-5. http://dx.doi.org/10.1067/mse.2002.121146
25. **Padegimas EM, Maltenfort M, Lazarus MD, Ramsey ML, Williams GR, Namdari S.** Future patient demand for shoulder arthroplasty by younger patients: national projections. Clin Orthop Relat Res 2015;473:1860-7. http://dx.doi.org/10.1007/s11999-015-4231-z
26. **Ponce BA, Menendez ME, Oladeji LO, Soldado F.** Diabetes as a risk factor for poorer early postoperative outcomes after shoulder arthroplasty. J Shoulder Elbow Surg 2014;23:671-8. http://dx.doi.org/10.1016/j.jse .2014.01.046
27. **Porter ME.** What is value in health care? N Engl J Med 2010;363:2477-81. http://dx.doi.org/10.1056/NEJMp1011024
28. **Porter ME, Teisberg EO.** Redefining health care: creating value-based competition on results. Boston: Harvard Business School Press; 2006 Available at: http://www.hbs.edu/faculty/Publication%20Files/ 20060502%20NACDS%20-%20Final%20 05012006%20for%20On%20Point_db5ede1d-3d06-41f0-85e3-c11658534a63.pdf. Accessed June 12, 2017.
29. **Scott CE, Oliver WM, MacDonald D, Wade FA, Moran M, Breusch SJ.** Predicting dissatisfaction following total knee arthroplasty in patients under 55 years of age. Bone Joint J 2016;98-B:1625-34. http://dx.doi.org/10.1302/0301-620X.98B12.BJJ-2016-0375.R1
30. **Singh JA, Houston TK, Ponce BA, Maddox G, Bishop MJ, Richman J, et al.** Smoking as a risk factor for short-term outcomes following primary total hip and total knee replacement in veterans. Arthritis Care Res (Hoboken) 2011;63:1365-74. http://dx.doi.org/10.1002/acr.20555
31. **Singh JA, Schleck C, Harmsen WS, Jacob AK, Warner DO, Lewallen DG.** Current tobacco use is associated with higher rates of implant revision and deep infection after total hip or knee arthroplasty: a prospective cohort study. BMC Med 2015;13:283. http://dx.doi.org/ 10.1186/s12916-015-0523-0
32. **The Commonwealth Fund.** Why not the best? Results from the National Scorecard on U.S. health system performance, 2011. http://www.commonwealthfund.org/publications/fund-reports/2011/oct/why-not-the-best-2011. Accessed June 10, 2016.
33. **The Commonwealth Fund.** US spends far more for health care than 12 industrialized nations, but quality varies. http://www.commonwealthfund .org/News/News-Releases/2012/May/US-Spends-Far-More-for-Health-Care-Than-12-Industrialized-Nations-but-Quality-Varies .aspx. Accessed July 14, 2016.
34. **U.**S. Department of Health and Human Services. Better, smarter, healthier: in historic announcement, HHS sets clear goals and timeline for shifting Medicare reimbursements from volume to value. https://wayback.archive-it.org/3926/20170127185400/https://www.hhs .gov/about/news/2015/01/26/better-smarter-healthier-in-historic-announcement-hhs-sets-clear-goals-and-timeline-for-shifting-medicare-reimbursements-from-volume-to-value.html. Accessed June 15, 2016.
35. **Westermann RW, Anthony CA, Duchman KR, Pugely AJ, Gao Y, Hettrich CM.** Incidence, causes and predictors of 30-day readmission after shoulder arthroplasty. Iowa Orthop J 2016;36:70-4.



# CAMPBELL CLINIC STAFF RESEARCH

# Is Soft Tissue Laxity Associated With Tissue Metal Concentrations After Total Knee Arthroplasty?


## ABSTRACT

**INTRODUCTION:** Long-term implant durability and successful outcomes following primary total knee arthroplasty (TKA) are believed to be dependent on implant-specific factors as well as surgical factors including: proper alignment of the components, proper patellar tracking, and recreation of equally balanced soft tissues and gaps in flexion and extension[1-3]. While excessive ligamentous laxity has been reported to increase anterior-posterior translation and internal-external rotation which increased polyethylene wear in a primary TKA [4-7], there is a paucity of literature evaluating the relationship between joint laxity and metallic wear debris production following TKA. The objective of this study was to determine the relationship between cobalt (Co), chromium (Cr), and titanium (Ti) concentrations in periprosthetic tissue and the laxity of the joint.

**METHODS:** After obtaining approval from the institutional review board, 15 cadaveric specimens with primary TKAs were collected as part of a multi-institutional implant retrieval program. Fluoroscopy imaging of all specimens was performed to determine if osteolysis was present; all implants were determined to be well-fixed with no radiolucent lines seen in any implant interface. Each specimen was mounted into a custom knee testing machine, and the anterior-posterior displacement, varus-valgus deflection, and internal-external rotation was tested at 0˚, 30˚, 60˚, and 90˚ of flexion. Tissue samples were collected from the medial and lateral gutters, the supra- and infra-patellar regions, and along the tibia-implant interface. Each of these tissue samples were digested using a modified method from Kerger et al [8]. The digestion was validated using the Luts-1 certified references from the national research council of Canada. Inductively coupled plasma mass spectrometry (ICP-MS) analysis was performed to measure the Co, Cr, and Ti concentrations in the periprosthetic tissue. Spearman rank correlations were performed to determine if a significant correlation ($p < 0.05$) existed between soft tissue laxity and tissue metal concentrations.

**RESULTS:** Median metal concentrations were as follows—Co: 23.3 µg/l (IQR: 47.8); Cr: 38.4 µg/l (IQR: 80.2); and Ti: 9.6 µg/l (IQR: 32.3). One specimen presented with metallosis as indicated by tissue discoloration **(Fig. 1)**; this specimen had extremely elevated Co (28,700 µg/l) and Cr (66,500 µg/l) concentrations. At 0˚ flexion, decreased posterior displacement was negatively correlated with elevated Co ($\rho = -0.72$, $p = 0.02$) and Cr concentrations ($\rho = -0.61$, $p = 0.05$). At 30˚ flexion, decreased external rotation was correlated with elevated Ti concentrations ($\rho = -0.63$, $p = 0.02$). Additionally, decreased varus laxity was negatively correlated with increased Ti concentrations at 30˚ flexion ($\rho = -0.63$, $p = 0.02$). At 60˚ flexion, decreased anterior displacement was negatively correlated with elevated tissue Cr concentrations ($\rho = -0.63$, $p = 0.03$). Additionally, decreased varus laxity was negatively correlated with increased Ti concentrations at 60˚ flexion ($\rho = -0.56$, $p = 0.05$). At 90˚ flexion, decreased anterior displacement was negatively correlated with elevated tissue Co ($\rho = -0.75$, $p = 0.02$) and Cr ($\rho = -0.81$, $p = 0.01$) concentrations.



**Meredith Perkins, BS[2]**
**Julie Lowell, BS[2]**
**Reed Butler[2]**
**Christina Arnholt, MS[3]**
**Joshua B. White[4]**
**Anita Kerkhof, RN[1,2]**
**Daniel MacDonald, MS[3]**
**Steven M. Kurtz, PhD[3,4]**
**William M. Mihalko, MD, PhD[1,2]**

[1] University of Tennessee-Campbell Clinic Department of Orthopaedic Surgery & Biomedical Engineering Memphis, Tennessee

[2] University of Tennessee Health Science Center Memphis, Tennessee

[3] Drexel University Philadelphia, Pennsylvania

[4] Exponent Inc. Philadelphia, Pennsylvania

**Corresponding author:**

William M. Mihalko, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
wmihalko@campbellclinic.com

**DISCUSSION:** To the author's knowledge, this is the first study to investigate the relationship between soft tissue laxity and periprosthetic tissue metal concentrations. Measurable concentrations of Co, Cr, and Ti were detected by ICP-MS in the periprosthetic tissues of specimens with primary TKA without any radiographic signs of implant loosening. This study suggests that laxity and metal debris generation are inversely related such that decreased ligament laxity may induce increased metal wear. Because intraoperative soft tissue balancing is subjective, based on the surgeon's feel and experience, surgeons should be aware that decreased laxity may increase metallic debris which may have implications in the etiology of TKA failure.

**Figure 1:** Necropsy specimen presenting with severe metallosis

## REFERENCES


1. **Potty A, Tzeng T, Sams J, Lovell M, Mihalko W, Thompson K, et al.** Diagnosis and management of intra-articular causes of pain after total knee arthroplasty. Instr Course Lect. 2015;64:389-401.
2. **Manning B, Lewis N, Tzeng T, Saleh J, Potty A, Dennis D, et al.** Diagnosis and management of extra-articular causes of pain after total knee arthroplasty. Instr Course Lect. 2015;64:381-8.
3. **Callaghan J, O'rourke M and Saleh K.** Why knees fail: lessons learned. J Arthroplasty. 2004;19:31.
4. **Lim H-A, Song E-K, Seon J-K, Park K-S, Shin Y-J and Yang H-Y.** Causes of aseptic persistent pain after total knee arthroplasty. Clin Orthop Surg. 2017;9:50-6.
5. **Kawanabe K, Clarke IC, Tamura J, Akagi M, Good VD, Williams PA, et al.** Effects of A–P translation and rotation on the wear of UHMWPE in a total knee joint simulator. J Biomed Mater Res A. 2001;54:400-6.
6. **McEwen H, Barnett P, Bell C, Farrar R, Auger D, Stone M, et al.** The influence of design, materials and kinematics on the in vitro wear of total knee replacements. J Biomech. 2005;38:357-65.
7. **Kretzer JP, Jakubowitz E, Sonntag R, Hofmann K, Heisel C and Thomsen M.** Effect of joint laxity on polyethylene wear in total knee replacement. J Biomech. 2010;43:1092-6.
8. **McEwen H, Fisher J, Goldsmith A, Auger D, Hardaker C and Stone M.** Wear of fixed bearing and rotating platform mobile bearing knees subjected to high levels of internal and external tibial rotation. Journal of Materials Science: Materials in Medicine. 2001;12:1049-52.
9. **Kerger BD, Gerads R, Gurleyuk H, Urban A and Paustenbach DJ.** Total cobalt determination in human blood and synovial fluid using inductively coupled plasma-mass spectrometry: method validation and evaluation of performance variables affecting metal hip implant patient samples. Toxicol Environ Chem. 2015;97:1145-63.

# Is Topical TXA Effective in Hybrid Fixation Total Knee Arthoplasty?


## ABSTRACT

**INTRODUCTION:** Total knee arthoplasty (TKA) is an effective solution to restore function and provide pain relief for patients with end stage knee arthritis. The amount of blood loss during a total knee arthoplasty has been shown to be highly variable among patients. This variability can be attributed to many different factors such as the use of tourniquet, length of the procedure, type of implants/surgical technique and even specific patient factors (such as genetics and home medications). With increasing amount of blood loss, patients have longer hospital stays, require transfusions and have an overall increase in morbidity and mortality. Tranexamic acid (TXA), an anti-fibrolytic, has been proven to reduce blood loss and the subsequent need for blood transfusions after surgery. Majority of the TXA studies focus only on the intravenous application of TXA and its use in cemented implants. This study aims to determine the efficacy of topical TXA in reducing postoperative blood transfusions in patients who undergo hybrid fixation (press-fit femoral component and cemented tibial component). Our hypothesis is that topical TXA will be as efficacious in a hybrid fixation as compared to fully cemented fixation.

**METHODS:** A retrospective chart review was preformed at a local Veterans Administration hospital. TKA patients' records were compared for blood transfusions and pre vs post-operative hemoglobin (Hgb). Inclusion criteria for the study were patients over the age 18 undergoing a primary total knee replacement, using either fully cemented fixation or hybrid for non-traumatic end stage osteoarthritis. Patients that were excluded from this study included patients with preexisting coagulopathy disorders and chronic anemic patients (Hct less than 30 preoperatively). Patients on preexisting anticoagulation medicine (such as aspirin and warfarin) were told to hold their medication at least 5-10 days before the surgery. To help control for variations in surgical technique between surgeons, only one surgeon was studied. Selection for hybrid or fully cemented fixation was based on surgery date, when the surgeon switched from fully cemented fixation to hybrid fixation. The use of tranexamic acid was also based off the when the surgeon implemented it into his practice. Topical TXA was used after the component fixation and before fascial closure. Postoperatively, all patients had similar order sets for DVT prophylaxis and fluids resuscitation. Patients received a blood transfusion if their postoperative hemoglobin was less than 7 or if the patient became symptomatic, such as orthostatic hypotension. Fischer's Exact test was used for analysis.

**RESULTS:** 139 patients were identified for this study, 92 patients underwent hybrid fixation and 47 patients underwent fully cemented fixation. Of the 139 patients, 52 patients received topical TXA. The groups were subdivided by the fixation and TXA as shown in **Table 1**. Overall, there were no blood transfusions in the topical TXA group (0/52) and 6 patients required a transfusion in the non-TXA group(6/87); p=0.016. When taking into account fixation, the hybrid group with TXA showed no transfusions (0/32) compared to five (5/32) transfusion in the group without TXA, p = 0.035. Cemented fixation with TXA also showed no transfusions (0/20) when with to the group without TXA (1/27). When comparing differences in postoperative hemoglobin, those receiving topical TXA had a smaller decrease in change in second day post-operative Hgb (TTXA=3.25; no TXA=3.90; p=0.011).



**J. Stephen Chambers, MD[1]**
**Luke Tidwell, MS[2]**
**Anita Kerkhof, MS[1,2]**
**Richard A. Smith, PhD[2]**
**William M. Mihalko, MD, PhD[1,2]**

[1] University of Tennessee-Campbell Clinic Department of Orthopaedic Surgery & Biomedical Engineering Memphis, Tennessee

[2] University of Tennessee Health Science Center Memphis, Tennessee

**Corresponding author:**

William M. Mihalko, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
wmihalko@campbellclinic.com

| | Implant Type | | Total |
|---|---|---|---|
| | Press fit | Cemented | |
| TTXA | | | |
| Yes | 32 | 20 | 52 |
| No | 60 | 27 | 87 |
| TTXA and Transfusion | 0/32 | 0/20 | 0/52 |
| No TXA and Transfusion | 5/60 | 1/27 | 6/87 |
| Total | 92 | 47 | 139 |

**Table 1:** TTXA and Implant Type Cross-tabulation

**DISCUSSION:** For patients receiving TKA, our results show topical TXA has a statistically significant protective effect on transfusion requirements and postoperative Hgb. Previous studies have proven that topical TXA reduces the need for blood transfusion for patients undergoing cemented fixation. Our results show that topical TXA decreases the rate of blood transfusions for hybrid fixation. To our knowledge this is the only study comparing hybrid implants with and without the use of topical TXA. Larger sample size is needed to quantify how much of an impact topical TXA has on hybrid fixation compared with fully cemented.

## REFERENCES


1. **Wang, H.** Blood Loss and Transfusion After Topical Tranexamic Acid Administration in Primary Total Knee Arthroplasty, Orthopedics, 2015;38(11)
2. **Ishii Y, Noguchi H, Sato J, Tsuchiya C, Toyabe S.** Effect of a single injection of tranexamic acid on blood loss after primary hybrid TKA. Knee. 2015 Jun;22(3):197-200
3. **Fleischman M, Hood M Jr, Ziemba-Davis M, Meneghini RM.** Tranexamic Acid and Computer-Assisted Surgery in Cemented and Cementless Total KneeArthroplasty: Are the Effects Additive for Blood Conservation? Surg Technol Int. 2017 Jul 25;30:268-273.

# Establishing a Baseline for the Relationship between Inflammatory Cytokines and Tissue Metal Concentrations in Autopsy Retrieved Total Hip Implants


## ABSTRACT

**INTRODUCTION:** Total hip arthroplasty (THA) is one of the most commonly performed and successful orthopaedic procedures for the treatment of osteoarthritis of the hip with almost 300,000 THAs performed annually. While many of these operations are successful, there are approximately 40,000 revisions occurring each year [1]. As the number of revisions has risen steadily over the last 20 years and is projected to continue to do so, there is a pressing need to understand what factors are facilitating failure of the prosthetic joint [1]. This study sought to investigate the levels of inflammatory cytokines and tissue metal concentrations in specimens with well-functioning THAs retrieved at autopsy to establish a baseline for these factors so that their role in implant survivorship may be elucidated.

**METHODS:** After obtaining institution review board approval, 13 cadaveric specimens with THAs were procured as part of a multi-institutional implant retrieval program. Fluoroscopy imaging of all specimens was performed prior to implant removal to determine if osteolysis or aseptic loosening was present; only implants that were well-fixed with no osteolysis were included in the study. Synovial fluid was aspirated from the joint before removal of the implant and was analyzed using a Magnetic Luminex Screening Assay for IL-1β, IL-6, MCP-1, MIP-3α, and M-CSF. Following aspiration of the joint, tissue samples were collected from anterior, posterior, superior and inferior to the acetabulum as well as from the taper. Each of these tissue samples were digested using a modified method from Kerger et al [2]. The digestion was validated using the Luts-1 certified references from the national research council of Canada. Inductively coupled plasma mass spectroscopy analysis measured the cobalt (Co), chromium (Cr), and titanium (Ti) concentrations in the periprosthetic tissue. Spearman rank correlations were performed to determine if a significant correlation ($p < 0.05$) existed between inflammatory cytokines and tissue metal concentration.

**RESULTS:** Mean ± standard error cytokine concentrations for the 13 specimens were as follows—IL-1β: 401 ± 280 pg/mL (range 20 to 3,724); IL-6: 463 ± 128 pg/mL (range 20 to 1,180); MCP-1: 1,493 ± 678 pg/mL (range 113 to 7,940); MIP-3α: 177.1 ± 146 pg/mL (range 7.9 to 1,920); and M-CSF 50,581 ± 5,048 pg/mL (range 14,964 to 77,613). Mean ± standard error metal concentrations were as follows—Co: 1.79 ± 0.40 µg/L (range 0.26 to 4.45); Cr: 28.4 ± 14.0 µg/L (range 1.29 to 186); and Ti: 24.0 ± 20.5 µg/L (range 0 to 270). A summary of the metal concentration of each specimen with their respective stem and head material is shown in **Table 1**. No correlation existed between IL-1β or M-CSF and Co, Cr, or Ti concentrations. Elevated IL-6 was positively correlated with increased Co debris present in the periprosthetic tissues ($r_s = 0.54$, $p = 0.057$); however, no correlation was reported between IL-6 and Cr or Ti. MCP-1 was strongly correlated with increased Co levels ($r_s = 0.76$, $p = 0.01$), but no correlation existed between MCP-1 and Cr or Ti. MIP-3α was also strongly correlated with elevated Co concentrations ($r_s = 0.66$, $p = 0.02$); no correlation was revealed between MIP-3α and Cr or Ti.

**DISCUSSION:** The objective of this study was to identify if a correlation existed between periprosthetic tissue metal concentrations and inflammatory cytokines related to macrophage recruitment in synovial fluid [3-5]. As each of these specimens were well-functioning



**Julie Lowell, BS[2]**
**Meredith Perkins, BS[2]**
**Christina Arnholt, MS[3]**
**Joshua B. White[4]**
**Daniel MacDonald, MS[3]**
**Anita Kerkhof, RN[1,2]**
**Steven M. Kurtz, PhD[3,4]**
**William M. Mihalko, MD, PhD[1,2]**

[1] University of Tennessee-Campbell Clinic Department of Orthopaedic Surgery & Biomedical Engineering Memphis, Tennessee

[2] University of Tennessee Health Science Center Memphis, Tennessee

[3] Drexel University Philadelphia, Pennsylvania

[4] Exponent Inc. Philadelphia, Pennsylvania

**Corresponding author:**

William M. Mihalko, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
wmihalko@campbellclinic.com

| Sample | Head material | Stem material | Co | Cr | Ti | IL-1β | IL-6 | MCP-1 | MIP-3α | M-CSF |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | CoCr | -- | 0.29 | 3.37 | 0.00 | 3724 | 703 | -- | 11.7 | 73237 |
| 2 | CoCr | Ti alloy | 0.80 | 8.09 | 0.75 | 20.2 | 830 | 511 | 9.6 | 51919 |
| 3 | Ceramic | Ti alloy | 2.30 | 5.24 | 0.00 | 53.2 | 735 | 2177 | 15.3 | 46051 |
| 4 | CoCr | CoCr | 1.33 | 1.29 | 0.00 | 144 | 81.7 | 272 | 14.2 | 54057 |
| 5 | CoCr | Ti alloy | 4.45 | 51.2 | 1.97 | 486 | 1180 | 7940 | 1920 | 32312 |
| 6 | CoCr | CoCr | 0.54 | 24.6 | 21.2 | 130 | 27.8 | 113 | 7.9 | 52170 |
| 7 | CoCr | Ti alloy | 3.87 | 4.82 | 0.00 | 45.4 | 885 | 4244 | 122 | 33172 |
| 8 | CoCr | CoCr | 1.18 | 1.50 | 0.00 | 178 | 20.2 | 412 | 29.0 | 14964 |
| 9 | CoCr | Ti alloy | 0.39 | 1.90 | 270 | 71.0 | 91.3 | 287 | 8.5 | 62938 |
| 10 | CoCr | Ti alloy | 2.27 | 44.4 | 3.03 | 116 | 87.1 | 414 | 18.7 | 69957 |
| 11 | CoCr | CoCr | 3.69 | 32.4 | 0.00 | 129 | 1180 | 650 | 101 | 77614 |
| 12 | CoCr | Ti alloy | 2.00 | 186 | 13.1 | 63.1 | 103 | 489 | 20.5 | 34835 |
| 13 | Ceramic | Ti alloy | 0.26 | 4.46 | 1.97 | 51.1 | 93.9 | 410 | 23.9 | 54335 |

**Table 1:** Summary of head and stem material from each specimen with metal concentrations (μg/L) and inflammatory cytokine concentrations (pg/mL)

at time of autopsy with no radiographic signs of osteolysis or aseptic loosening, we did not expect to find strong correlations between the inflammatory cytokines and metallic debris. Instead, we hoped to establish a baseline of these factors to be used for future comparisons with failed implants retrieved during revision surgeries. However, when correlations were revealed, the biomarkers were tied with elevated Co concentrations suggesting that Co may play a role in the immune response to implant debris. By increasing the sample size of cadaveric specimens as well as retrieving failed implants, this study hopes to better understand the biologic response to implant debris and how it mediates failure of implants.

## REFERENCES


1. **Kurtz S, Ong K, Lau E, Mowat F, Halpern M.** Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg. 2007;89(4):780-5.
2. **Kerger BD, Gerads R, Gurleyuk H, Urban A and Paustenbach DJ.** Total cobalt determination in human blood and synovial fluid using inductively coupled plasma-mass spectrometry: method validation and evaluation of performance variables affecting metal hip implant patient samples. Toxicol Environ Chem. 2015;97:1145-63.
3. **Cobelli N, Scharf B, Crisi GM, Hardin J, Santambrogio L.** Mediators of the inflammatory response to joint replacement devices. Nat Rev Rheumatol. 2011;7(10):600.
4. **Lee SH, Brennan FR, Jacobs JJ, Urban RM, Ragasa DR, Glant TT.** Human monocyte/macrophage response to cobalt-chromium corrosion products and titanium particles in patients with total joint replacements. Journal of orthopaedic research. 1997;15(1):40-9.
5. **Nivbrant B, Karlsson K, and Kärrholm J.** Cytokine levels in synovial fluid from hips with well-functioning or loose prostheses. J Bone Joint Surg Br. 1999;81(1):163-166.

# Inflammatory Cell-Induced Corrosion in Total Knee Replacements


## ABSTRACT

**Introduction:** Cobalt chromium alloys are widely used in total knee arthroplasties (TKAs). Recently, a new type of damage has been investigated in CoCr femoral components termed "inflammatory cell-induced corrosion" (ICIC). Metal debris is believed to bring about an immune response in some patients leading to inflammatory cells directly attacking the metal surface. An alternative theory for this unique corrosion pattern is that the cause is due to electrocautery damage from revision surgeries. This study aims to examine the unique corrosive patterns found on implants to shed some light on the issue and determine if ICIC is truly the cause.

**Methods:** Following institution review board approval, four cadaveric primary total knee arthroplasty specimens were obtained. A Keyence microscope was utilized to identify areas of interest indicative of ICIC-like damage. Microscopic analysis of the four implants was performed using a scanning electron microscope (SEM). High kV backscattering imaging (BEC) is used to examine the corroded regions on the implant. Energy dispersive X-ray spectrometry (EDS) is used to analyze the elemental compositions at various points using points in the non-corroded as a baseline for comparison.

**Results:** SEM and EDS results are shown in **Figure 1** for two points among two of the implants. Frosted regions can be seen made up of fine pits and streaks. Circular regions can be observed consisting of small pits and crater-like features. These areas are believed to be caused by individual cell attacks on the surface. Elemental analysis revealed high concentrations of carbon and salts in these areas, as well as varying iron concentrations in specific regions.

**Conclusion:** EDS has indicated that all four implants have signs of cellular remnants and biological materials. The pits containing these materials vary from 10-20 μm, which correlates with the size of inflammatory cells. Evidence of ICIC is further supported by what looks like a migration path of the cell as it was corroding the surface in **Figure 1a**. Iron is known to be a fundamental component in phagocytic cells. The iron remnants could also suggest a Fenton-like reaction occurring. Further investigation should take place to compare these corroded regions with those left from an electrocautery tool. The likelihood of actual contact between the implant and the electrocautery tool should also be examined in comparison with how prevalent this type of damage is seen among implants.



**Griffin Heise[2,3]**

**Meredith Perkins, BS[2,3]**

**Brian Morrow[2]**

**William M. Mihalko, MD, PhD[1,2]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery &
Biomedical Engineering
Memphis, Tennessee

[2] University of Tennessee Health Science Center
Memphis, Tennessee

[3] University of Memphis
Memphis, Tennessee

**Corresponding author:**

William M. Mihalko, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
wmihalko@campbellclinic.com


## REFERENCES


1. **Gilbert, Jeremy L.**, et al. "Direct in vivo inflammatory cell-induced corrosion of CoCrMo alloy orthopedic implant surfaces." Journal of Biomedical Materials Research Part A 103.1 (2015): 211-223.
2. **Di Laura, Anna, et al.** "Clinical relevance of corrosion patterns attributed to inflammatory cell-induced corrosion: A retrieval study." Journal of Biomedical Materials Research Part B: Applied Biomaterials 105.1 (2017): 155-164.
3. **Cerquiglini, Arianna, et al.** "Inflammatory cell-induced corrosion in total knee arthroplasty: a retrieval study." Journal of Biomedical Materials Research Part B: Applied Biomaterials 106.1 (2018): 460-467.
4. **Yuan, Nathaniel, et al.** "Revisiting the concept of inflammatory cell-induced corrosion." Journal of Biomedical Materials Research Part B: Applied Biomaterials (2017).
5. **Kubacki, Gregory W.**, Shiril Sivan, and Jeremy L. Gilbert. "Electrosurgery Induced Damage to Ti-6Al-4V and CoCrMo Alloy Surfaces In Orthopedic Implants In Vivo and In Vitro." The Journal of Arthroplasty (2017).

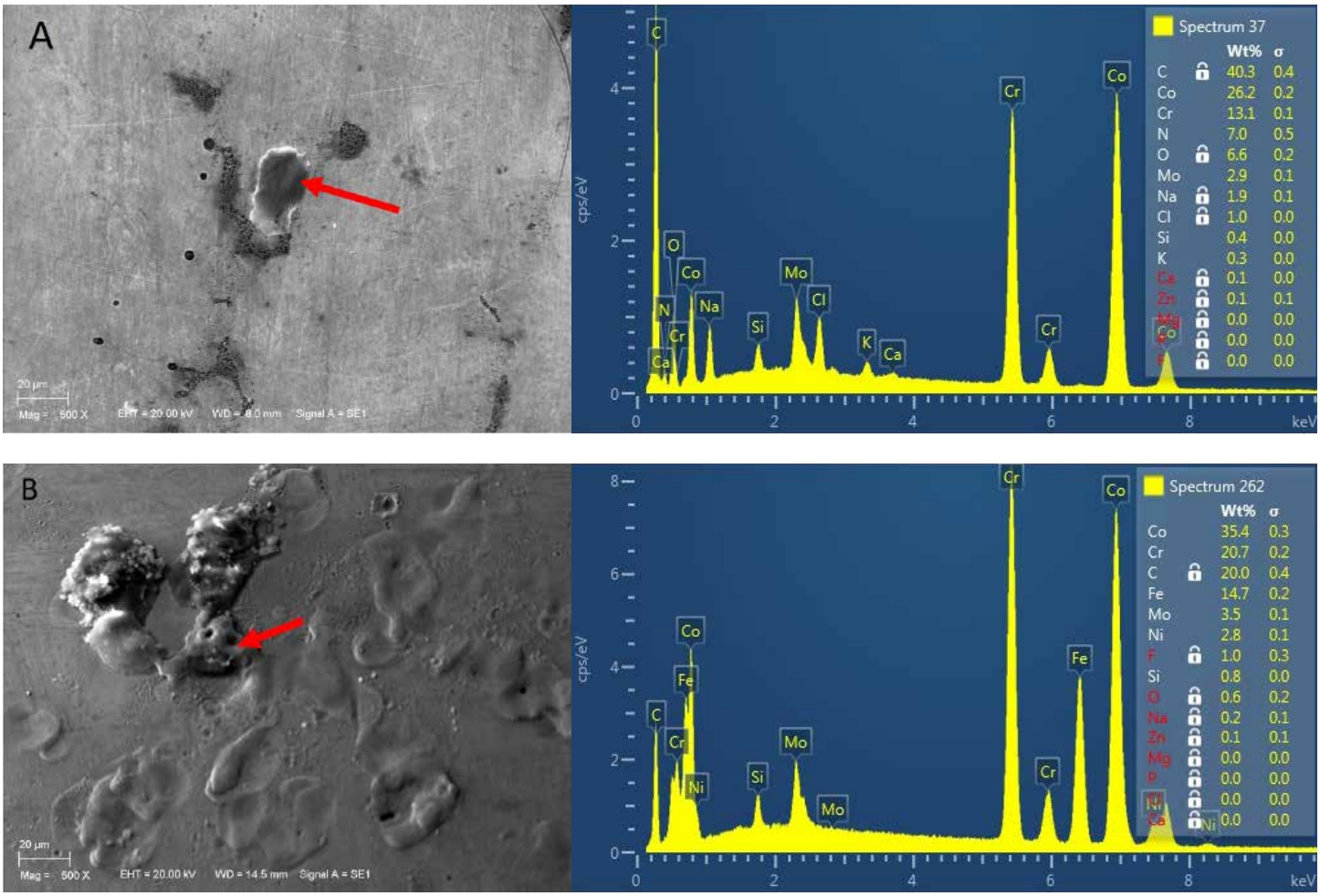



**Figure 1:** BEC and EDS results among two separate points showing ICIC damage

# Intermediate-Term Outcomes of Intramedullary Total Ankle Arthroplasty

**Jane C. Yeoh, MD[1]**
**G. Andrew Murphy, MD[2]**
**David R. Richardson, MD[2]**
**Benjamin J. Grear, MD[2]**
**Brandon A. Taylor, MD[3]**
**J. Stephen Chambers, MD[2]**

[1] University of British Columbia
Department of Orthopedics
Vancouver BC, Canada

[2] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery &
Biomedical Engineering
Memphis, Tennessee

[3] Palm Harbor
Orthopedic Specialist
Palm Harbor, FL

## ABSTRACT

**Introduction:** Currently, third-generation total ankle arthroplasty (TAA) and ankle arthrodesis are both regarded as appropriate treatment for end-stage ankle arthritis for which conservative management has failed. This study retrospectively examined intermediate-term outcomes of intramedullary TAA done by a group of subspecialty-trained foot and ankle surgeons.

**Methods:** We retrospectively assessed intramedullary TAA (INBONE I and INBONE II, Wright Medical Technology, Inc., Memphis TN) implanted between October 2008 and April 2015 with ≥2 years follow-up. Preoperative (baseline), intraoperative, and postoperative data were collected, including demographic and patient health information (age, gender, body mass index (BMI), smoking status, comorbidities), American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Scale, Visual Analog Scale (VAS) for pain, and preoperative radiographic Canadian Orthopaedics Foot and Ankle Society (COFAS) classification4. Intraoperative information included procedures performed, implants placed, tourniquet time, and intraoperative complications. Postoperative information included major or minor complications, revision or impending revision, additional surgeries, range of motion, and radiographic complications or findings. Standard weight-bearing anteroposterior, mortise, and lateral radiographs of the ankle were reviewed by 2 foot and ankle fellowship-trained orthopaedic surgeons.

**Results:**

**Preoperative / Baseline**

Of 75 intramedullary TAAs, 45 (42 patients) had ≥2 year follow-up. Twenty-five patients were female and 17 were male. Average BMI was 31.1 ± 5.8 kg/m2. Average preoperative VAS was 7.1 / 10 and preoperative AOFAS Ankle-Hindfoot scale was 43 / 100. Eleven ankles (24%) had a non-inflammatory arthritis, 9 (20%) had inflammatory arthritis, and 28 (62%) had post-traumatic arthritis (3 had both post-traumatic and inflammatory etiologies). Seven ankles (16%) had valgus ankle arthritis in combination with stage 4 posterior tibial tendon insufficiency or adult flatfoot deformity, 4 (8.9%) had varus ankle arthritis in combination with a cavovarus foot deformity, and 3 (6.7%) had clinical and/or radiographic evidence of talar osteonecrosis. There were 16 (36%) COFAS type 1, 9 (20%) type 2, 3 (6.7%) type 3 and 17 (38%) type 4 ankle arthritis.

**Intraoperative**

Eight INBONE I and 37 INBONE II TAAs were implanted. A total of 64 concomitant procedures were performed. There was one intraoperative complication (EHL laceration repaired primarily). Average tourniquet time was 113 minutes (range 70 to 135 minutes).

**Postoperative**

Average follow-up was 39 months (24 to 96 months). To date, there are no TAA explants or revisions, no polyethylene exchange, no periprosthetic or deep infections, and no major medical complications. There was 1 hospital readmission for periprosthetic fracture. Sev-

**Corresponding author:**

Jane C. Yeoh, MD
University of British Columbia
Department of Orthopaedics
2775 Laurel Street, 11th Floor
Vancouver, BC V5Z 1M9, Canada
P: 604-616-7192
janeyeoh@gmail.com

enteen of 45 ankles (38%) had 20 postoperative major or minor complications; 2 patients required non-revision reoperations. Seventeen complications were minor and did not require reoperation or additional procedures. There was no radiographic malalignment of components (>5° varus or valgus or >5° flexion or extension). Three ankles with periprosthetic osteolysis have been managed thus far with close observation. One ankle with large periprosthetic osteolysis (>10 mm diameter) was treated with bone grafting and retention of the stable TAA implant.

**Discussion and Conclusion:** Our study population had an implant survival rate of 98% (1 below knee amputation), non-revision reoperation rate of 4.4%, and no revision reoperations to date. Our complication rate (38%) is comparable with other studies of this intramedullary TAA implant with comparable follow-up durations.1-3 A significant portion of TAAs were classified as complex and performed with concomitant procedures for adjacent joint arthritis and deformity correction.

## REFERENCES


1. **Adams Jr SB.** Demetracopoulos CA, Queen RM, Easley ME, DeOrio JK, Nunley JA. Early to mid-term results of fixed-bearing total ankle arthroplasty with a modular intramedullary tibial component. J Bone Joint Surg Am 2014; 96(23): 1983-1989.
2. **Hsu AR, Haddad SL.** Early clinical and radiographic outcomes of intramedullary-fixation total ankle arthroplasty. J Bone Joint Surg Am 2015;97(3):194-200.
3. **Lewis JS, Green CL, Adams SB, Easley ME, DeOrio JK, Nunley JA.** Comparison of first- and second-generation fixed-bearing total ankle arthroplasty using a modular intramedullary tibial component. Foot Ankle Int 2015;36(8): 881-890.
4. **Krause FG, Di Silvestro M, Penner MJ, et al.** Inter- and intraobserver reliability of the COFAS end-stage ankle arthritis classification system. Foot Ankle Int 2010; 31(2):103-108.

# Headless Compression Screw Fixation of Jones Fractures: A Clinical and Radiographic Comparison Study


## ABSTRACT

**Background:** Controversy remains over intramedullary screw implants for fixation of fifth metatarsal Jones fractures. Promising results have been reported for both indication-specific partially threaded screws (PT) and variable-pitched headless compression (HC) screws. Our objective was to compare clinical and radiographic results of Jones fracture patients treated with these two screw types. We also evaluated the association of patient and fracture characteristics with surgical failure.

**Methods:** We performed a retrospective comparative analysis of all Jones fractures treated with primary intramedullary screw fixation from 1995 through 2015. Chart review yielded patient and fracture characteristics, implant, postoperative course, and serial radiographs for fracture classification (Torg and anatomic zone) and radiographic union. The primary endpoint was number of surgical failures (delayed union, nonunion, or refracture). Secondary endpoints included time to radiographic union, weight bearing, and pain resolution.

**Results:** Fifty-nine feet (47 PT, 12 HC) were reviewed with mean age 30 years and follow-up 9.6 months. The PT group showed greater failures (10/47, 21.3% vs. 1/12, 8.3%; p=0.31) and greater weeks to full weight (4.2 vs. 3.3, p=0.06), without differences in time to radiographic union or pain resolution. Most failures were delayed unions. Pooled union rate was 96.6%. Significant correlations with failure were age, diabetes, and BMI, without significant correlation with tobacco or gender. No differences were found between zone II and III fractures.

**Conclusion:** This is the first clinical comparison between PT and HC screws for Jones fractures and one of the largest clinical series on the subject. The two groups had similar clinical and radiographic results, both with high union rates. The PT group 21% failure is concerning and may warrant further investigation. Increasing age, diabetes, and BMI were associated with worse outcomes. This supports the headless compression screw as a viable Jones fracture treatment.

**Level of Evidence:** III



**Keywords:** Jones fracture; Fifth metatarsal; Headless compression; Variable pitch; Indication-specific; Partially threaded; Intramedullary screw



**David J. Ruta, MD[1]**
**Robert T. Ellis, MD[2]**
**Benjamin Grear, MD[3]**
**Susan Ishikawa, MD[3]**
**David R. Richardson, MD[3]**
**G. Andrew Murphy, MD[3]**

[1] St. Lukes Department of Orthopedic & Sports Medicine
Duluth, Minnesota

[2] University of Missouri
Orthopedic Residency
Columbia, Missouri

[3] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery & Biomedical Engineering
Memphis, Tennessee

**Corresponding author:**

David J. Ruta, MD
1012 E. 2nd Street
Duluth, MN 55805
P: 218-249-6360
david.j.ruta@gmail.com


## REFERENCES


1. **Clapper MF, O'Brien TJ, Lyons PM.** Fractures of the fifth metatarsal. Analysis of a fracture registry. Clin Orthop Relat Res. 1995(315):238-241.
2. **Den Hartog BD.** Fracture of the proximal fifth metatarsal. J Am Acad Orthop Surg. 2009;17(7):458-464.
3. **Kavanaugh JH, Brower TD, Mann RV.** The Jones fracture revisited. J Bone Joint Surg Am. 1978;60(6):776-782.
4. **Dameron TB.** Fractures of the Proximal Fifth Metatarsal: Selecting the Best Treatment Option. J Am Acad Orthop Surg. 1995;3(2):110-114.
5. **Shereff MJ, Yang QM, Kummer FJ, Frey CC, Greenidge N.** Vascular anatomy of the fifth metatarsal. Foot Ankle. 1991;11(6):350-353.
6. **Smith JW, Arnoczky SP, Hersh A.** The intraosseous blood supply of the fifth metatarsal: implications for proximal fracture healing. Foot Ankle. 1992;13(3):143-152.
7. **Fern√°ndez Fairen M, Guillen J, Busto JM, Roura J.** Fractures of the fifth metatarsal in basketball players. Knee Surg Sports Traumatol Arthrosc. 1999;7(6):373-377.
8. **Carreira DS, Sandilands SM.** Radiographic factors and effect of fifth metatarsal Jones and diaphyseal stress fractures on participation in the NFL. Foot Ankle Int. 2013;34(4):518-522.
9. **Chuckpaiwong B, Queen RM, Easley ME, Nunley JA.** Distinguishing Jones and proximal diaphyseal fractures of the fifth metatarsal. Clin Orthop Relat Res. 2008;466(8):1966-1970.

10. **Murawski CD, Kennedy JG.** Percutaneous internal fixation of proximal fifth metatarsal jones fractures (Zones II and III) with Charlotte Carolina screw and bone marrow aspirate concentrate: an outcome study in athletes. Am J Sports Med. 2011;39(6):1295-1301.
11. **Nagao M, Saita Y, Kameda S, et al.** Headless compression screw fixation of jones fractures: an outcomes study in Japanese athletes. Am J Sports Med. 2012;40(11):2578-2582.
12. **Polzer H, Polzer S, Mutschler W, Prall WC.** Acute fractures to the proximal fifth metatarsal bone: development of classification and treatment recommendations based on the current evidence. Injury. 2012;43(10):1626-1632.
13. **Mologne TS, Lundeen JM, Clapper MF, O'Brien TJ.** Early screw fixation versus casting in the treatment of acute Jones fractures. Am J Sports Med. 2005;33(7):970-975.
14. **Japjec M, Starešinić M, Starjački M, Žgaljardić I, Štivičić J, Šebečić B.** Treatment of proximal fifth metatarsal bone fractures in athletes. Injury. 2015;46 Suppl 6:S134-136.
15. **Metzl J, Olson K, Davis WH, Jones C, Cohen B, Anderson R.** A clinical and radiographic comparison of two hardware systems used to treat jones fracture of the fifth metatarsal. Foot Ankle Int. 2013;34(7):956-961.
16. **Hunt KJ, Anderson RB.** Treatment of Jones fracture nonunions and refractures in the elite athlete: outcomes of intramedullary screw fixation with bone grafting. Am J Sports Med. 2011;39(9):1948-1954.
17. **O'Malley M, DeSandis B, Allen A, Levitsky M, O'Malley Q, Williams R.** Operative Treatment of Fifth Metatarsal Jones Fractures (Zones II and III) in the NBA. Foot Ankle Int. 2016;37(5):488-500.
18. **Lawrence SJ, Botte MJ.** Jones' fractures and related fractures of the proximal fifth metatarsal. Foot Ankle. 1993;14(6):358-365.
19. **Torg JS, Balduini FC, Zelko RR, Pavlov H, Peff TC, Das M.** Fractures of the base of the fifth metatarsal distal to the tuberosity. Classification and guidelines for non-surgical and surgical management. J Bone Joint Surg Am. 1984;66(2):209-214.
20. **Portland G, Kelikian A, Kodros S.** Acute surgical management of Jones' fractures. Foot Ankle Int. 2003;24(11):829-833.
21. **Lee KT, Park YU, Jegal H, Kim KC, Young KW, Kim JS.** Factors associated with recurrent fifth metatarsal stress fracture. Foot Ankle Int. 2013;34(12):1645-1653.
22. **Lareau CR, Hsu AR, Anderson RB.** Return to Play in National Football League Players After Operative Jones Fracture Treatment. Foot Ankle Int. 2016;37(1):8-16.
23. **Jones R.** I. Fracture of the Base of the Fifth Metatarsal Bone by Indirect Violence. Ann Surg. 1902;35(6):697-700.692.
24. **Egol K, Walsh M, Rosenblatt K, Capla E, Koval KJ.** Avulsion fractures of the fifth metatarsal base: a prospective outcome study. Foot Ankle Int. 2007;28(5):581-583.
25. **Wiener BD, Linder JF, Giattini JF.** Treatment of fractures of the fifth metatarsal: a prospective study. Foot Ankle Int. 1997;18(5):267-269.
26. **Shahid MK, Punwar S, Boulind C, Bannister G.** Aircast walking boot and below-knee walking cast for avulsion fractures of the base of the fifth metatarsal: a comparative cohort study. Foot Ankle Int. 2013;34(1):75-79.
27. **Akimau PI, Cawthron KL, Dakin WM, Chadwick C, Blundell CM, Davies MB.** Symptomatic treatment or cast immobilisation for avulsion fractures of the base of the fifth metatarsal: a prospective, randomised, single-blinded non-inferiority controlled trial. Bone Joint J. 2016;98-B(6):806-811.
28. **Rettig AC, Shelbourne KD, Wilckens J.** The surgical treatment of symptomatic nonunions of the proximal (metaphyseal) fifth metatarsal in athletes. Am J Sports Med. 1992;20(1):50-54.
29. **Ritchie JD, Shaver JC, Anderson RB, Lawrence SJ, Mair SD.** Excision of symptomatic nonunions of proximal fifth metatarsal avulsion fractures in elite athletes. Am J Sports Med. 2011;39(11):2466-2469.
30. **Habbu RA, Marsh RS, Anderson JG, Bohay DR.** Closed intramedullary screw fixation for nonunion of fifth metatarsal Jones fracture. Foot Ankle Int. 2011;32(6):603-608.
31. **Nunley JA, Glisson RR.** A new option for intramedullary fixation of Jones fractures: the Charlotte Carolina Jones Fracture System. Foot Ankle Int. 2008;29(12):1216-1221.
32. **Stokes IA, Hutton WC, Stott JR.** Forces acting on the metatarsals during normal walking. J Anat. 1979;129(Pt 3):579-590.
33. **Reese K, Litsky A, Kaeding C, Pedroza A, Shah N.** Cannulated screw fixation of Jones fractures: a clinical and biomechanical study. Am J Sports Med. 2004;32(7):1736-1742.
34. **Sides SD, Fetter NL, Glisson R, Nunley JA.** Bending stiffness and pull-out strength of tapered, variable pitch screws, and 6.5-mm cancellous screws in acute Jones fractures. Foot Ankle Int. 2006;27(10):821-825.
35. **Orr JD, Glisson RR, Nunley JA.** Jones fracture fixation: a biomechanical comparison of partially threaded screws versus tapered variable pitch screws. Am J Sports Med. 2012;40(3):691-698.
36. **Japjec M, Stare≈°ini*ƒ*á M, Starja*ƒ*çki M, ≈Ωgaljardi*ƒ*á I, ≈†tivi*ƒ*çi*ƒ*á J, ≈†ebe*ƒ*çi*ƒ*á B.** Treatment of proximal fifth metatarsal bone fractures in athletes. Injury. 2015;46 Suppl 6:S134-136.
37. **Porter DA, Rund AM, Dobslaw R, Duncan M.** Comparison of 4.5- and 5.5-mm cannulated stainless steel screws for fifth metatarsal Jones fracture fixation. Foot Ankle Int. 2009;30(1):27-33.

# Proximal Both-Bone Forearm Fractures In Children: Factors Predicting Outcome*


## ABSTRACT

The literature is replete with outcomes studies of pediatric forearm fractures; however, information concerning the outcomes of both-bone fractures of the proximal radius and ulna is limited. The purpose of our study was to evaluate the prognosis and outcomes in children with combined fractures of the proximal radius and ulna, with special attention to complications. A single-center, retrospective study identified patients aged 3 to 15 years old with proximal forearm fractures treated between January of 1994 and February of 2014. Patients were excluded if they did not have both-bone fractures of the proximal forearm. Records were reviewed with a focus on outcomes and their association with age at the time of injury, severity of injury, type of treatment, and complications. Thirty-one patients met inclusion criteria. Significant differences were seen between patients younger than 10 years of age and patients 10 years of age or older in rates of requiring operative treatment (p=0.048) and returning to the operating room (p=0.037). There was no significant difference in nerve injury (p=0.519) or range-of-motion deficits (p=0.872) based on age. In addition, no difference was seen in range-of-motion deficits based on severity of injury as determined by displacement (complete or none) (p=0.139). Most proximal both-bone forearm fractures in children, including olecranon and radial neck fractures, Monteggia type IV fractures, and nonspecific proximal both-bone forearm fractures, have good-to-excellent results. In our study, older age, defined as 10 years of age or older at the time of injury, resulted in more frequent need for operative intervention, a higher rate of return to the OR, and greater risk of nerve injury. The older children were not more likely to have range-of-motion deficits despite a more involved course, which contradicts previous reports, and older age at the time of injury did not necessarily predict poorer outcomes.



**Travis W. Littleton, MD[1]**
**Zachary K. Pharr, MD[1]**
**Derek M. Kelly, MD[1]**
**Alice Moisan, BSN, RN, CCRP[2]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery &
Biomedical Engineering
Memphis, Tennessee

[2] Paraxel International
200 West Street
Memphis, Tennessee

**Corresponding author:**

Derek M. Kelly, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
dkelly@campbellclinic.com


## INTRODUCTION

Forearm fractures constitute approximately 4% of all pediatric fractures and almost a third of all pediatric upper extremity fractures.[1,2] The forearm and elbow are the most common sites of fractures in children aged 0 to 16 years, and the frequency of these fractures appears to be increasing over the past decade.[1] Better insight into the expected outcomes and potential complications of these fractures is essential for optimal patient care. Although the literature is replete with outcomes studies on pediatric forearm fractures, including the more common Monteggia-type fractures,[3-16] information concerning the outcomes of both-bone fractures of the proximal radius and ulna is limited.[17]

The purpose of this study was to evaluate outcomes and identify prognostic factors in children with both-bone fractures of the proximal radius and ulna, with special attention to residual defects resulting from the injury and from subsequent treatment such as nerve palsies, decreased motor function, restriction in elbow flexion and extension, deficits in supination and pronation, radioulnar synostosis, and a decrease in overall range of motion.


* Reproduced with permission from Littleton TW, Pharr ZK, Kelly DM, Moisan A. Proximal both-bone forearm fractures in children: factors predicting outcome. Curr Orthop Pract. 2018; 29(3):000-000.

## MATERIALS AND METHODS

Initial screening identified 366 patients aged 3 to 15 years with a forearm fracture treated between January 1994, and February, 2014. Because no ICD-9 codes were available to distinguish fractures of the proximal one-third of the forearm from more distal fractures, chart review and radiographic analysis were used to exclude fractures involving the distal one-third and middle one-third of the forearm. We divided the forearm into 3 zones: distal, middle, and proximal third based on the length of the forearm. If the fracture site was not clearly within the proximal-third zone, exclusion was decided at the discretion of the research team. Patients with an injury involving the radius or ulna alone also were excluded, which eliminated any Monteggia-type fractures other than Bado18 type IV **(Fig. 1)**. Additionally, one child with a shotgun wound was excluded, leaving 31 patients for retrospective chart review. The 15 males and 16 females had an average age at the time of injury of 7.5 years (range, 3 to 14 years). None had a prior upper extremity fracture.

Fracture patterns were categorized as Monteggia type IV (9 fractures), olecranon and radial neck (14 fractures), or nonspecific proximal both-bone forearm (8 fractures). Nonspecific proximal both-bone forearm fractures involved the proximal one-third of the radial and ulnar shafts with no involvement of the olecranon process or radial neck. There was only one open fracture in this group. One patient with a Monteggia type IV fracture had ipsilateral distal radial and ulnar fractures, and one patient with nonspecific proximal both-bone forearm fractures had an ipsilateral distal radial fracture.

The mechanism of injury was a fall onto an outstretched hand in 25 (81%) of the 31 patients. Other mechanisms of injury were football-related injuries (3 patients) and a dirt-bike accident (1 patient).

At initial presentation, clinical examinations were performed to assess deformity, soft-tissue involvement, and neurovascular status. In addition, radiographs of the elbow were obtained to assess fracture location, angulation, and amount of displacement. Serial examinations were repeated at follow-up visits to assess pain, deformity, function, and range of motion. Radiographs also were obtained at each follow-up visit to evaluate remodeling, angulation, displacement, and evidence of healing, malunion, or nonunion.

**Fig. 1:** Bado classification of Monteggia fracture-dislocations. **Type I**, anterior dislocation of radial head and anterior angulation of ulnar fracture. **Type II**, posterior dislocation of radial head and posterior angulation of ulnar fracture. **Type III**, lateral dislocation of radial head and lateral angulation of ulnar fracture. **Type IV**, fractures of radial and ulnar shafts and dislocation of radial head. *(From Sawyer JR, Spence DD: Fractures and dislocations in children. In Azar FM, Beaty JH, Canale ST, editors. Campbell's Operative Orthopaedics, 13th edition. Philadelphia, Elsevier, 2017.)*

## TREATMENT

After evaluation with radiographic imaging at the initial time of injury, 16 of the 31 patients required surgical intervention, and the remaining 15 were treated non-operatively. Based on the severity of the injury, type of fracture, and the surgeon's preference, patients were treated with one of four methods: closed treatment without manipulation, closed manipulation and casting, closed reduction and percutaneous pinning (CRPP), or open reduction and internal fixation (ORIF).

Non-operative treatment consisted of immobilization in a long-arm cast for 3 to 6 weeks. Patients returned approximately 1 month after cast removal for evaluation of range of motion and final radiographic examination. If appropriate healing was evident on radiographs and no range-of-motion


**Fig. 2: A and B**, Anteroposterior and lateral radiographs of non-specific proximal both-bone injury. **C and D**, Reduction and fixation with 2.5-mm nail (ulna) and 0.62-mm Kirschner wire (radius).

deficits or other complaints were present, return to normal activity was allowed.

CRPP was used for stabilization of 2 olecranon and radial neck fractures, 1 Monteggia type IV fracture, and 1 nonspecific proximal both-bone forearm fracture. The olecranon and radial neck fractures were treated with one Kirschner wire to provide adequate reduction of the radial neck fracture. Both olecranon fractures were nondisplaced and did not require fixation. An arthrogram of the Monteggia type IV fracture showed adequate reduction of the radial head, but the proximal ulna was unstable, and a 2-mm flexible nail was used to stabilize the ulnar fracture. The nonspecific proximal both-bone forearm fracture was treated with a 2.5-mm stainless steel nail to stabilize the ulnar fracture and a 0.62-mm smooth Kirschner wire placed from lateral to medial to stabilize the radial neck fracture **(Figure 2)**. All four patients were placed in a long-arm cast, and radiographs showed good reduction of all fractures.

The 12 fractures that could not be treated non-operatively and required ORIF included 5 olecranon and radial neck fractures, 3 Monteggia type IV fractures, and 4 nonspecific proximal both-bone forearm fractures. The fracture sites were exposed through standard surgical approaches. Kirschner wires were typically used for percutaneous reduction and fixation of radial fractures, and flexible intramedullary nails, Kirschner wires, or tension banding in a figure-of-eight configuration were used for ulnar fractures, depending on the exact fracture location and configuration. The patient's arm was then moved through a complete range of motion, and radiographs were taken in multiple orthogonal views to verify adequate reduction. If alignment and reduction were acceptable, the incision was closed and a long-arm cast was applied. An additional procedure was necessary in one patient. This patient required a return to the operating room because of continued anterior radial head subluxation and nonunion of an ulnar osteotomy originally performed to help reduce the radial head. The procedures performed included an open reduction of the dislocated radial head, ORIF of the ulna, bone graft of the nonunion site, and annular ligament reconstruction with a Bell-Tawse19 type technique.

## RESULTS

Initial radiographs showed no angulation at the fracture site in 18 patients and mild angulation in 13 patients. Twelve patients had no displacement, 15 had moderate displacement, and 4 had complete displacement. Displacement was categorized as <5%, 5 to 95%, and >95% respectively.

At an average follow-up of 4 months (range 1 to 26 months), 29 of the 31 patients had excellent results, with radiographs showing appropriate healing and no pain or range-of-motion deficits on physical examination. Only 2 patients had suboptimal outcomes. One patient, a 9 + 4-year-old, was treated with closed manipulation and casting. Her final radiographs showed mild valgus deformity of the radial shaft with respect to the radial neck, but her radiocapitellar articulation was appropriately reduced **(Figure 3)**. She also had range-of-motion deficits with restriction of active extension to 30 to 40 degrees and flexion to 90 to 100 degrees. In addition, she had mild pain with supination and pronation, but had no neurovascular problems. The other patient with suboptimal results, an 11 + 8-year-old, had a closed fracture that


**Fig. 3: A and B**, Anteroposterior and lateral radiographs of proximal radial and ulnar fractures in a 9-year-old girl. **C and D**, Mild valgus deformity of radial shaft after healing with non-operative treatment.

required ORIF for continued radial head subluxation. At follow-up, he had a transient posterior interosseous nerve palsy that fully recovered by 7 weeks after injury, but he had range-of-motion deficits with supination and pronation to 20 to 30 degrees and lacked 20 degrees of full extension and flexion to 90 to 100 degrees.

Three patients had nerve injuries: 1 involving the ulnar nerve and 2 involving the posterior interosseous nerve. The ulnar nerve injury presented as fifth-digit pain and numbness, but symptoms diminished spontaneously within a month. One posterior interosseous nerve injury recovered fully after 3 months of physical therapy, and the other recovered spontaneously after 7 weeks.

The only patient who required a return to the operating room was older than 10 years of age, an 11 + 8-year-old. This patient required a return to the operating room for residual subluxation of the radial head seen at the first follow-up visit. Nerve injury occurred in 1 of 6 patients ≥ 10 years of age and in 2 of 25 patients younger than 10 years of age. Five of the 6 patients ≥ 10 years of age required ORIF compared to only 7 of 25 of the younger patients. Range-of-motion deficits were similar in the two age groups: 1 of 6 older patients and 3 of 25 younger patients **(Table 1)**

In summary, the children 10 years of age or older were more likely to require operative treatment (p=0.048) and require a subsequent return to the operating room (p=0.037). However, the older children were not more likely to sustain nerve injury or develop range of motion deficits despite a more involved course. This contradicts previous reports that older age at the time of injury indicates a poorer outcome.

In our study population, there was no difference in the frequency of range-of-motion deficits in patients with complete displacement and those with no displacement at the fracture site (p=0.139). None of the 4 patients with complete displacement developed range-of-motion deficits, while 2 patients with no displacement developed deficits. The one patient with an open fracture did not develop range-of-motion deficits, while 4 of 30 patients with closed fractures developed deficits.

Finally, there was no significant difference in the rate of range-of-motion deficits among the three fracture types: 3 of 14 with olecranon or radial neck fractures, 1 of 8 with nonspecific both-bone forearm fractures, and none of 9 with Monteggia type IV fractures.

## DISCUSSION

Although a number of studies have described the outcomes of pediatric forearm fractures, including the more common Monteggia fractures,[3-16] information is limited on the expected outcomes of proximal-third both-bone forearm fractures,[17] including the uncommon type IV Monteggia fracture (proximal-third radial and ulnar fractures with anterior dislocation of the radial head).[20] To determine factors predictive of outcomes of these proximal fractures, we reviewed 31 such injuries treated nonoperatively and operatively over a 10-year period.

More proximal fracture location has been cited as a predictor of early radiographic failure[5] and the need for conversion to operative treatment[9] after non-operative treatment of both-bone forearm fractures in children. None of the 15 non-operatively treated patients in our series required a subsequent operative treatment.

| Variable | Age at time of injury | | P value |
|---|---|---|---|
| | < 10 years old (25) | ≥ 10 years old (6) | |
| Return to OR | 0 | 1 | 0.037 |
| Nerve injury | 2 | 1 | 0.519 |
| ORIF | 7 | 5 | 0.048 |
| ROM deficit | 3 | 1 | 0.872 |
| Mild angulation | 10 | 3 | 0.892 |
| No angulation | 15 | 3 | 0.656 |
| Moderate displacement | 11 | 4 | 0.535 |
| Complete displacement | 4 | 0 | 0.294 |
| No displacement | 10 | 2 | 0.581 |
| *Also evaluated were: loss of reduction, need for remanipulation, vascular injury, heterotopic ossification, radioulnar stynosis, osteonecrosis, re-fracture, or severe angulation of which there were none of the listed complications in either age group. | | | |

**Table 1:** Outcomes based on age at time of injury

All three types of proximal forearm fractures included in this study had good-to-excellent functional outcomes. This supports the idea that, regardless of the type of fracture, injury mechanism, or treatment modality, most children with proximal forearm fractures have good outcomes.[4,6,16] Two suggested potential risk factors for poor outcomes are the severity of the injury and patient age at the time of injury, with multiple studies identifying an increased risk of nonunion, delayed union, and overall complications in older children.[5,8-10,12] This, however, was not the case in our patients: there were no statistically significant differences in nerve injury or in range-of-motion deficits between patients younger than 10 years and those older **(Table 1)**. This lack of correlation between poor functional outcomes and fracture severity or age at injury may be a reflection of the small numbers of patients in this study. Nonetheless, it suggests that older patients with more severe injuries should not be presumed to have a poorer prognosis; however, they do require closer attention and monitoring because they are at increased risk for certain complications.

We also found no substantial difference in outcomes or complications between open and closed fractures. Although most open fractures require operative fixation and this may introduce a bias to more severe injuries being treated operatively, this study showed that an open fracture is not necessarily a predictor of a worse clinical outcome, regardless of radiographic findings.

Nerve injury was a relatively uncommon complication in our study population, occurring in only 9.7% of patients, which is consistent with previous reports on pediatric forearm fractures.[12] Transient neuropraxia is the most common nerve injury with forearm fractures.[7] All three of the nerve injuries in our patients were transient and spontaneously resolved.

This study has several limitations. The first is a lack of long-term follow-up. Certain long-term complications, such as osteonecrosis and radioulnar synostosis, could occur and remain unrecognized without long-term follow-up. Finally, the retrospective nature of this study and the small number of patients in our subgroup comparisons are weaknesses, but this does not ultimately change our conclusions.

## REFERENCE


1. **Hedstrom EM, Svensson O, Bergstrom U, et al.** Epidemiology of fractures in children and adolescents. Acta Orthop. 2010; 81:148-153.
2. **Cooper C, Dennison EM, Leufkens G, et al.** Epidemiology of childhood fractures in Britian: a study using the general practice research database. J Bone Miner Res. 2004; 19:1976-1981.
3. **Agarwal A.** Type IV Monteggia fracture in a child. Can J Surg. 2008; 51:E44-45.
4. **Baldwin K, Morrison MJ 3rd, Tomlinson LA, et al.** Both bone forearm fractures in children and adolescents, which fixation strategy is superior—plates or nails? A systematic review and meta-analysis of observational studies. J Orthop Trauma. 2014; 28:e8-e14.
5. **Bowman EN, Mehlman CT, Lindsell CJ, et al.** Nonoperative treatment of both-bone forearm shaft fractures in children: predictors of early radiographic failure. J Pediatr Orthop. 2011; 31:23-32.
6. **Carmichael KD, English C.** Outcomes assessment of pediatric both-bone forearm fractures treated operatively. Orthopedics. 2007; 30:379-383.
7. **Davis DR, Green DP.** Forearm fractures in children: pitfalls and complications. Clin Orthop Relat Res. 1976; 120:172-183.
8. **Flynn JM, Jones KJ, Garner MR, et al.** Eleven years experience in the operative management of pediatric forearm fractures. J Pediatr Orthop. 2010; 30:313-319.
9. **Franklin CC, Wren T, Ferkel E, et al.** Predictors of conversion from conservative to operative treatment of pediatric forearm fractures. J Pediatr Orthop B. 2014; 23:150-154.
10. **Ho CA, Jarvis DL, Phelps JR, et al.** Delayed union in internal fixation of pediatric both-bone forearm fractures. J Pediatr Orthop B. 2013; 22:373-387.
11. **Leonidou A, Pagkalos J, Lepetsos P, et al.** Pediatric Monteggia fractures: a single center study of the management of 40 patients. J Pediatr Orthop. 2012; 32:352-356.
12. **Martus JE, Preston RK, Schoenecker JG, et al.** Complications and outcomes of diaphyseal forearm fracture intramedullary nailing: a comparison of pediatric and adolescent age groups. J Pediatr Orthop. 2013; 33:598-607.
13. **Olney BW, Menelaus MB.** Monteggia and equivalent lesions in childhood. J Pediatr Orthop. 1989; 9:219-223.
14. **Ring D, Jupiter JB, Waters PM.** Monteggia fractures in children and adults. J Am Acad Orthop Surg. 1998; 6:215-24.
15. **Tan BH, Mahadev A.** Radial neck fractures in children. J Orthop Surg (Hong Kong). 2011; 19:209-212.
16. **Teoh KH, Chee YH, Shortt N, et al.** An age- and sex-matched comparative study on both-bone diaphyseal paediatric forearm fracture. J Child Orthop. 3:367-373.
17. **Nenopoulos SP, Beslikas TA, Gigis JP.** Long-term follow-up of combined fractures of the proximal radius and ulna during childhood. J Pediatr Orthop B. 2009; 18:252-260.
18. **Bado JL.** The Monteggia lesion. Clin Orthop Rel Res. 1967; 50:71-86.
19. **Bell-Tawse AJS.** The treatment of malunited anterior Monteggia fractures in children. J Bone Joint Surg Br. 1965; 47:718-723.
20. **Gibson WK, Timperlake RW.** Operative treatment of a type IV Monteggia fracture-dislocation in a child. J Bone Joint Surg Br. 1992; 74:780-781.

# Ninety-Day Readmission and Complication Rate After Minimally Invasive Transforaminal Lumbar Interbody Fusions


## ABSTRACT

**Background:** The aim of this study was to investigate the 90-day rate of readmissions, complications, and patient satisfaction in consecutive patients with elective minimally invasive transforaminal lumbar interbody fusion (TLIF) by a single surgeon.

**Methods:** Records of 153 patients (78 females, 75 males) who had minimally invasive TLIF from January 1, 2010, to June 1, 2015, were reviewed. Clinical outcomes were assessed by the visual-analog-score (VAS) and the Oswestry Disability Index (ODI). Patient-reported outcomes were analyzed by age, indication for surgery, and insurance type. Complications, readmissions, infections, reoperations, and patient-reported satisfaction were reported.

**Results:** Indications for surgery included degenerative disc disease (DDD) (n=56), spondylolisthesis (n=79), post laminectomy syndrome (PLS) (n=14) and others (n=4). Thirty-five (22.9%) procedures were done as outpatient at a private surgery center. Within the 90-day postoperative period there were 5 (3.3%) readmissions due to all causes and (2.6%) readmission due to surgical complications: two revisions for graft extrusion, one pulmonary embolism, one for pain control, and one patient had an unrelated hemorrhoidectomy. There were no surgical site infections or wound complications. There was a statistically significant improvement in 90-day post-operative ODI and VAS scores, with the greatest improvement in spondylolisthesis patients, followed by PLS, and DDD showing the smallest improvement. There was no difference at 90 days in VAS/ODI scores between inpatient and outpatient surgery patients. While not statistically significant, patients with private insurance and Medicare showed clinically significant better outcomes compared to those with Medicaid and Workers Compensation insurance. Patients over 65 years old showed a trend towards better functional outcomes, but had no difference in pain scores compared to those under 65.

**Conclusions:** MITLIF was shown to be an effective intervention for treatment of symptomatic lumbar pathology. In our cohort we had no wound complications, and only 3.3% all cause readmissions and (2.6%) readmission due to surgical complications within 90 days. Patients with spondylolisthesis showed the most significant improvement in VAS and ODI, followed by PLS and DDD, respectively.

**Level of Evidence:** Level 4 Retrospective Case Series



**Chad Campion, MD[1]**
**Catherine Olinger, MD[1]**
**Raymond J. Gardocki, MD[1]**
**Richard A. Smith, PhD[1]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery &
Biomedical Engineering
Memphis, Tennessee

**Corresponding author:**

Raymond J. Gardocki, MD
1211 Union Avenue, Suite 510
Memphis, TN 38104
P: 901-759-3270
F: 901-759-3278
rgardocki@campbellclinic.com


## REFERENCES


1. **Perez-Cruet, M. J., Hussain, N. S., White, G. Z., Begun, E. M., Collins, R. A., Fahim, D. K., Yacob, S. A.** (2014). Quality-of-Life Outcomes With Minimally Invasive Transforaminal Lumbar Interbody Fusion Based on Long-Term Analysis of 304 Consecutive Patients. Spine, 39(3), E191-E198.
2. **Fan, S., Hu, Z., Zhao, F., Zhao, X., Huang, Y., & Fang, X.** (2009, October 30). Multifidus muscle changes and clinical effects of one-level posterior lumbar interbody fusion: Minimally invasive procedure versus conventional open approach. European Spine Journal Eur Spine J, 19(2), 316-324.
3. **Parker, S. L., Mendenhall, S. K., Shau, D. N., Zuckerman, S. L., Godil, S. S., Cheng, J. S., & Mcgirt, M. J.** (2014). Minimally Invasive versus Open Transforaminal Lumbar Interbody Fusion for Degenerative Spondylolisthesis: Comparative Effectiveness and Cost-Utility Analysis. World Neurosurgery, 82(1-2), 230-238.
4. **Goldstein, C. L., Macwan, K., Sundararajan, K., & Rampersaud, Y. R.** (2016, March). Perioperative outcomes and adverse events of minimally invasive versus open posterior lumbar fusion: Meta-analysis and systematic review.Journal of Neurosurgery: Spine, 24(3), 416-427.
5. **Bernatz, J. T., & Anderson, P. A.** (2015, October). Thirty-day readmission rates in spine surgery: Systematic review and meta-analysis. Neurosurgical Focus, 39(4).
6. **Pelton, M. A., Phillips, F. M., & Singh, K.** (2012, October). A Comparison of Perioperative Costs and Outcomes in Patients With and Without Workers' Compensation Claims Treated With Minimally Invasive or Open Transforaminal Lumbar Interbody Fusion. Spine, 37(22), 1914-1919.
7. **Akamnonu, C., Cheriyan, T., Goldstein, J. A., Lafage, V., Errico, T. J., & Bendo, J. A.** (2015). Unplanned Hospital Readmission After Surgical Treatment of Common Lumbar Pathologies. Spine, 40(6), 423-428.

# Cyclops Lesions after ACL Reconstruction: Bone-Tendon-Bone Autograft compared to Hamstring Autograft


## ABSTRACT

**Introduction:** Anterior Cruciate Ligament (ACL) reconstruction is commonly performed with either bone-tendon-bone autograft or hamstring autograft. Each of these options has inherent advantages and disadvantages that are well documented. However, to our knowledge, no study has compared the incidence of cyclops lesions between bone-tendon-bone autograft and hamstring autograft. By focusing on cyclops lesions, a source of knee extension loss following ACL reconstruction, our study aims to expand the comparison between these two autograft options.

**Methods:** A single-center, retrospective review identified 1,902 patients between the ages of 8 and 66 years old treated with ACL reconstruction between January 1st, 2000 and October 31st, 2015. 1534 patients received a bone-tendon-bone (BTB) autograft. 368 patients received a hamstring autograft. ACL reconstructions were performed by 19 different orthopaedic surgeons. Cyclops lesions were confirmed by a second arthroscopy in patients treated for a loss of full knee extension, and the incidence between BTB and hamstring autograft was compared. In addition, the incidence of cyclops lesions in males and females was also compared as a secondary outcome.

**Results:** Cyclops lesions occurred in 14 of 1534 (0.91%) bone-tendon-bone autografts and 5 of 368 (1.35%) hamstring autografts (p=0.39). Thus, there was no statistically significant difference between the two groups. In regards to gender, cyclops lesions occurred in 5 out of 1125 (0.44%) males and 14 out of 777 (1.44%) females (p=0.004). This was statistically significant, illustrating a higher incidence of cyclops lesions in females compared to males with a relative risk of 4 (CI 1.4-11).

**Conclusion:** Bone-tendon-bone autografts and hamstring autografts continue to be viable options for ACL reconstruction. An increased incidence of cyclops lesions is a potential disadvantage that has not been previously compared between these two graft options. This study found no statistically significant difference in the incidence of cyclops lesions between the two groups. These results minimize any concern for an increased cyclops lesion risk when debating between bone-tendon-bone autograft and hamstring autograft. Secondarily, surgeons should be cognizant when treating females that the relative risk of a cyclops lesion is four times higher compared to males.



**Zachary K. Pharr, MD[1]**
**Andrew Dickerson, BS[2]**
**Frederick M. Azar, MD[1]**
**Thomas W. Throckmorton, MD[1]**
**Anthony A. Mascioli, MD[1]**

[1] University of Tennessee-Campbell Clinic
Department of Orthopaedic Surgery &
Biomedical Engineering
Memphis, Tennessee

[2] College of Medicine
University of Tennessee Health Science Center
Memphis, Tennessee

**Corresponding author:**

Anthony A. Mascioli, MD
7545 Airways Blvd.
Southaven, MS 38671
P: 901-759-3211
F: 901-435-5783
amascioli@campbellclinic.com


## REFERENCES


1. **Miyasaka KC, Daniel DM, Stone ML.** The incidence of knee ligament injuries in the general population. Am J Knee Surg 1991;4:43-48. 2 Brown CH, Carson EW. Revision anterior cruciate ligament surgery. Clin Sports Med 1999;18:109-171.
2. **Hewett TE, Lindenfeld TN, Riccobene JV, Noyes FR.** The effect of neuromuscular training on the incidence of knee injury in female athletes: a prospective study. Am J Sports Med 1999;27:699–706
3. **American Academy of Orthopaedic Surgeons, July 2007, Anterior Cruciate Ligament Injury: Surgical Considerations, http://orthoinfo.**aaos.org/topic.cfm?topic=A00297#A00297_R4_anchor (July 11, 2008).
4. **Griffin LY.** Noncontact Anterior Cruciate Ligament Injuries: Risk Factors and Prevention Strategies. Journal of the American Academy of Orthopaedic Surgeons. 2000;8:141-150.
5. **Freedman KB, D'Amato MJ, Nedeff DD, et al.** Arthroscopic Anterior Cruciate Ligament Reconstruction: A Metaanalysis Comparing Patellar Tendon and Hamstring Tendon Autografts. Am J Sports Med 2003;31(1):2-11. 59.
6. **Sachs R, Daniel D, Stone M, et al.** Patellofemoral problems after anterior cruciate ligament reconstruction. Am J Sports Med 1989;17(6):760-765.
7. **Pinczewski LA, Deehan DJ, Salmon LJ, et al.** A Five-Year Comparison of Patellar Tendon Versus Four-Strand Hamstring Tendon Autograft for Arthroscopic Reconstruction of the Anterior Cruciate Ligament. Am J Sports Med 2002;30(4):523-536.
8. **Shaieb MD, Kan DM, Chang SK, et al.** A Prospective Randomized Comparison of Patellar Tendon Versus Semitendinosus and Gracilis Tendon Autografts for Anterior Cruciate Ligament Reconstruction. Am J Sports Med 2002;30(2):214-220.

9. **Recht MP, Piraino DW, Cohen MA, Parker RD, Bergfeld JA.** Localized anterior arthrofibrosis (cyclops lesion) after reconstruction of the anterior cruciate ligament: MR imaging findings. AJR Am J Roentgenol. 1995 Aug;165(2):383-5. PubMed PMID: 7618562.
10. **Sheldon PJ, Forrester DM, Learch TJ.** Imaging of intra-articular masses. Radiographics 2005;25:105-19.
11. **Bradley DM, Bergman AG, Dillingham MF.** MR imaging of cyclops lesions. AJR Am J Roentgenol. 2000 Mar;174(3):719-26. PubMed PMID: 10701615.
12. **Recht MP, Piraino DW, Applegate G, Richmond BJ, Yu J, Parker RD, et al .** Complications after anterior cruciate ligament reconstruction: Radiographic and MR findings. AJR Am J Roentgenol 1996;167:705-10.
13. **Delcogliano A, Franzese S, Branca A, et al.** Light and scan electron microscopic analysis of cyclops syndrome: etiopathogenic hypothesis and technical solutions. Knee Surg Sports Traumatol Arthrosc. 1996; 4(4):194–199.
14. **Delince P, Krallis P, Descamps PY, et al.** Different aspects of the cyclops lesion following anterior cruciate ligament reconstruction: a multifactorial etiopathogenesis. Arthroscopy. 1998; 14(8):869–876.
15. **Balcarek P, Sawallich T, Losch A, et al.** Delayed cyclops syndrome: symptomatic extension block four years after anterior cruciate ligament reconstruction. Acta Orthop Belg. 2008; 74(2):261–265.
16. **Dandy DJ, Edwards DJ.** Problems in regaining full extension of the knee after anterior cruciate ligament reconstruction: does arthrofibrosis exist? Knee Surg Sports Traumatol Arthrosc. 1994;2(2):76-9. PubMed PMID: 7584188.
17. **Cha J, Choi SH, Kwon JW, Lee SH, Ahn JH.** Analysis of cyclops lesions after different anterior cruciate ligament reconstructions: a comparison of the single-bundle and remnant bundle preservation techniques. Skeletal Radiol. 2012 Aug;41(8):997-1002. doi: 10.1007/s00256-011-1347-4. Epub 2012 Jan 5. PubMed PMID: 22218831.
18. **Marzo JM, Bowen MK, Warren RF, et al.** Intraarticular fibrous nodule as a cause of loss of extension following anterior cruciate ligament reconstruction. Arthroscopy. 1992; 8(1):10–18.
19. **Cannon WD Jr, Vittori JM.** The role of arthroscopic debridement after anterior cruciate ligament reconstruction. Arthroscopy. 1991;7(4):344-9. PubMed PMID:1755881.
20. **Fujii M, Furumatsu T, Miyazawa S, Okada Y, Tanaka T, Ozaki T, Abe N.** Intercondylar notch size influences cyclops formation after anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 2015 Apr;23(4):1092-9. doi: 10.1007/s00167-014-2891-y. Epub 2014 Feb 19. PubMed PMID: 24549261.

# Campbell Clinic Orthopaedics is my team's **MVP.**

My team includes three boys, and a husband who still thinks he's 18. I rely on Campbell Clinic to treat breaks, sprains, and all sorts of pains.

Campbell Clinic's team features more than 50 of the world's best orthopaedic specialists. So good, in fact, they actually wrote the book on orthopaedic care.

That's why **I picked the world's best for my team**.

Campbell Clinic®
ORTHOPAEDICS

**OFFICIAL SPORTS MEDICINE PROVIDER**

**Collierville | Germantown | Medical Center | Southaven | Spine Center | CampbellClinic.com**

# Campbell Foundation Achievements


## Jack R. Blair

Chairman, Board of Trustees
Campbell Foundation


Founded by Dr. Willis Campbell's original partners, the Campbell Foundation has worked over seventy years to enhance quality of life for people everywhere through the science of orthopaedic medicine. I've been privileged to work directly with the physicians of Campbell Clinic for more than a decade and a half, and I've seen amazing discoveries made possible in that time. The key, I believe, is an innate curiosity about a clinical observation or problem, combined with determination to find answers. Why is this patient reacting differently to this treatment? If the result is better, how can we ensure that everyone achieves this kind of outcome? These very questions launch the research pursuit and the discoveries follow. Often, the hypothesis that is presented seems almost radical - is it possible that we could expect this kind of result if we make this kind of change?

The story of the Russell-Taylor Intramedullary Femoral nail described in this volume is a great example of the research process. I also had the benefit of leading the team at Smith & Nephew when this project was launched and I saw first-hand the benefits of curious and determined surgeons, combined with a multidisciplinary team of individuals dedicated to finding a better solution to the problem of a complex femoral fracture. The thought of a patient with a femoral fracture lying in traction in the hospital for a month or more seems absurd now, but it was standard practice over 30 years ago. However, the dogged determination of the project team led to revolutionary methods for the treatment of these major fractures.

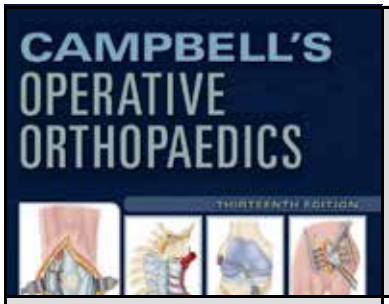
This story is just one reason why the Campbell Foundation is dedicated to supporting research. Not only has it been a part of our heritage since our founding in 1946, but it continues to deliver discoveries and innovation that transform people's lives. Earlier this year, the Campbell Foundation Board of Trustees gathered for a critical review of the achievements of the prior year. We learned of studies examining alternative and multi-modal methods of pain management, ways to enhance bone healing and prevent post-surgical complications, and additional work exploring biological solutions to the problems of osteoarthritis. Results from these projects will appear in future volumes of this journal. All of this work will serve to accelerate the discovery of better answers to challenging clinical questions for patients everywhere.

Reflecting on the past year, we also are excited about the development of a world-class center for the treatment of children with cerebral palsy - a multidisciplinary center that places the patient and his family at the center of the clinical team and brings together all of the various surgeons and therapists and nursing staff to allow the child to grow to his greatest potential. This center, made possible through a transformational gift from the Children's Foundation of Memphis, honors the determined women who wanted to improve the quality of life for a child crippled by polio, who joined forces with Dr. Willis Campbell to build a hospital for crippled children. Now, 100 years later, a new vision has taken shape and advancements and new research are underway.

Ongoing donor support sustains our momentum and can expand our impact. I hope you see the potential of the work in these pages and will join us in our efforts to expand this research. Only through research and innovation will we be able to provide enhanced quality of life for patients everywhere. I invite you to visit the Campbell Foundation website today (campbell-foundation.org), and please give generously to help expand our impact.

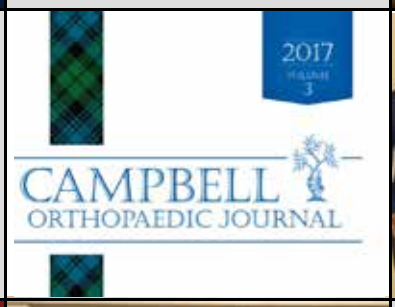
Jack R. Blair, Chairman
Campbell Foundation Board of Trustees

# Thank you, Campbell Alumni




Community Health Care Outreach

Award Winning Research




40 Residents Trained


Thank you for your continued support.

The Campbell Foundation wishes to thank the Alumni who supported our mission in 2017.

Thank you for making an impact!

# Report from Alumni


## Greg Behm, M.D.
Campbell Club President


May, 2018

Dear Campbell Alumni,

Thank you for your continued support of the Campbell Foundation and sustaining its mission of resident education, orthopaedic research, and community healthcare outreach. Your gifts are vital and make the *Campbell Orthopaedic Journal* and the research activity that fills these pages a reality.

As I near the end of my three-year term as Campbell Club President and have become more involved in the Campbell Foundation's work during that time, I realize the importance to financially support the efforts of the Foundation so that the next generation of orthopaedic surgeons has every opportunity to excel. It is our responsibility as alumni to sustain the Campbell tradition of excellence.

During the last three years of Academy meetings and social events, I have had a great time reconnecting with fellow alums and am grateful to have had the opportunity to meet some of the current residents and fellows. We can all be proud of this impressive group of young physicians who will one day lead our chosen field of orthopaedics.

Campbell Clinic has fully matched again this year and the class of 2023 will soon begin their residency journey. I'm excited to learn more about the eight future WCC residents and see the impact that training at Campbell Clinic will have on the lives of these young physicians and their families. I'll certainly never forget a mix of feelings when starting my Campbell residency. If you were like me, you were excited, somewhat confused, cautiously hopeful, and a bit overwhelmed.

Your gifts strengthen the residency program and help provide these young surgeons with the resources and innovative technology essential for their orthopaedic training. Thank you for your continued support and I hope to see you at Triennial in the Fall.

Sincerely,
Greg Behm '99
Campbell Club President

# Campbell Club In Memoriam

Alfons Altenberg, MD
Lewis D. Anderson, MD
Robin Arena, MD
Borden Bachynski, MD
Troy Bagwell, MD
James Barnett, MD
Robert Basist, MD
Henry Beck, MD
Reginald V. Bennett, MD
Dan R. Bigelow, MD
Thomas H. Blake, Sr., MD
W. Griffin Bland, MD
Michael Bluhm, MD
Harrison O. Bourkard, MD
Robert L. Bourland, MD
William J. Bourland, MD
Harold B. Boyd, MD
Hanes H. Brindley, Sr., MD
Robert G. Brashear, MD
Louis P. Britt, MD
Joseph C. Burd, MD
John G. Caden, MD
Rocco A. Calandruccio, MD
Willis C. Campbell, MD
Dan Carlisle, MD
Peter G. Carnesale, MD
Charles O. Carothers, MD
Charles A. Carraway, MD
Paul A. Caviale, M.D.
Tom Phillip Coker, MD
Romulo E. Colindres, MD
Harry Collins, MD
Francis V. Costello, MD
P. Thurman Crawford, MD
A. Hoyt Crenshaw, Sr., MD
Henry I. Cross, MD
Jere M. Disney, MD
Daniel B. Eck, MD
Thomas S. Eddleman, MD
Allen S. Edmonson, MD
E.W. Ewart, MD
W. McDaniel Ewing, MD
Edward L. Farrar, MD
M. Craig Ferrell, MD
Bryan Fleming, MD
Dale E. Fox, MD
Kermit W. Fox, MD
Isaac L. George, MD
Marvin M. Gibson, MD
Gary Giles, MD
A. Lee Gordon, III, MD
Harry R. Gossling, MD
John T. Gray, MD
Basil Griffin, MD
Herbert Alfred Hamel, MD
Joe Frank Hamilton, Jr., MD
Joe Frank Hamilton, Sr., MD
Richard M. Harkness, MD
Benjamin L. Hawkins, MD
David N. Hawkins, MD
C. Leon Hay, MD
Don Henard, MD
Edward D. Henderson, MD
George B. Higley, Sr., MD
Kenneth C. Hill, MD
John T. Hocker, MD
Frank C. Hodges, MD
John M. Hundley, MD
Alvin J. Ingram, MD
E.R. 'Rickey' Innis, MD
Otis E. James, Jr., MD
Leland H. Johnson, Jr., MD
David S. Johnston, MD
Orville N. Jones, MD
Dan Klinar, MD
Robert A. Knight, MD
F. E. Linder, MD
Stanley Lipinski, MD
John F. Lovejoy, MD
William L. Lovett, MD
Harry A. Luscher, MD
Athey R. Lutz, MD
Michael Lynch, MD
H. B. Macey, MD
Paul H. Martin, MD
Juan A. Mayne, MD
James M. McBride, MD
Frank O. McGhee, MD
C. C. McReynolds, MD
I. S. McReynolds, MD
Walter C. Metz, MD
Lee W. Milford, MD
T. Rothrock Miller, MD
Alfred F. Miller, MD
William L. Minear, MD
J. M. Mitchell, MD
Joseph Mitchell, MD
J. M. Mitchner, MD
Larry B. Morrison, MD
James S. Mulhollan
John T. Murphy, MD
Vernon Nickel, MD
Arthur Osborne, MD
W. Martin Payne, MD
Samuel B. Prevo, MD
George D. Purvis, MD
R. Beverly Ray, MD
Thomas A. Richardson, MD
S. L. Robbins, MD
R. C. Robertson, MD
R. C. Rountree, MD
Fred P. Sage, MD
Stanley Schwartz, MD
T. David Sisk, MD
W. H. Sisler, MD
Donald Slocum, MD
Hugh Smith, MD
J. Spencer Speed, MD
William B. Stanton, MD
Marcus J. Stewart, MD
Bruce Stivers, MD
Mario M. Stone, MD
Henry Thomas Stratton, MD
Ernest J. Tarnow, MD
Ethan O. Todd, MD
Robert E. Tooms, MD
Phillip C. Trout, MD
Fredrico Van Domselaar, MD
Isaac L. Van Zandt, MD
John A. Vann, MD
R. H. Walker, Jr., MD
Thomas L. Waring, MD
Gilbert G. Whitmer, MD
James H. Wiley, MD
Frank D. Wilson, MD
Frederick C. Workmon, MD
B. T. Wright, MD

Andrew H. Crenshaw Jr. MD
Editor-in-Chief

www.c-orthopaedicpractice.com

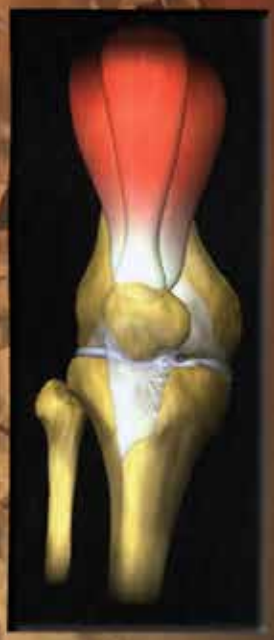
# Current Orthopaedic Practice

A REVIEW AND RESEARCH JOURNAL

## Your Comprehensive Source for Orthopaedic Information

Share your experience and research with your peers in COP

- Reviews - all Orthopaedic Specialties
- Original Research
- Innovations in Practice
- Orthopaedic Pathology
- Case Reports
- Resident Research



Visit our website for a complete table of contents
www.c-orthopaedicpractice.com

Wolters Kluwer Health | Lippincott Williams & Wilkins

**THOMAS R. ACOTT, M.D.**
**Hometown:** San Clemente, CA

**Undergraduate Institution:** University of Illinois at Urbana-Champaign

**Medical School:** Saint Louis University School of Medicine

Dr. Acott is the oldest of six children and the first in his immediate family to pursue a medical career, chosen because it requires complex problem solving combined with the humanistic intent of improving someone else's life.

Dr. Acott found specializing in orthopaedics appealing in that you can improve your patient's function and really affect their quality of life.

**Plans After Campbell:** Dr. Acott will complete a Hand fellowship at Indiana Hand to Shoulder Center.

*"Thank you to all staff, faculty, and co-residents for the education and the experience over the last 5 years."*

---

**JUSTIN D. HALLOCK, M.D.**
**Hometown:** Memphis, TN

**Undergraduate Institution:** Birmingham Southern College

**Medical School:** University of Tennessee Health Science Center College of Medicine

Dr. Hallock is the oldest of three children and the first in his immediate family to pursue a medical career. His choice of a career in medicine dates back to high school where he developed an interest and aptitude in science. This was affirmed when he shadowed an orthopaedic surgeon at Vanderbilt prior to starting college.

He and his wife Melinda, an elementary school teacher, met in a SCUBA diving class in junior year of college. They have two daughters - Libby, three years old, and Logan, two years old – and a son, Brice, born this year.

Dr. Hallock was attracted to specialize in orthopaedics for having the ability to make a diagnosis and fix the problem. A broken bone can be fixed, an arthritic joint can be replaced, and a ruptured tendon can be repaired or reconstructed. All of these problems are extremely painful to the patient but are easily managed and fixed with the skills of an orthopaedic surgeon.

**Plans After Campbell:** Dr. Hallock will complete a Sports Medicine Fellowship at Mississippi Sports Medicine and Orthopaedic Center in Jackson, MS.

*"I want to thank the Clinic for an amazing experience over the last five years. I am truly honored and humbled to have trained at such a prestigious program. Thanks to all the Campbell Clinic Faculty and Campbell Foundation staff for the endless support, guidance, patience, and caring during my training here. You all have made me feel part of a large family and I cannot thank you enough for the experience. I also want to thank my co-residents. You are what make this place so special and enjoyable. We've been through the trenches together developed friendships and bonds over the years that will not be lost. I've learned so much from all of you and you've made me a better person and physician.*

*Lastly and most importantly, I want to thank my wife Melinda for all she has put up with over the last 9 years. Medical school and certainly orthopaedic residency are not easy on a relationship but we made it through. I couldn't have done it without your constant love and support. You've worked a full time job, raised three kids, and managed to take care of me basically on your own. You deserve all the credit. I love you more than anything!"*

**DAVID CHRISTOPHER CARVER, M.D.**
**Hometown:** Johnson City, TN

**Undergraduate Institution:** East Tennessee State University

**Medical School:** East Tennessee State University

Dr. Carver is the third of four children and the first in his immediate family to pursue a medical career. He chose to pursue a career in medicine because he had a strong interest in human anatomy and physiology that fueled a desire to enter a surgical specialty.

He and his wife, Karen, have two daughters, Katelyn, born in March 2016, and Taylor Rae, born March 2018.

Dr. Carver chose to specialize in orthopaedics after witnessing the impact an orthopedic surgeon can have on improving people's function and quality of life.

**Plans After Campbell:** Dr. Carver will complete a sports medicine fellowship at Tahoe Orthopedics and Sports Medicine in Lake Tahoe; he will then return home to the Tri-Cities region of East Tennessee to join Watauga Orthopaedics where he plans to have a general orthopedic practice.

*"I am truly grateful for all the hard work and effort put forth by the faculty and Campbell Clinic staff to ensure that we all become well-trained orthopedic surgeons. It is certainly a time consuming and often thankless process. I also want to thank all of the other residents I've worked with during my five years here – I appreciate all of their hard work and all of the crazy times that have made this a memorable experience."*

---

**TRAVIS W. LITTLETON, M.D.**
**Hometown:** Memphis, TN

**Undergraduate Institution:** Lipscomb University

**Medical School:** University of Tennessee Health Science Center School of Medicine

Dr. Littleton is the oldest of two children; his younger sister is a speech pathologist in Little Rock, Arkansas. The field of medicine allows him to continually learn and better himself while still allowing him to have close relationships with his patients and colleagues.

Dr. Littleton chose to specialize in orthopaedics surgery, in particular, because it allows him to combine what he loves about medicine with the ability to work with his hands. He considers orthopaedic surgery the best specialty in medicine, and he is honored to be able to be a part of this exciting, humbling, and rewarding field.

**Plans After Campbell:** Dr. Littleton will complete a Hand and Upper Extremity fellowship with Dr. Mark Baratz at UPMC in Pittsburgh, PA.

*"I would like to thank my parents for their constant and unwavering support through this entire journey. I could not ask for more understanding, supportive, and loving parents. Thank you, and I love you so much.*

*It has been my honor to train at the Campbell Clinic. It is amazing to train at the same program as many of the founders of orthopaedics. We truly stand on the shoulders of giants here at the Campbell Clinic. I am grateful to have spent the last five years of residency with an institution and staff with the values of "faith, family, and the Campbell Clinic." I would like to specifically thank the Hand staff: Drs. Calandruccio, Jobe, Cannon, and Mauck for their teaching, mentorship, and constant support of my pursuit of a career in hand surgery. Secondly I am grateful to Drs. Beaty, Azar, and Throckmorton for their leadership of the clinic and this fabulous residency. Lastly, I want to say thank you to seven of my closest friends and colleagues. It has been an absolute pleasure to train as your fellow resident. I will miss each one of you but promise to stay in touch."*

**TIMOTHY M. LONERGAN, M.D.**
**Hometown:** Columbia, MO

**Undergraduate Institution:** Saint Louis University

**Medical School:** Saint Louis University School of Medicine

Dr. Lonergan is the oldest of two children. With medicine as a career choice, Dr. Lonergan follows his uncle, who is a physician in Dayton, Ohio.

He chose to pursue a career in medicine and specialize in orthopaedics because of the never ending challenge of keeping the ultimate machine running.

Dr. Lonergan met his wife Hayley, a Physical Therapist, through a mutual friend at Steak 'n Shake. They have been married since 2011.

**Plans After Campbell:** Dr. Lonergan will complete a Foot and Ankle fellowship at Washington University in St. Louis, then move on to a private practice in Bowling Green, Kentucky.

*"To staff: thank you for the time and energy you have given in passing on this education. Your mentorship is so much more than what can be obtained from any book. To residents and fellows: your fellowship through this process made the last five years enjoyable and a period of my life I will never forget."*

---

**A. RYVES MOORE, M.D.**
**Hometown:** Memphis, TN

**Undergraduate Institution:** University of Mississippi

**Medical School:** University of Mississippi School of Medicine

Dr. Moore is the youngest of two children. He is the first in his immediate family to pursue a career in medicine; however, his wife Mary Chris is a nurse practitioner. They have two daughters - four-year-old Darby, and Mary Mason, two years old.

Dr. Moore pursued a career in medicine to help improve the lives of patients.

Dr. Moore chose to specialize in orthopaedics because he enjoys putting back together things that are broken and to see immediate satisfaction in patients' lives after treatment.

**Plans After Campbell:** Dr. Moore will complete a sports medicine fellowship in Birmingham, Alabama.

*"I would just like to say thank you to all of the Campbell Clinic staff for their patience with me during my training and their influence on my future orthopedic career. I would also like to thank the amazing men and women of my residency class who have helped me tremendously over the years and have become life-long friends."*

**ERIN M. MEEHAN, M.D.**
**Hometown:** Atlanta, GA

**Undergraduate Institution:** Clemson University, Clemson, South Carolina

**Medical School:** Mercer University School of Medicine, Macon, Georgia

Dr. Meehan is the youngest of three children. With medicine as a career choice, Dr. Meehan follows her father, a Pediatric Orthopaedic Surgeon who has been practicing for 43 years in Atlanta, Georgia.

Dr. Meehan says she chose to pursue a career in medicine "because I was introduced to medicine at a young age by a wonderful example, my dad. I think interest and curiosity in many professions starts with a parent that is an inspiration. As I grew up, I continued to be fascinated and enamored by the world of medicine and orthopaedic surgery. What started out as inspiration in childhood transformed into my own passion, and my skills with people and the desire to help others developed into my own".

Dr. Meehan chose to specialize in orthopaedics because she very genuinely thinks it is the most interesting and rewarding field of medicine and surgery. The ability to fix things that are broken, correct things that are not working quite the way they were intended, all while improving patients' quality of life, is a unique and special field. Orthopaedic surgery is a specialty that can understand and provide good outcomes.

**Plans After Campbell:** Dr. Meehan will complete a fellowship in Pediatric Orthopaedic Surgery in Atlanta, Georgia, at Children's Healthcare of Atlanta.

*"I wish to thank each and every one of my attendings at the Campbell Clinic as each of them provided me with knowledge and wisdom throughout the course of my residency. In addition, I cannot adequately thank the previous residents who taught me and provided me with a good example as a resident and a doctor. Lastly, I want to thank the current residents for contributing to such a good training experience. Most of all, I want to thank Travis Littleton, for being a fantastic co-resident and my best friend throughout this journey."*

---

**DANIEL B. WELLS, M.D.**
**Hometown:** Macon, Georgia

**Undergraduate Institution:** University of Georgia, Athens, Georgia

**Medical School:** Mercer University School of Medicine - Macon, Macon, Georgia

Dr. Wells is the oldest of four children. With medicine as his career choice, he follows in the footprints of his father, who is an Obstetrics and Gynecology physician.

Dr. Wells chose to pursue a career in medicine because it provides a unique and challenging work environment to interact with and serve the community in which he lives.

Dr. Wells chose to specialize in orthopaedics due in large part to Dr. Larry Medders, an orthopaedic surgeon in Athens, GA, who allowed Dr. Wells to shadow him during college.

**Plans After Campbell:** Dr. Wells will complete a Spine Fellowship with Dr. Frank Eismont at the University of Miami.

*"I would like to thank everyone who has contributed to my education and development not only in medicine, but in life as well. Special thanks to Dr. Willams, Dr. Beaty, Dr. Dabov, and Ms. Kay."*

**TODD K. CONLAN, M.D.**
**Trauma Fellow**

**Hometown:** Virginia Beach, Virginia

**Undergraduate Institution:** The Ohio State University

**Medical School:** University of Toledo College of Medicine

**Orthopaedic Residency:** University of Michigan University Hospital

With medicine as Dr. Conlan's career choice, he follows in the footprints of his father, who is a total joint replacement surgeon in Canton, Ohio. His sister is also a physician. He and his wife Teresa met in college and have been married since 2009.

Dr. Conlan chose to pursue a career in medicine to help people, specializing in orthopaedics to give him a chance to have real, immediate impact on patient care.

**Plans After Campbell:** Dr. Conlan will work as a Traumatologist at a Level 1 or 2 Trauma center.

*"To the residents, thanks showing me the finer parts of Memphis. To the staff, thanks for your patience and teaching at the Med. It was a fun, busy year."*

---

**OLUWATOSIN J. OJO, M.D. • Foot and Ankle Fellow**
**Hometown:** Lagos, Nigeria

**Undergraduate Institution:** Kennesaw State University, Marietta, Georgia

**Medical School:** Northeast Ohio Medical University, Rootstown, Ohio

**Orthopaedic Residency:** Medical College of Georgia

Dr. Ojo is the sixth of seven children. He is the first in his immediate family to pursue a medical career; however his wife Tawanna is also a physician. Together they have two children, Noah Ojo (age 2) and Isabel Ojo (8 months).

Dr. Ojo chose to pursue a career in medicine because it is a service-driven field that continues to evolve as we learn more about ourselves. It is also a very humbling and rewarding field that tasks us to put others first. It is a field that has always appealed to him, and he is very happy that he chose to pursue a career in medicine.

Dr. Ojo chose to specialize in orthopaedics because, "it affords me the opportunity to care for others with musculoskeletal conditions. It has always been a childhood dream of mine and I am very fortunate that dream eventually became a reality."

**Plans After Campbell:** Dr. Ojo will join a private practice in Macon, Georgia.

*"My sincere appreciation to the faculty, especially the foot/ankle attending physicians, Campbell clinic staff and residents. You have all contributed in one way or another to my education here and I am forever grateful. This has been a phenomenal year and it's because of all your hard work and commitment to education. Thank you."*

**JOSEPH INGRAM, M.D.**
**Hand Fellow**

**Hometown:** Hattiesburg, Mississippi

**Undergraduate Institution:** Millsaps College, Jackson, Mississippi

**Medical School:** University of Mississippi School of Medicine, Jackson, Mississippi

**Orthopaedic Residency:** University of Alabama at Birmingham

With medicine as Dr. Ingram's career choice, he joins his brother who is a general surgeon. He and his wife Elizabeth, a physical therapist, met in college and have one daughter, two-year-old Emma Kate.

Dr. Ingram chose to pursue a career in medicine because it's an enjoyable occupation with the opportunity to help others. He chose to specialize in orthopaedics because it suited his skill set and was the most rewarding aspect of medicine that he encountered in his beginning years of training.

**Plans After Campbell:** Dr. Ingram will join a private practice in Birmingham, Alabama.

*"I would like to express my sincerest thanks to all my staff for allowing me the opportunity to work with them and to all the residents, I wish them all the best in all their future endeavors."*

---

**IAN POWER, M.D. • Sports Fellow**
**Hometown:** Albuquerque, New Mexico

**Undergraduate Institution:** University of New Mexico

**Medical School:** University of New Mexico School of Medicine

**Orthopaedic Residency:** University of New Mexico

Dr. Power is the oldest of three children. He is the first in his immediate family to pursue a medical career; however, he has two cousins who are pediatricians. He met his wife Emily, a pharmacist, when they were in the same lab group in Genetics. She noticed his Red Sox hat, and he noticed her Red Sox shirt (they both have family from Massachusetts). They have three children – Connor (5), Logan (3), and Daniel (1 month).

Dr. Power chose to pursue a career in medicine after he left his previous career as a police officer, looking for something challenging while still working with and helping people. Medicine was the perfect combination of applied science and dealing with people.

Dr. Power says he chose to specialize in orthopaedics because "my dad worked in construction, and I was always interested in building things and how they worked. In college I chose the police department because I knew I couldn't work behind a desk. Orthopaedics is very similar. You are working with your hands, collaborating with patients to come up with a treatment plan and hopefully make them better. I felt like other areas of medicine didn't have the positive results of returning people to what is important to them like Orthopaedics does".

**Plans After Campbell:** Dr. Power will join a private practice in Farmington, NM, in the Four Corners region.

*"All of the people at Campbell Clinic have welcomed me for this year. The attendings are all eager to share their experience and time to make you a better doctor. I am indebted to them for making this year great. The residents have all been first class, and indicative of the strength of this residency program."*

**JACQUELINE NGUYEN, M.D. • Foot and Ankle Fellow**
**Hometown:** Atherton, CA

**Undergraduate Institution:** University of California Los Angeles

**Medical School:** Georgetown University School of Medicine

**Orthopaedic Residency:** San Francisco Orthopedic Residency Program

Dr. Nguyen is the oldest of three children. With medicine as a career choice, she follows in the footsteps of her father, who is an orthopaedic surgeon with a subspecialty in spine.

Dr. Nguyen chose to pursue a career in medicine because she wanted to be a doctor since she was six years old. She has always found the human body entirely fascinating and still does. Dr. Nguyen loves helping people, and she believes that medicine is one of the most rewarding careers.

Dr. Nguyen says she chose to specialize in orthopaedics because, "I have always loved the human body, but more specifically, I have always loved the musculoskeletal system, even at a very young age. It is the foundation of movement. I discovered that I really liked biomechanics, as well as using my brain and hands simultaneously to solve a problem. Plus, orthopedic surgeons like to laugh and have fun. When I rotated on ortho as a med student, I felt like I fit right in".

**Plans After Campbell:** Dr. Nguyen will join a private practice in Napa, CA.

*Thank you so much to Dr. Murphy, Dr. Grear, Dr. Richardson, and Dr. Bettin. I learned so much from all of you and had a great time while doing so. I'm so grateful to be part of the Campbell Clinic family. And thank you to Tosin, best co-fellow ever.*

---

**KENT L. WALKER, M.D. • Pediatric Fellow**
**Hometown:** Cincinnati, Ohio

**Undergraduate Institution:** Belmont University, Nashville, TN

**Medical School:** Lincoln Memorial University-DeBusk College of Osteopathic Medicine, Harrogate, Tennessee

**Orthopaedic Residency:** Wellmont Orthopedic Residency Program,Kingsport, Tennessee

Dr. Walker is the oldest of five children. He is the first in his immediate family to pursue a medical career; however, his wife Destiny is a Radiology Technician. Together they have three children, Grant, four years old; Kyntlee, two years old; and Kynadee, nine months old.

Dr. Walker chose to pursue a career in medicine because he has always had a passion to help people. Medicine is a selfless profession that not only gives him the opportunity to help people but also the satisfaction of truly loving what he does.

Dr. Walker chose to specialize in orthopaedics because he is a hands-on learner, and orthopaedics has allowed him the opportunity to use his motor skills in addition to his cognitive skills to help people, especially children.

**Plans After Campbell:** Dr. Walker plans to join a hybrid practice of general orthopaedics and pediatric orthopaedics.

*"I would like to thank the entire pediatric orthopaedic staff at the Campbell Clinic. I am truly blessed to have the opportunity to train at Campbell Clinic. I plan to take the knowledge I learn in fellowship and apply it to the best of my abilities."*

# Superior Strength* and Profile for Uncompromised Performance

## ORTHOLOC™ 2 with 3Di Technology

**Ankle Fracture LP System**

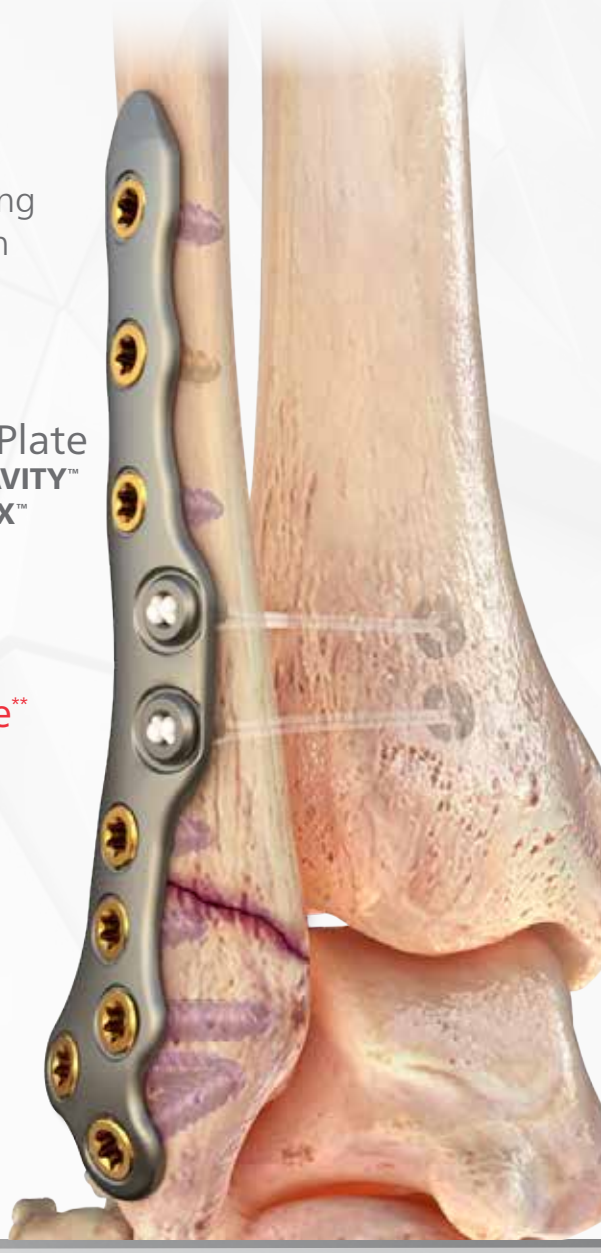
## Anatomic Syndesmotic Fixation

Fibula plates feature offset syndesmosis slots, allowing for centralized tibial fixation and anatomic reduction

## Low-Profile Plating Options

Low-Profile Plates Designed to Reduce Soft Tissue Irritation

Offset Fibula Plate with **GRAVITY™ SYNCHFIX™**



**14%** Decrease in Plate Thickness VS **Competitive** Lateral Fibula Plate**


Competitive Lateral Fibula Plate

ORTHOLOC™ 2 Lateral Fibula Plate

WRIGHT

**Strength***
Type II Ti Alloy Provides Increased Material Fatigue Strength Superior to Color Anodized Ti Alloy & Stainless Steel

**Profile**
Low Profile Plates Designed to Reduce Soft Tissue Irritation

**Speed**
Implants and Instruments Designed to Reduce Steps and Improve Efficiency

WRIGHT™
FOCUSED EXCELLENCE

*Data on file.
** Based on publicly available product literature for Arthrex®
All products not available in all markets.

# Current Orthopaedic Residents

## INTERNS

**Nathaniel B. Alexander, M.D.**
**Undergraduate:** University of Arkansas
**Medical School:** University of Arkansas for Medical Sciences College of Medicine

**Stephanie N. Chen, M.D.**
**Undergraduate:** Case Western Reserve University
**Medical School:** University of Toledo College of Medicine

**Travis B. Eason, M.D.**
**Undergraduate:** North Carolina State University
**Medical School:** Brody School of Medicine at East Carolina University

**Richard A. Hillesheim, M.D.**
**Undergraduate:** Washington University in St. Louis
**Medical School:** Sidney Kimmel Medical College at Thomas Jefferson University

**Austin B. Murphy, M.D.**
**Undergraduate:** Samford University
**Medical School:** University of Alabama School of Medicine

**David L. Parker, M.D.**
**Undergraduate:** Brigham Young University
**Medical School:** University of North Dakota School of Medicine and Health Sciences

**Naveen Pattisapu, M.D.**
**Undergraduate:** University of Texas at Austin
**Medical School:** Baylor College of Medicine

**Devon Tobey, M.D.**
**Undergraduate:** University of Georgia
**Medical School:** Mercer University School of Medicine

## CLINICAL YEAR 2

**J. Stephen Chambers, M.D.**
**Undergraduate:** Georgia Institute of Technology
**Medical School:** Mercer University School of Medicine-Savannah

**Joseph T. Cline, M.D.**
**Undergraduate:** Davidson College
**Medical School:** University of North Carolina at Chapel Hill School of Medicine

**Parker P. Duncan, M.D.**
**Undergraduate:** University of Memphis
**Medical School:** University of Tennessee Health Science Center College of Medicine

**Charles T. Fryberger, III, M.D.**
**Undergraduate:** Auburn University
**Medical School:** University of Alabama School of Medicine

**Matt 'Jejo' Matthew, M.D.**
**Undergraduate:** University of Kansas
**Medical School:** University of Kansas School of Medicine

**S. Gray McClatchy, M.D.**
**Undergraduate:** Mississippi State University
**Medical School:** University of Arkansas for Medical Sciences College of Medicine

**Trenton T. Stevens, M.D.**
**Undergraduate:** University of North Carolina at Chapel Hill
**Medical School:** University of Tennessee Health Science Center College of Medicine

**Carson D. Strickland, M.D.**
**Undergraduate:** University of Georgia
**Medical School:** Mercer University School of Medicine-Savannah

# Current Orthopaedic Residents

## CLINICAL YEAR 3

**Chad E. Campion, M.D.**
**Undergraduate:** Stevens Institute of Technology
**Medical School:** Rutgers New Jersey Medical School

**Ryan B. Eads, M.D.**
**Undergraduate:** University of Kentucky
**Medical School:** University of Kentucky
College of Medicine

**Matthew N. Fournier, M.D.**
**Undergraduate:** University of Wyoming
**Medical School:** University of Washington
School of Medicine

**Peter R. Henning, M.D.**
**Undergraduate:** Marquette University
**Medical School:** Medical College of Wisconsin

**Andrew M. Holt, M.D.**
**Undergraduate:** University of Tennessee
**Medical School:** Baylor College of Medicine

**Catherine R. Olinger, M.D.**
**Undergraduate:** Creighton University
**Medical School:** Creighton University
School of Medicine

**Zachary K. Pharr, M.D.**
**Undergraduate:** Lipscomb University
**Medical School:** University of Tennessee
Health Science Center College of Medicine

**Carson M. Rider, M.D.**
**Undergraduate:** Union University
**Medical School:** University of Tennessee
Health Science Center College of Medicine

## CLINICAL YEAR 4

**Austin R. Davidson, M.D.**
**Undergraduate:** Lipscomb University
**Medical School:** University of Tennessee
Health Science Center College of Medicine

**Steven M. DelBello, M.D.**
**Undergraduate:** Rhodes College
**Medical School:** University of Texas
Medical Center, Houston

**Donald B. Franklin, M.D.**
**Undergraduate:** Samford University
**Medical School:** University of Tennessee
Health Science Center College of Medicine

**Clay G. Nelson, M.D.**
**Undergraduate:** University of North Carolina
**Medical School:** Eastern Virginia Medical School

**Mims G. Oschsner, M.D.**
**Undergraduate:** University of Georgia
**Medical School:** Mercer University
School of Medicine

**Colin W. Swigler, M.D.**
**Undergraduate:** Florida State University
**Medical School:** Florida State
College of Medicine

**Kirk M. Thompson, M.D.**
**Undergraduate:** Rose-Hulman Institute of Technology
**Medical School:** Southern Illinois University
School of Medicine

**Jordan D. Walters, M.D.**
**Undergraduate:** Furman University
**Medical School:** Wake Forest
School of Medicine

When treating pain from osteoarthritis (OA) of the knee, choose

# A SOLUTION FOR YOUR KNEEDS


**Indication**

SYNVISC® (hylan G-F 20) and Synvisc-One® (hylan G-F 20) are indicated for the treatment of pain in osteoarthritis (OA) of the knee in patients who have failed to respond adequately to conservative non-pharmacologic therapy and simple analgesics, e.g., acetaminophen.

**Important Safety Information**

SYNVISC and Synvisc-One are contraindicated in patients with known hypersensitivity to hyaluronan products or patients with infections in or around the target knee.

Hypersensitivity reactions including anaphylactic reaction, anaphylactoid reaction, anaphylactic shock and angioedema have been reported.

Syringe image for illustration purposes only

## VISIT US AT OUR BOOTH

## Exclusively for SYNVISC and Synvisc-One

my SYNVISC ONE

### Inventory Management

- Reminder alerts when it's time to reorder
- Settings for multiple clinics to see and transfer inventory
- Dispensing function

### eOrdering

- Next-day delivery of SYNVISC and Synvisc-One when you order online*

### Benefit Verification

- Fast turnaround: Majority of cases within 4 hours†,‡
- On average, 98% of patient cases that were NOT cancelled received coverage[1,†]

**Please see full Prescribing Information for SYNVISC and Synvisc-One at our booth.**

* If order is placed by 3 PM Eastern Time.
† Based on turnaround data as of January 2017.
‡ If submitted by 1 PM Eastern Time and no prior authorization or additional information required.

**Reference: 1.** Data on file. Genzyme Corporation.



SYNVISC HYLAN G-F 20 | SYNVISC ONE HYLAN G-F 20

# A UNIFIED APPROACH TO **HANDS-ON TRAINING**

**SINCE 1994, MERI HAS BEEN A PIONEER IN FULL-SERVICE SURGICAL TRAINING** FOR MEDICAL DEVICE COMPANIES, MEDICAL SOCIETIES, AND EDUCATION PROGRAMS.

Whether your lab is booked in our 27,000-square-foot facility in Memphis, in our fully equipped mobile lab, or a venue of your choice, you'll have our full complement of:

- State-of-the-art instruments including Orthopedic Power, C-arms and Bovie
- Quality anatomic tissue sourced with integrity from our partner Genesis Legacy Whole Body Donation Foundation
- Highly trained staff to ensure your participants have the most successful experience possible

Visit **MERI.ORG** to learn more and schedule your training.

MERI

MEDICAL EDUCATION & RESEARCH INSTITUTE

*Advancing knowledge. Honoring life.*

MERI | GENESIS

MERI promotes medical education and research for the advancement of medicine with the support of our Genesis Legacy Whole Body Donation Foundation.

Campbell Clinic ORTHOPAEDICS

CAMPBELL FOUNDATION ESTABLISHED 1946