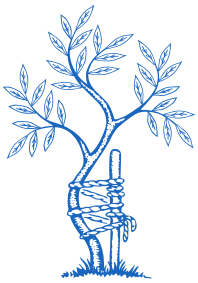
VOLUME 2



CAMPBELL ORTHOPAEDIC JOURNAL

2016

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CAMPBELL ORTHOPAEDIC JOURNAL

Volume 2, May 2016

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Campbell Clinic Orthopaedics • The Campbell Foundation
University of Tennessee-Campbell Clinic Department of Orthopaedic Surgery & Biomedical Engineering

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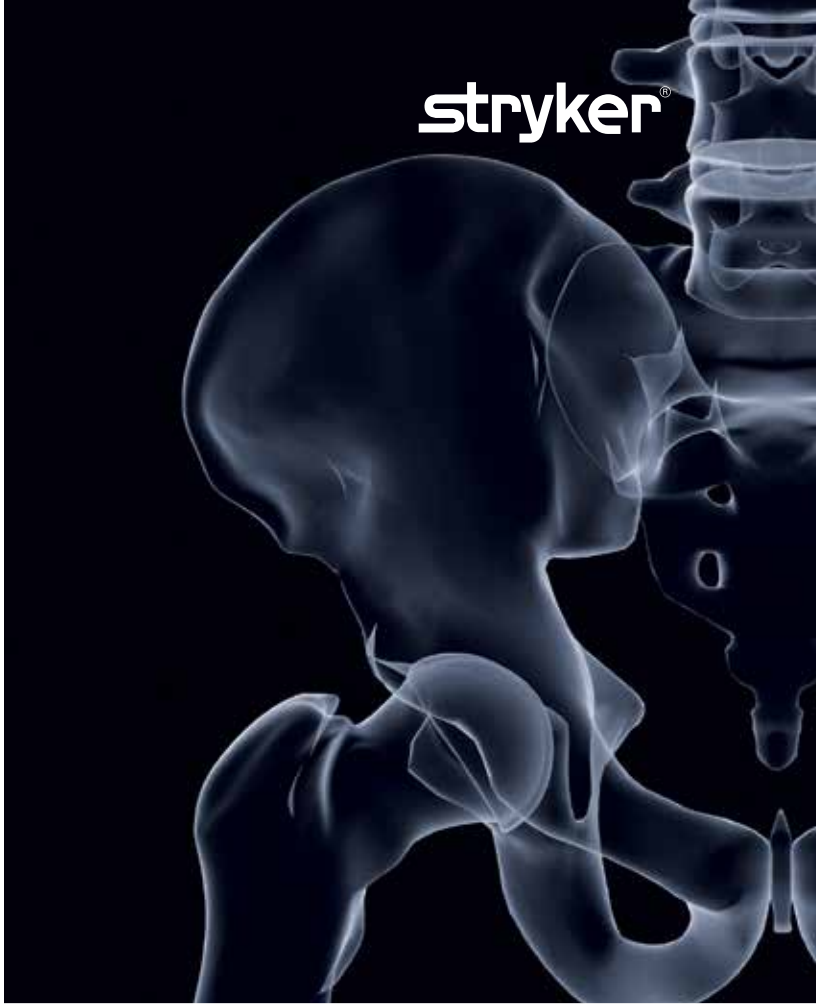

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[1] R. Papannagari, G. Hines, J. Sprague and M. Morrison, "Long-term wear performance of an advanced bearing knee technology," ISTA, Dubai, UAE, Oct 6-9, 2010.
[2] Australian Orthopaedic Association National Joint Replacement Registry Annual report. Adelaide: AOA; 2012.

Letter from the Editor-in-Chief

S. Terry Canale, M.D.

Campbell Foundation President

May, 2016

Dear Colleagues,

I hope that you enjoy this second volume of the Campbell Orthopaedic Journal, a joint publication of the Campbell Foundation, Campbell Clinic and the University of Tennessee-Campbell Clinic Department of Orthopaedic Surgery and Biomedical Engineering. We were inspired to begin this publication in 2015 to highlight research excellence among our staff, residents and fellows. Their ongoing commitment to research fuels innovation that translates to excellent, patient-centered care, vastly improving quality of life. We remain dedicated to the vision that this publication will present original research, and will also provide updates highlighting some of our accomplishments from this last year.

This volume contains 19 original articles and is but a small sample of the publications and presentations made by our staff, residents and fellows nationally and internationally. The first eight articles are the senior projects of our 2016 Graduating Resident Class. Each of these young men will be continuing in a Fellowship program in their chosen orthopaedic subspecialty, and we are proud to claim them as alumni. The journal has been sent to every orthopaedic chairman and program director in the country to add to their libraries, to the more than 600 distinguished alumni of our educational program, and to other donors and friends of the Campbell Foundation.

None of this would be possible without the guidance and support of the physicians, nurses and researchers at Campbell Clinic, the editorial staff of the Campbell Foundation, most notably Kay Daugherty, our editorial director, and the researchers at the University of Tennessee who are pursuing discoveries at the cellular level. We are grateful for their commitment to excellence and the enhancement of quality of life through the science of orthopaedic medicine.

We hope that this edition of the Journal reminds us all of what makes the educational experience at Campbell Clinic so special: the unique features of Memphis, our city on the banks of the muddy Mississippi, where physicians become excellent and compassionate orthopaedic surgeons, learn to pursue answers to curious questions, cultivate enduring friendships, and develop a love of life-long learning.

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

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

I am humbled to step into the role held by so many of my mentors, and those whom I greatly admire. As of April 1, 2016, it is my honor to serve as the ninth chairman of the department founded in 1921 by Willis C. Campbell, MD. During his decade and a half as Chairman, Dr. S. Terry Canale expanded the department, and further sustained the legacy of education and research excellence for which it was known, and I recognize the large shoes that I have to fill.

RESEARCH

Under Dr. Canale's guidance, the department expanded to consist 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 99 scientific articles published in peer-reviewed publications, along with 59 podium presentations, and 28 posters highlighting our research presented at national and international meetings last year. Campbell Clinic continues to collaborate in prominent multicenter studies, and we have attracted both industry- and government-sponsored clinical research studies and grants. Our team will expand this year with the addition of a fifth 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 residents. Fellowships in the subspecialties are available, and we average from 5-8 fellows per year.

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. Beginning this past fall, the Campbell Foundation initiated a Visiting Professor Lecture Series, funded with donor support. This important series, is open to area orthopaedic surgeons, nurses, physicians assistants, engineers and researchers, and 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 continue to publish Campbell's Operative Orthopaedics approximately every four years, with the 13th edition due out in November 2016.

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

Since 1909, the Campbell Clinic has treated patients suffering from musculoskeletal injury and disease both locally and nationally. The tradition of teaching and research begun by our founder, Dr. Willis C. Campbell, continues today. With Dr. James H. Beaty's appointment as Chairman of the UT-Campbell Clinic Department of Orthopaedic Surgery & Biomedical Engineering and the Harold B. Boyd Professor, we proudly continue the legacy established by Dr. Campbell. We offer one of the nation's most competitive residency and fellowship training programs in orthopaedics. This past year, we received more than 850 applications for one of our eight residency positions. We search for compassionate physicians who work to become skilled technicians, but who retain a balance between faith, family, and patient care.

Three years ago, we strategically focused our research efforts, ensuring that our scientific output is both substantial and award-winning garnering national recognition. Improving access for patients through convenience and affordability has long been a critical issue for us. As healthcare seeks solutions to the compound issues of optimal outcomes and cost efficiency, value becomes paramount. We thoroughly examined the safety and outcomes of procedures once performed in an inpatient setting, and several of those procedures may safely be moved to the ambulatory surgery center setting.

The enhancements and physical improvements our organization completed in recent years have worked to reach a singular goal: offering access to quality orthopaedic care for every patient in the Mid-South. Campbell Clinic now operates five outpatient clinics and two ambulatory surgery centers in the Mid-South region and has expanded the access to Shelby County, much of Northwest Mississippi, and Eastern Arkansas. We have added two new staff members this past year-Dr. Norfleet Thompson, a Campbell Clinic alumnus, as a hand specialist and Dr. Henry Sherman, a sports medicine family practice physician.

Our staff continues to improve the patient experience by offering expanded automation for registration, scheduling, and communication. The Germantown and Southaven offices both operate After Hours clinics for the treatment of acute or urgent injuries. In addition, many of our providers offer regular evening additional clinics. These innovations demonstrate our staff's willingness to put the patient first. Unlike our After Hours clinics, which cater to urgent, acute injuries, the evening clinics allow our providers to actually schedule patients during a "third shift." This allows patients to see a specific provider for a specific need at a specific time that is convenient for their busy schedule. This program has been met with a great deal of satisfaction and gratitude from our patients.

Campbell Clinic physicians have taken the lead in the bundled payment care initiative (BPCI) for total joint replacement, and our initial results have been outstanding. Our BPCI Case Manager effectively works with each total joint patient, the patient's support system, and the various providers to coordinate perioperative care. This collaborative approach has enhanced the patient experience, is promoting positive outcomes, and maximizes value to the patient and provider.

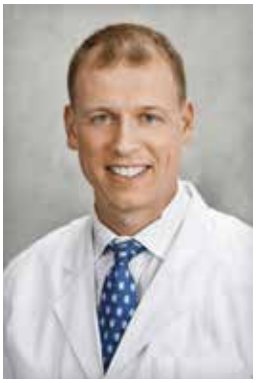
Our outpatient joint replacement program that began more than three years ago continues to be a game-changer for our clinic and its patients. Our total joint surgeons perform hip, knee, and shoulder replacement surgeries on healthy patients in the outpatient setting. The patient is discharged within 23 hours of having their surgery to the comforts of home - most often within eight or fewer hours. In addition to joint replacement, we also continue to perform a number of minimally-invasive spine surgeries in the outpatient setting. The success and safety of this program are the result of collaboration of care that is patient-focused.

In all, we treated more than 170,000 patients in 2015. Our operational and financial successes were a true team effort and remain a testament to the dedication of my partners and our staff.

State of the Residency

Thomas W. 'Quin' Throckmorton, M.D

Orthopaedic Residency Director, Associate 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 550 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. In addition to our responsibilities for teaching residents, we continue to author Campbell's Operative Orthopaedics, now in press for 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 all orthopaedic subspecialties, 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 In-service 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, adult reconstruction, hand surgery, foot and ankle surgery, and spine surgery. And in this era when 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 100 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 have been committed to sharing our research at regional, national, and international meetings, and in academic and scientific publications. In 2015, the program published almost 100 papers and, most recently, won the Charles S. Neer award for shoulder and elbow research and was named Best of the AAOS at the 2016 Annual Meeting in multiple categories.

Our international elective medical mission program continues, with sponsorship of an international community service medical mission. Our residents have served in Nicaragua, Guatemala, Honduras and, this year, Tanzania. In this way, we imbue a commitment to community service within our residents.

This year, we will celebrate the graduation of our 91st residency class, whose members are profiled within this publication. We are proud of these eight skilled orthopaedic surgeons, who all matched into outstanding fellowship programs for subspecialty training. 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 2021 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, M.D.

Dedicated Lectureship Series:

Alvin J. Ingram, MD Memorial Lecture 2015 and 2016

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. The Ingram Lecture was opened 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.

2015 Alvin J. Ingram, MD Memorial Lecture • May 22, 2015

Distinguished Professor: J. Lawrence Marsh, M.D.
Chairman, Professor
Residency Director, Carroll B. Larson Chair
Department of Orthopaedic Surgery
University of Iowa Hospitals & Clinics
Iowa City, Iowa


J. Lawrence Marsh, M.D.

2015 Distinguished Professor, Dr. J. Lawrence Marsh MD, is a renowned expert in trauma treatments and adult reconstruction. He has developed the techniques of minimally invasive articular fracture surgery. Dr. Marsh is the past president of the Mid-American Orthopedic Association and the American Orthopaedic Association (AOA).

Dr. Marsh's lecture, "Tipping Points in Surgical Education and Skills Training", highlighted the historical events that have molded GME programs over the years from the Halsted system to the G.I. Bill. These events, among others, caused GME to cross a threshold or "tip" to a new system. Dr. Marsh discussed the challenges surrounding surgical skills training, the basic educational path and competency training and evaluation. Rather than have unfavorable changes imposed upon the profession, Dr. Marsh challenged orthopaedic leaders to learn from the past, evaluate the present, and mold the future in the development of physicians ready for independent practice.

Another highlight of the 2015 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 2015 Hugh Smith Presentation Award was presented to Dr. Byron Stephens, for "Optimal Baseplate Rotational Alignment for Locking Screw Fixation in Reverse Total Shoulder Arthoplasty: A Three-Dimensional Computer-Aided Design Study".

2016 Alvin J. Ingram, MD Memorial Lecture • May 20, 2016

Distinguished Professor: William J. Maloney, M.D.
Chairman, Professor
Professor, Orthopaedic Surgery
Chairman, Stanford University School of Medicine
Redwood City, CA


William J. Maloney, M.D.

William J. Maloney MD is the Elsbach-Richards Professor in Surgery and the Chairman of Orthopaedic Surgery for Stanford University School of Medicine. He attended undergraduate school at Stanford University, received a medical degree from Columbia College of Physicians and Surgeons, and was a clinical fellow in hip reconstruction surgery at Massachusetts General Hospital.

Dr. Maloney's clinical practice is devoted to improved understanding of the causes of failure of surgical joint replacement with national and international recognition as an expert. The investigations of Dr. Maloney have led to the establishment of a critical link between polyethylene wear debris and bony erosion. His research in the area of joint replacement has twice won awards from the Hip Society.

Dr. Maloney is the first vice president of the American Academy of Orthopedic Surgeons (AAOS) Board of Directors. In addition, he is a member of the Central Program Committee of the AAOS, and he chairs multiple national committees, including the National Hip and Knee Registry Work Group of the AAOS, the Awards and Publications Committee of the Hip Society, and the ABC Exchange Fellowship Subcommittee of the American Orthopedic Association (AOA).

Dr. Maloney will participate in the Total Joint Symposium, and his Keynote Address will be "Surgical Management of the Failed Total Hip Replacement".

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

2015 -2016 Visiting Professor Lecture Series

Lori Karol, MD

"Normal and Abnormal Pediatric Gait"

Assistant Chief of Staff
Medical Director of Performance Improvement
& the Movement Science Laboratory
Texas Scottish Rite Hospital for Children
2222 Welborn St.
Dallas, TX 75219

November 30, 2015
Campbell Foundation Classroom

Brian Wolf, MD

*"Managing Bone Loss in Shoulder Instability"**

Ralph & Marcia Congdon Professor
Vice Chairman, Department of Orthopaedic Surgery
Director, Orthopaedic Sports Medicine Fellowship
University of Iowa
200 Hawkins Drive
Iowa City, IA 52242

January 25, 2016
Folk's Folly Restaurant
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Judy Baumhauer, MD, MPH

"Patient Reported Outcomes in the Accountable Care Era"

Associate Chair of Academic Affairs
Professor, Division of Foot & Ankle Surgery
Department of Orthopaedic Surgery
University of Rochester Medical Center
Medical Director of the PROMIS for UR Health Care System
Rochester, NY 14642

April 4, 2016
Memphis Bioworks Auditorium

Mike Neel, MD

Orthopaedic Oncology

Orthopaedic Surgery Division
St. Jude Children's Research Hospital
orthomemphis
6286 Briarcrest Ave., #200
Memphis, TN 38120

June 13, 2016
Contact Karen Watson to register
(901) 759-3233 or kwatson@campbell-foundation.org

Total Joint Replacement

Speaker to be announced
November 14, 2016
Contact Karen Watson to register
(901) 759-3233 or kwatson@campbell-foundation.org

AAOS Presents Tipton Leadership Award to S. Terry Canale, MD

Dr S. Terry Canale was awarded the William W. Tipton Jr., MD Leadership Award at the 2016 annual meeting of the American Academy of Orthopaedic Surgeons (AAOS) in Orlando. The award was presented by AAOS President David D. Teuscher, MD during the Ceremonial Meeting, and caps a notable career by this renaissance man, known and cherished by so many.

For more than 40 years, Dr. Canale has served his patients, profession and community. He joined the staff of Campbell Clinic in 1974, eventually becoming the chief of staff (1994-2001). Dr. Canale is Professor and Chairman-Emeritus of the University of Tennessee-Campbell Clinic Department of Orthopaedic Surgery & Biomedical Engineering, and is President of the Campbell Foundation. He has made extensive contributions to the orthopaedic literature in journals and textbooks, as well as his memorable editorials in the journal he founded, AAOS Now, the Academy's member newsmagazine. Two of those commentaries earned Gold Awards from the American Society of Healthcare Publications Editors. He is the former president of both POSNA and AAOS and chaired the board of directors of Orthopaedics Overseas (now Health Volunteers Overseas) and the Orthopaedic Research and Education Foundation (OREF).

In 1998, he led the campaign to measure the public's perception of orthopaedic surgery. This survey revealed that orthopaedists were viewed as "high-tech, low touch" specialist. Dr. Canale founded the AAOS Communications Skills Mentoring Program and became a teacher/coach in the program. He championed the Academy's "Sign Your Site" surgical safety program and chaired a task force on wrong-site surgery.

Dr. Canale's service to others extends beyond patients and physicians to the community as well. He serves or has served with 18 civic organizations in and around the Memphis, Tennessee area including St. Peters Orphanage, University Club of Memphis, First City Bank Board of Directors, Synergy Foundation Board of Directors, Shelby County Drug Court, and the Greater Memphis Arts Council.

Over the years, Dr. Canale has been involved in the education of approximately 5,500 medical students, 300 orthopaedic residents, 20 pediatric orthopaedic fellows, and countless national and international observers. It has been estimated that he has treated more than 100,000 patients. Dr James Beaty, past AAOS president and Campbell Clinic colleague, commented that it is impossible to even estimate the number of orthopaedic surgeons he has instructed during AAOS CME courses, skills courses and annual meeting instructional courses.

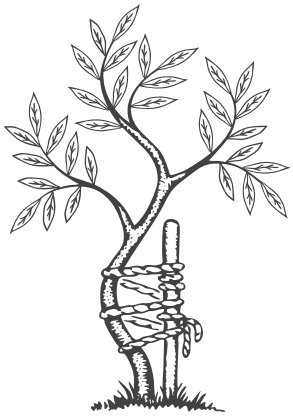
We salute Dr. Terry Canale in his receipt of this well deserved honor.

Neer Award Presented to Quin Throckmorton, M.D., and Collaborators

Earlier this year, Dr. Thomas "Quin" Throckmorton, along with co-authors residents Tyler J. Brolin, MD, and Ryan P. Mulligan, MD, and Campbell Clinic Chief of Staff, Frederick M. Azar, MD were awarded the Charles S. Neer Clinical Science Award for their work entitled, "Outpatient Total Shoulder Arthroplasty in the Ambulatory Surgery Center Environment is a Safe Alternative to the Inpatient Hospital Setting," presented during Specialty Day for the American Shoulder and Elbow Surgeons in Orlando. The abstract of this work is included herein, and will be published later this year in the Journal of Shoulder and Elbow Surgeons.

This research documents that total shoulder replacement in the outpatient setting is comparable to surgery done in the hospital setting in terms of safety. It also sets the stage for ongoing research to measure outcomes and cost-effectiveness for total shoulder arthroplasty in the ambulatory surgery center setting in order to make the value proposition.

Our congratulations are extended to all on the occasion of this prestigious award.



CLASS OF 2016 RESIDENT RESEARCH

Posterolateral Corner Reconstruction Using the Ipsilateral Anterior Tibial Tendon from a Concomitant Below-Knee Amputation

Kaku Barkoh, MD[1]

Anthony A. Mascioli, MD[1]

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

The frequency of ligamentous injuries of the knee in association with high-energy fractures of the femur and tibia has been reported to range from 22% to 48%.[1-6] Because of the more apparent and often life-threatening injuries in patients with polytrauma, these injuries may not be identified in the initial patient evaluation.[7-13] Once recognized, ligamentous injuries resulting in knee instability must be repaired or reconstructed to prevent disabling functional deficits. In this patient with open distal tibial and fibular fractures that ultimately necessitated a below-knee amputation, posterolateral corner reconstruction and arthrodesis of the proximal tibiofibular joint were done to allow efficient use of a below-knee prosthesis.

CASE DESCRIPTION AND SURGICAL TECHNIQUE

A 34-year-old man was brought to our Level 1 trauma center with a pulseless right lower extremity after a motorcycle accident. Orthopaedic examination after stabilization according to ATLS protocol[14] found gross deformity of the right distal tibia and ankle, open anterolateral wounds proximally and distally, and no palpable dorsalis pedis pulse. Radiographs revealed AO type 43-C2 open fractures of the distal tibia and fibula **(Figs. 1A and 1B)**, which were reduced and splinted; after fracture reduction, the dorsalis pedis pulse was palpable. Cefazolin was given for antibiotic prophylaxis. After formal irrigation and debridement, antibiotic beads were placed in the open wounds, both wounds were closed primarily, and the fractures were stabilized with a joint-spanning external fixator. Intraoperative fluoroscopy obtained for proximal fixator pin placement showed joint space asymmetry and posterolateral widening suggestive of ligamentous instability, which was confirmed

Figure 1: A and B: Lateral and A/P views of AO type 43-C2 open fractures of the distal tibia and fibula sustained in a motorcycle accident.

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Figure 2: Harvest of the anterior tibial tendon from the amputated lower limb.

with manual knee examination. A knee immobilizer was placed, and MRI evaluation revealed posterolateral corner (PLC) injury.

Two days after surgery, the soft tissue around the patient's distal tibia and ankle, starting at the open wounds and extending anteriorly and posteriorly, began to devitalize and form eschar. Over the next several days, the necrosis continued to demarcate circumferentially. Before open reduction and definitive fracture fixation, plastic surgery consultation was obtained to assess the options for soft-tissue coverage. Free-flap coverage was recommended, but because of the patient's heavy tobacco use there were concerns about healing. The risks, benefits, and morbidity of open reduction and internal fixation with free-flap coverage were discussed with the patient, and the option of below-knee amputation was presented. After lengthy discussions with the orthopaedic and plastic surgery teams, family members, the hospital chaplain, and a below-knee amputee, the patient opted for amputation.

Eight days after the initial debridement, a standard below-knee amputation[15] was performed, and the anterior tibial tendon was harvested from the amputated lower limb **(Fig. 2)**. Examination of the knee joint through a standard lateral approach found a tear in the lateral capsule, avulsion of the popliteus tendon from the femoral condyle, and tear of the lateral collateral ligament. A suspected subluxation of the proximal tibiofibular joint was confirmed on fluoroscopic imaging, and a fully-threaded 3.5-mm screw with a washer was placed with a lag technique through four cortices to stabilize the joint **(Fig. 3)**. Posterolateral corner reconstruction then was done without complications **(Fig. 4)**.

The patient was kept non-weight-bearing in a cast for 3 weeks, at which time he began gentle range-of-motion exercises. A below-knee prosthesis was fitted at 4 weeks and he began strength and gait training. He regained knee range of motion of 0-90 degrees and reported no subjective symptoms of knee instability. At 4 months after the surgery, he was able to perform all activities of daily living and had returned to his occupation as a tattoo artist.

The patient was informed that data, radiographs, and photographs concerning his case would be submitted for publication, and he agreed to this.

DISCUSSION

This unusual case highlights several important concepts in trauma care. First, in patients with polytrauma, a secondary (tertiary) survey is mandatory to identify injuries that may have been missed on initial evaluation of other more severe injuries. The reported frequency of missed injuries in polytrauma patients ranges from 1% to 42%, with orthopaedic injuries making up 50% to 75%.[7-13] Enderson et al.[8] were the first to describe the concept of a tertiary survey, emphasizing the impor-

Figure 3: Stabilization of the joint with a fully-threaded 3.5-mm screw and washer.

Figure 4: Reconstruction of the PLC.

tance of repeat examinations as trauma patients regain consciousness and become more active. They reported a 9% occurrence of missed injuries in nearly 400 trauma patients, and cited a low index of suspicion by the examiner as a factor in missed injuries. In our patient, the ligamentous knee injury was not discovered on a formal tertiary survey, but a high index of suspicion led to a close inspection of fluoroscopic images and identification of the knee injuries during initial debridement.

The frequency of ligamentous knee injuries in conjunction with femoral and tibial shaft fractures has been well-documented, with reported occurrences of 22% to 48% for femoral fractures[1,2,5,6] and 22% to 36% for tibial fractures.[3,4] A prospective study using MRI evaluation of 25 patients with 27 mid-shaft femoral fractures found internal knee derangement in 19 (70%).[1] We found no report of an association of knee ligament injuries with distal tibial fractures, but, as evidenced by our case, the high-energy trauma required to produce severe open fractures of the distal tibia and fibula also can result in ipsilateral multi-ligament knee injury. This suggests that a thorough knee examination should be performed in all patients with high-energy lower extremity fractures to avoid missing a knee ligament injury that could lead to disabling functional deficiency.

Although a hamstring autograft usually is chosen for PLC reconstruction,[16,17] the anterior tibial tendon autograft obtained from the ipsilateral amputated limb had several advantages in this case: it subjected the patient to no additional surgery for graft harvest, it avoided the morbidity associated with the use of a hamstring graft (myositis ossificans, decrease in semitendinosus muscle mass, strength deficit),[18-20] and it provided a graft with biomechanical strength equivalent to that of a bone-patellar tendon-bone graft.[21-23] In this unusual situation, we were able to achieve a strong, stable reconstruction with minimal morbidity and provide a functional knee joint that allowed our patient efficient use of his below-knee prosthesis.

REFERENCES

1. **Dickson KF, Galland MW, Barrack RL, et al.** Magnetic resonance imaging of the knee after ipsilateral femur fracture. J Orthop Trauma. 2002; 16:567-571.
2. **Kim JG, Lim HC, Kim HJ, Hwang MH, Yoon YC, Oh JK.** Delayed detection of clinically significant posterior cruciate ligament injury after peri-articular fracture around the knee of 448 patients. Arch Orthop Trauma Surg. 2012; 132:1741-1746.
3. **Templeman DC, Marder RA.** Injuries of the knee associated with fractures of the tibial shaft. Detection by examination under anesthesia: a prospective study. J Bone Joint Surg Am. 1989; 71:1392-1395.
4. **Thiagarajan P, Ang KC, Das De S, Bose K.** Ipsilateral knee ligament injuries and open tibial diaphyseal fractures: incidence and nature of knee ligament injuries sustained. Injury. 1997; 28:87-90.
5. **Walker DM, Kennedy JC.** Occult knee ligament injuries associated with femoral shaft fractures. Am J Sports Med. 1980; 8:172-174.
6. **Walling AK, Seradge H, Spiegel PG.** Injuries to the knee ligaments with fractures of the femur. J Bone Joint Surg Am. 1982; 64:1324-1327.
7. **Aaland MO, Smith K.** Delayed diagnosis in a rural trauma center. Surgery. 1996; 120:774-778.
8. **Chen CWS, Chu CM, Yu WY, Lou YT, Lin MR.** Incidence rate and risk factors of missed injuries in major trauma patients. Accid Anal Prev. 2011; 43:823-828.
9. **Enderson BL, Reath DB, Meadors J, Dallas W, DeBoo JM, Maull KI.** The tertiary trauma survey: a prospective study of missed injury. J Trauma. 1990; 30:666-669.
10. **Houshian S, Larsen MS, Holm C.** Missed injuries in a level I trauma center. J Trauma. 2002; 52:715-719.
11. **Lawson CM, Daley BJ, Ormsby CB, Enderson B.** Missed injuries in the era of the trauma scan. J Trauma. 2011; 70:452-456.
12. **Pfiefer R, Pape HC.** Missed injuries in trauma patients: a literature review. Patient Saf Surg. 2008; 2:20.
13. **Thomson CB, Greaves I.** Missed injury and the tertiary trauma survey. Injury. 2008; 39:107-114.
14. **ATLS Subcommittee, American College of Surgeons' Committee on Trauma, and the International ATLS working group.** Advanced Trauma Life Support (ATLS®), 9th edition. Chicago: American College of Surgeons, 2012.
15. **Mihalko MJ.** Amputations of the lower extremity. In: Canale ST, Beaty JH, eds. Campbell's Operative Orthopaedics, 12th edition. Philadelphia, PA: Elsevier, 2013:640-642.
16. **Levy BA, Stuart MJ, Whelan DB.** Posterolateral instability of the knee: evaluation, treatment, results. Sports Med Arthrosc Rev. 2010; 18:254-262.
17. **Miller RH, Azar FM.** Knee injuries. In: Canale ST, Beaty JH, eds. Campbell's Operative Orthopaedics, 12th edition. Philadelphia, PA: Elsevier, 2013:2119, 2132-2133.
18. **Ardern CL, Webster KE, Taylor NF, Feller JA.** Hamstring strength recovery after hamstring tendon harvest for anterior cruciate ligament reconstruction: a comparison between graft types. Arthroscopy 2010; 26:462-469.

19. **Davies JF, Chandramohan M, Groves C, Grogan RJ, Bollen S.** Myositis ossificans as a complication of hamstring autograft harvest for open primary anterior and posterior cruciate ligament and posterolateral corner reconstruction. Knee Surg Sports Traumatol Arthrosc 2011; 19:108-111.

20. **Snow BJ, Wilcox JJ, Burks RT, Greis PE.** Evaluation of muscle size and fatty infiltration with MRI nine to eleven years following hamstring harvest for ACL reconstruction. J Bone Joint Surg Am 2012; 94:1274-1282.

21. **Almqvist KF, Jan H, Vercruysse C, Verbeeck R, Verdonk R.** The tibialis tendon as a valuable anterior cruciate ligament allograft substitute: biomechanical properties. Knee Surg Sports Traumatol Arthrosc 2007; 15:1326-1330.

22. **Caborn DN, Selby JB.** Allograft anterior tibialis tendon with bioabsorbable interference screw fixation in anterior cruciate ligament reconstruction. Arthroscopy 2002; 18:102-105.

23. **Lawhorn KW, Howell SM, Traina SM, Gottlieb JE, Meade TD, Freedberg HI.** The effect of graft tissue on anterior cruciate ligament outcomes: a multicenter, prospective, randomized controlled trial comparing autograft hamtrings with fresh-frozen anterior tibialis allograft. Arthroscopy 2012; 28:1079-1086.

Biomechanical Effects of Two Hip Arthroscopic Capsulotomy Techniques - Interportal vs T-shaped

ABSTRACT

Background: Different arthroscopic capsulotomy techniques may be utilized to better visualize the hip joint. We hypothesized that an unrepaired standard 12-3 o'clock capsulotomy would have more rotational laxity than an unrepaired T-capsulotomy, and that after repair, both techniques would have no significant difference compared to the measured laxity prior to arthrotomy.

Methods: Ten hip specimens had the femur and pelvis potted to simulate a neutral standing position. Native specimens were tested with the femur at full extension and at 90º of flexion using 1.5Nm internal and external rotational torque and a joint compressive force (30N). The specimens were then tested with the following surgical techniques: a standard interportal capsulotomy, a repaired standard interportal capsulotomy, a T-capsulotomy, and a repaired T-capsulotomy. The rotation from the normal neutral position was then compared in the transverse plane to determine the change in rotational laxity of the joint. A Wilcoxon signed rank test with a Holms-Sidak correction was used to determine statistical significance; p-values less than 0.05 were considered significant at the 95% confidence level.

Results: More rotational laxity in external rotation was recorded after the unrepaired T-capsulotomy compared to the unrepaired interportal capsulotomy however this did not reach a significant difference **(Figure 1)**. Six out of twenty suture repairs experienced partial suture failure. There existed a significant greater rotational laxity with internal rotation in both flexion and extension with the unrepaired interportal capsulotomy technique as well as with external rotation and flexion of the unrepaired T-capsulotomy technique. There was no statistically significant difference in laxity between the normal hip and either of the repaired capsulotomy techniques.

Conclusion: This data is important for surgeons to realize that when better access to the joint is necessary it comes with the possibility of more external rotational laxity. Although repair of both techniques offered a normalization of support, suture failures did occur, and external rotation of the joint after surgery may need to be limited until the capsular repair is established.

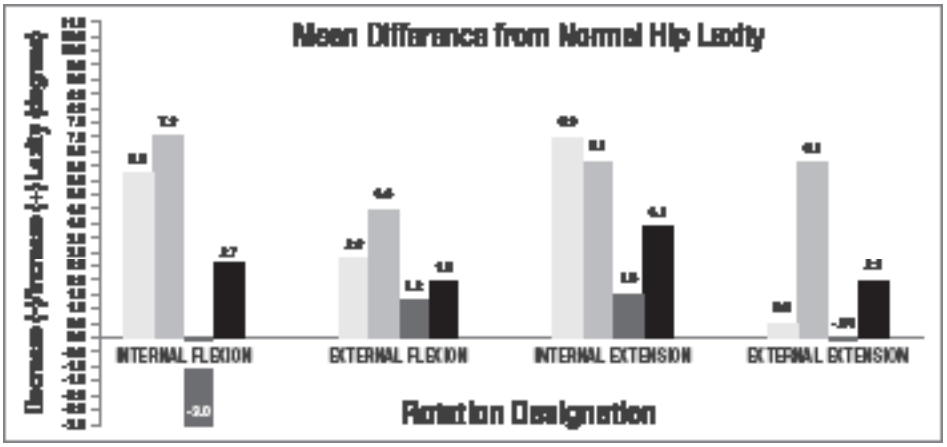

Figure 1: Mean values of paired differences in internal and external deflections from normal at ±10Nm of torque. Error bars represent the standard error of the mean (SEM), and stars represent significant differences.

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REFERENCES

1. **Bedi A, Galano G, Walsh C, Kelly BT.** Capsular management during hip arthroscopy: from femoroacetabular impingement to instability. Arthroscopy. 2011;27(12):1720–1731. doi:10.1016/j.arthro.2011.08.288.
2. **Scopp JM, Moorman CT.** The assessment of athletic hip injury. Clin Sports Med. 2001;20(4):647–659.
3. **Shetty VD, Villar RN.** Hip arthroscopy: current concepts and review of literature. Br J Sports Med. 2007;41(2):64–8– discussion 68. doi:10.1136/bjsm.2006.027755.
4. **Shindle MK, Ranawat AS, Kelly BT.** Diagnosis and management of traumatic and atraumatic hip instability in the athletic patient. Clin Sports Med. 2006;25(2):309–26–ix–x. doi:10.1016/j.csm.2005.12.003.
5. **Philippon MJ, Schenker ML.** Athletic Hip Injuries and Capsular Laxity. Operative Techniques in Orthopaedics. 2005;15(3):261–266. doi:10.1053/j.oto.2005.07.001.
6. **D BGDM, D MJPM, D BDGM.** Arthroscopic Capsulotomy, Capsular Repair, and Capsular Plication of the Hip: Relation to Atraumatic Instability. Arthroscopy. 2013;29(1):162–173. doi:10.1016/j.arthro.2012.04.057.
7. **Shu B, Safran MR.** Hip instability: anatomic and clinical considerations of traumatic and atraumatic instability. Clin Sports Med. 2011;30(2):349–367. doi:10.1016/j.csm.2010.12.008.
8. **Colvin AC, Harrast J, Harner C.** Trends in hip arthroscopy. J Bone Joint Surg Am. 2012;94(4):e23. doi:10.2106/JBJS.J.01886.
9. **Bozic KJ, Chan V, Valone FH, Feeley BT, Vail TP.** Trends in hip arthroscopy utilization in the United States. J Arthroplasty. 2013;28(8 Suppl):140–143. doi:10.1016/j.arth.2013.02.039.
10. **Montgomery SR, Ngo SS, Hobson T, et al.** Trends and Demographics in Hip Arthroscopy in the United States. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2013;29(4):661–665. doi:10.1016/j.arthro.2012.11.005.
11. **Bayne CO, Stanley R, Simon P, et al.** Effect of Capsulotomy on Hip Stability- A Consideration During Hip Arthroscopy. 2014;(April):160–165.
12. **Myers CA, Register BC, Lertwanich P, et al.** Role of the acetabular labrum and the iliofemoral ligament in hip stability: an in vitro biplane fluoroscopy study. Am J Sports Med. 2011;39 Suppl(1_suppl):85S–91S. doi:10.1177/0363546511412161.
13. **Matsuda DK.** Acute iatrogenic dislocation following hip impingement arthroscopic surgery. Arthroscopy. 2009;25(4):400–404. doi:10.1016/j.arthro.2008.12.011.
14. **Ranawat AS, McClincy M, Sekiya JK.** Anterior dislocation of the hip after arthroscopy in a patient with capsular laxity of the hip. A case report. J Bone Joint Surg Am. 2009;91(1):192–197. doi:10.2106/JBJS.G.01367.
15. **Mei-Dan O, McConkey MO, Brick M.** Catastrophic failure of hip arthroscopy due to iatrogenic instability: can partial division of the ligamentum teres and iliofemoral ligament cause subluxation? Arthroscopy. 2012;28(3):440–445. doi:10.1016/j.arthro.2011.12.005.
16. **Mihalko WM, Whiteside LA.** Hip mechanics after posterior structure repair in total hip arthroplasty. Clin Orthop Relat Res. 2004;(420):194–198.
17. **Martin HD, Savage A, Braly BA, Palmer IJ, Beall DP, Kelly B.** The function of the hip capsular ligaments: a quantitative report. Arthroscopy. 2008;24(2):188–195. doi:10.1016/j.arthro.2007.08.024.
18. **Byrd JW, Pappas JN, Pedley MJ.** Hip arthroscopy: an anatomic study of portal placement and relationship to the extra-articular structures. Arthroscopy. 1995;11(4):418–423.
19. **Crawford MJ, Dy CJ, Alexander JW, et al.** The 2007 Frank Stinchfield Award. The biomechanics of the hip labrum and the stability of the hip. Clin Orthop Relat Res. 2007;465:16–22. doi:10.1097/BLO.0b013e31815b181f.

Outpatient Total Shoulder Arthroplasty in the Ambulatory Surgery Center Environment is a Safe Alternative to the Inpatient Hospital Setting: A Matched Cohort Study

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Background: Total shoulder arthroplasty (TSA) is a well-recognized treatment for glenohumeral arthritis. As the health care policy environment continues to evolve, increasing emphasis has been placed on high quality healthcare that can be delivered in a safe and efficient manner. To that end, there has been recent increased interest in outpatient total joint arthroplasty. We proposed to compare a matched cohort of outpatient anatomic total shoulder arthroplasties with those performed in the inpatient hospital setting to evaluate episode-of-care complications.

Methods: Thirty patients underwent outpatient TSA at a freestanding ambulatory surgery center (ASC). An age and co-morbidities matched cohort consisted of 30 patients undergoing TSA in the traditional inpatient hospital setting. Ninety day episode-of-care measures included hospital (re)admissions, reoperations, and complications. Two-tailed t-tests were used to evaluate differences between ASC and inpatient groups. Differences with $p<0.05$ were considered statistically significant.

Results: No statistically significant differences were seen between the ASC and hospital cohorts regarding average age (52.6 vs. 54.2 years), pre-operative American Society of Anesthesiologists (ASA) score (2.1 vs. 2.3), operative indication, and body mass index (31.6 vs. 31.5). None of the patients required re-operation. There were no hospital admissions from the ASC cohort and no re-admissions from the hospital cohort. There were 3 minor complications in the ASC cohort including 2 cases of arthrofibrosis and 1 patient with mild asymptomatic anterior subluxation. There was 1 major complication in an outpatient who fell at 11 weeks postoperatively and disrupted his subscapularis repair. There were 3 minor complications in the hospital cohort including mild asymptomatic anterior subluxation, blood transfusion, and superficial vein thrombosis. The complication rate (13% vs. 10%, P=1.0) was not statistically significant between groups. There were no cardiopulmonary complications in either group.

Conclusions: This study demonstrates that TSA performed in the outpatient ASC setting is a safe alternative to hospital admission in appropriately selected patients. Further investigation is warranted to evaluate the longer term outcomes and cost-effectiveness of TSA performed on an outpatient basis.

Level of Evidence: Level III, Retrospective Cohort Design

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REFERENCES

1. **Aldinger PR, Raiss P, Rickert M, Loew M.** Complications in shoulder arthroplasty: an analysis of 485 cases. International Orthopaedics 2010:34;517-24.
2. **Anthony CA, Westermann RW, Gao Y, Pugely AJ, Wolf BR, Hettrich CM.** What are risk factors for 30-day morbidity and transfusion in total shoulder arthroplasty? A review of 1922 cases. Clin Orthop Relat Res 2015:473;2099-2105.
3. **Aynardi M, Post Z, Ong A, Orozco F, Sukin DC.** Outpatient surgery as a means of cost reduction in total hip arthroplasty: a case –control study. HSS J 2014:10;252-5.
4. **Belmont Jr PJ, Goodman GP, Waterman BR, Bader JO, Schoenfeld AJ.** Thirty-day postoperative complications and mortality following total knee arthroplasty: incidence and risk factors among a national sample of 15,321 patients. J Bone Joint Surg Am 2014:96;20-6.

5. **Berend ME, Berend KR, Vombardi Jr AV.** Advances in pain management: game changers in knee arthroplasty. Bone Joint J 2014:96B(11SupplA);7-9

6. **Berger RA, Kusuma SK, Sanders SA, Thill ES, Sporer SM.** The feasilibility and perioperative complications of outpatient knee arthroplasty. Clin Orthop Relat Res 2009:467;1443-9.

7. **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.

8. **Chalmers PN, Gupta AK, Rahman Z, Bruce B, Romeo AA, Nicholson GP.** Predictors of early complications of total shoulder arthroplasty. The Journal of Arthroplasty 2014:29;856-860.

9. **Chin PYK, Sperling JW, Cofield RH, Schleck C.** Complications of total shoulder arthroplasty: are they fewer or different? J Shoulder Elbow Surg 2006 Jan/Feb 19-22.

10. **Courtney PM, Rozell JC, Melnic CM, Lee GC.** Who should not undergo short stay hip and knee arthroplasty? Risk factors associated with major medical complications following primary total joint arthroplasty. The Journal of Arthroplasty 2015 in press.

11. **Cross MB, Berger R.** Feasibility and safety of performing outpatient unicompartmental knee arthroplasty. International Orthopaedics 2014:38;443-7.

Preoperative MRI as a Prognostic Factor for Outcomes of Core Decompression for Osteonecrosis of the Femoral Head

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Introduction: Osteonecrosis of the femoral head (ONFH) is a potentially debilitating condition that is commonly progressive, leading to early joint destruction and the eventual need for total hip arthroplasty (THA). Due to the high rate of failure after non-operative treatment, hip core decompression has become a common pre-collapse surgical technique. However, failures are common and literature to guide the surgeon to appropriately select a patient for hip core decompression is limited. The aim of this study was to examine how pre-operative MRI findings correlate with outcomes of a modified core decompression technique.

Methods: Inclusion criteria are patients with a preoperative MRI, Steinberg stage I or II osteonecrosis, and greater than 1 year of documented follow-up. Patients who had a previous history of acetabular surgery or hip trauma were excluded. All pre-operative MRIs were interpreted by a musculoskeletal-trained radiologist. Patients were stratified according to percent involvement of the femoral head (0-15%, 15-30%, >30%) and hip effusion grade (0-3). The lead surgeon performed core decompression with a modified technique on all patients. Standard operative and post-operative protocols were used. Failure of procedure is defined as the patient needing a total hip arthroplasty. Fisher's exact test and multivariate logistic regression were used for statistical analysis with p-values < 0.05 considered significant.

Results: One hundred patients were included with an average follow up of 40 months (12 to 97 months). Forty-two of one hundred (42%) underwent THA. Increased grade of effusion was an independent risk factor for THA (OR=2.30, 95% CI (1.27-4.18), p=0.006). THA was ultimately necessary in 1/13 (8%) patients with grade 0 effusion, 17/42 (42%) grade 1, 12/35 (34%) grade 2, and 12/12 (100%) grade 3. Percent involvement of the femoral head was also an independent risk factor for THA (OR=4.66, 95% CI (2.07-10.52), p<0.001). THA was performed in 0/17 (0%) of patients with 0-15% head involvement, 10/32 (31%) with 15-30% head involvement, and 32/51 (63%) with >30% head involvement. There were no failures in patients (0/10) with grade 1 or less effusion and <15% femoral head involvement, p<0.001. Patients with grade 2 or higher effusion and >30% femoral head involvement underwent THA in 20/29 (69.0%) patients, p<0.001.

Discussion and Conclusion: Grade of hip effusion and percent involvement of the femoral head are prognostic indicators of success/failure of core decompression for ONFH. Patients with minimal hip effusion and/or minimal involvement of diseased femoral head should be counseled to undergo a less invasive procedure like core decompression. Conversely, patients with a large hip effusion or significant amount of diseased femoral head may be better served with total hip arthroplasty.

Multivariate Analysis	Failure of Procedure	p-value
Grade <1 effusion and <15% head involvement	0% (0/10)	<0.001
Grade >2 effusion and >30% head involvement	69% (20/29)	<0.001

% Involvement of Femoral Head**	Failure of Procedure
0-15%	0% (0/17)
15-30%	31% (10/32)
>30%	63% (32/51)

**Independent risk factor for THA (OR=4.66, 95% CI (2.07-10.52), p<0.001)

Grade of effusion*	Failure of Procedure
0	8% (1/13)
1	42% (17/42)
2	34% (12/35)
3	100% (12/12)

*Independent risk factor for THA (OR=2.30, 95% CI (1.27-4.18), p=0.006)

REFERENCES

1. **Steinberg ME, Larcom PG, et al: Core decompression with bone grafting for osteonecrosis of the femoral head.** Clinical Orthop 386: 71-78, 2001.
2. **Arlet J, Ficat RP: Forage-biopsie de la tete femorale dans l'osteonecrose primitive.** Observations histo-pathologiques portant sur huit foranes. Rev Rhum Ed Fr 31:257-264, 1964.
3. **Ficat RP: Idiopathic bone necrosis of the femoral head.** J Bone Joint Surg 67B:3-9, 1985.
4. **Mont MA, Carbone JJ, Fairbank AC: Core Decompression versus nonoperative management for osteonecrosis of the hip.** Clin Orthop 323:169-178, 1996.
5. **Chandler HP, Reinreck FT, Wixson RL, McCarthy JC: Total hip replacement in patients younger than thirty years old.** A five year follow up study. J Bone Joint Surg 63A:1426-1434, 1981.
6. **Mankin HJ: Nontraumatic necrosis of bone (osteonecrosis).** New Engl J Med 326:1473-1479, 1992.
7. **Solacoff D, Mont MA, Krackow KA: Uncemented total hip arthroplasty in patients less than 45 years with avascular necrosis.** Orthop Trans 17:1085, 1993-1994.
8. **Camp JF, Colwell Jr CW: Core decompression of the femoral head for osteonecrosis.** J Bone Joint Surge 68A:1313-1319, 1986
9. **Hopson CN, Siverus SW: Ischemic necrosis of the femoral head.** Treatment by core decompression. J Bone Joint Surg 70A:1048-1051, 1988.
10. **Robinson Jr HJ, Springer JA: Success of core decompression in the management of early stages of avascular necrosis: A four-year prospective study.** Orthop Trans 16:707, 1992-1993.
11. **Stulberg BN, Davis AW, Bauer TW, Levine M, Easley K: Osteonecrosis of the femoral head.** A prospective randomized treatment protocol. Clin Orthop 268:140-151, 1991.
12. **Lieberman JR: Core decompression for osteonecrosis of the hip.** Clin Orthop 418:29-33, 2004.
13. **Lieberman JR, Bery DJ, Mont MA, et al: Osteonecrosis of the hip: Management in the twenty-first century.** J Bone Joint Surg 15:834-853, 2002.
14. **Koo KH, Kim R, Ko GH, Song HR, Cho JH.** Preventing collapse in early osteonecrosis of the femoral head: A randomized clinical trial of core decompression. J Bone Joint Surg. 1995;77B:870-874.
15. **Fairbank AC, Bahtia D, Jinnah RH, Hungerford DS.** Long-term results of core decompression for ischemic necrosis of the femoral head. J Bone Joint Surg. 1995;77B:42-49.
16. **Smith SW, Fehring TR, Griffin WI, et al.** Core decompression of the osteonecrotic femoral head. J Bone Joint Surg. 1995;77A:674-680.
17. **Marker DR, Seyler TM, Ulrich SD, Srivastava S, Mont MA.** Do modern techniques improve core decompression outcomes with hip osteonecrosis? Clin Orthop. 2008;466:1093-1103.
18. **Mont MA, Lonner JH, Ragland PS.** Osteonecrosis of the hip. In: Barrack RL, editor. Orthopaedic knowledge update: hip and knee reconstruction 3. 3rd ed. Rosemont (IL): American Academy of Orthopaedic Surgeons; 2006:511-519.
19. **Chiu KH, Shen WY, Ko CK, Chan KM.** Osteonecrosis of the femoral head treated with cementless total hip arthroplasty. A comparison with other diagnoses. J Arthroplasty 1997;12:683-688.
20. **Rajagopal M, Samora JB, Ellis TJ.** Efficacy of core decompression as treatment for osteonecrosis of the hip: a systematic review. Hip Int 2012;22:489-493
21. **Saito S, Ohzono K, Ono K.** Joint-preserving operations for idiopathic avascular necrosis of the femoral head. Results of core decompression, grafting, and osteotomy. J Bone Joint Surg Br. 1988;70:78-84.
22. **Smith SW, Meyer RA, Connor PM, Smith SE, Hanley EN.** Interobserver reliability and intraobserver reproducibility of the modified Ficat classification system of osteonecrosis of the femoral head. J Bone Joint Surg 1996;78:1702-1706.
23. **Yoon TR, Song EK, Rowe SM, Park CH.** Failure after core decompression in osteonecrosis of the femoral head. Int Orthop 2001;24:316-318.
24. **Mitchell DG et al.** MRI of joint fluid in the normal and ischemic hip. American Journal of Roentgenology 1986;146:1215-1218.
25. **Steinberg ME, Brighton CT, Hayken GD, Tooze SE, Steinberg DR.** Early results in the treatment of avascular necrosis of the femoral head with electrical stimulation. Orthop Clin North Am 1984;15:163-175.
26. **Glimcher MJ, Kenzora JE.** The biology of osteonecrosis of the human femoral head and its clinical implications. III. Discussion of etiology and genesis of the pathological sequelae: comments on treatment. Clin Orthop 1979;140:273-312.
27. **Chan WP, Liu YJ, Huang GS, Jiang CC, Huang S, Chang YC.** MRI of joint fluid in femoral head osteonecrosis. Skeletal Radiol 2002;31:624-630.

Safety and Cost-effectiveness of Outpatient Unicompartmental Knee Arthroplasty in the Ambulatory Surgery Center: A Matched Cohort Study

Background: Unicompartmental knee arthroplasty (UKA) has an established track record for pain relief and improved function in patients with unicompartmental osteoarthritis of the knee. Historically, UKA was performed in the inpatient hospital setting. However, with renewed emphasis on procedural safety, efficiency, and cost effectiveness in the healthcare industry, many surgeons and patients are finding the ambulatory surgery center (ASC) to be a viable option for arthroplasty procedures. We proposed to compare a matched cohort of outpatient ASC UKA's with those performed in the inpatient hospital setting to evaluate episode-of-care complications. We also proposed to investigate our ASC UKA total facility charges.

Methods: Sixty-seven patients underwent UKA performed by one of two surgeons at a freestanding ASC. An age and co-morbidities- matched cohort included 48 patients undergoing UKA in the standard inpatient hospital setting. Ninety day episode-of-care measures included complications, hospital (re)admissions, and reoperations. Total facility charges were evaluated for all ASC patients. Statistical differences ($p<0.05$) between the ASC and inpatient groups were determined by two-tailed t-tests.

Results: The ASC and hospital cohorts revealed no statistically significant differences with respect to age (58.8 vs 59.4), sex (15M/33F vs 20M/28F), BMI (34.3 vs 32.9), and preoperative ASA scores (1.94 vs 2.08). One minor complication was noted in the ASC group including one superficial stitch abscess. There were no major complications in the ASC group and no patients required hospital admission or reoperation. In the hospital cohort there was one minor complication: a superficial skin rash. Four major complications were noted: one deep venous thrombosis (DVT), one pulmonary embolus (PE), one acute postoperative infection, and one postoperative periprosthetic fracture. All four of the hospital cohort patients with complications required readmission, while two of the hospital cohort patients required reoperation. The average total charge for all ASC patients was $29,475.14.

Discussion: These results demonstrate that outpatient UKA in the ASC is a safe and reasonable alternative to UKA performed in the traditional inpatient hospital setting. Additionally, the average total charge for UKA in the ASC compares favorably to reported inpatient total charges for UKA and total knee arthroplasty in the literature. Despite our favorable short-term results with UKA in the ASC, further investigation is required to address the long-term safety and cost-effectiveness of UKA performed in the ASC setting.

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REFERENCES

1. **Berger RA, Meneghini RM, Jacobs JJ, et al.** Results of unicompartmental knee arthroplasty at a minimum of ten years follow up. J Bone Joint Surg Am 2005;87(5):999
2. **Gondusky JS, Leera C, Gorab R, et al.** Day of surgery discharge after unicompartmental knee arthroplasty: An effective perioperative pathway.
3. **Lyons MC, MacDonald SJ, Somerville LE, et al.** Unicompartmental vs total knee arthroplasty database analysis: is there a winner? Clin Orthop 2012;470(1):84
4. **Brown NM, Sheth NP, Davis K, et al.** Total knee arthroplasty has higher postoperative morbidity than unicompartmental knee arthroplasty: a multicenter analysis. J Arthroplasty 2012;27 (8 Suppl 1):86
5. **Berger RA, Kusuma SK, Sanders SA, et al.** The feasibility and perioperative complications of outpatient knee arthroplasty. Clin Orthop 2009;467 (6): 1443
6. **Lovald ST, Ong KL, Malkani AL, Manley MT, et al.** Complications, mortality, and costs for outpatient and short-stay total knee arthroplasty patients in comparison to standard-stay patients. J Arthroplasty 2014;29:510-515
7. **Cross MB, Berger R.** Feasibility and safety of performing outpatient unicompartmental knee arthroplasty. SICOT 2014;38:443-447
8. **Dervin GF, Madden SM, Crawford-Newton BA, et al.** Outpatient unicompartmental knee arthroplasty with indwelling femoral nerve catheter. J Arthoplasty 2012;27(6):1159

9. **Weinstein AM, Rome BN, Reichmann WM, Losina E, et al.** Estimating the burden of total knee replacement in the United States. J Bone Joint Surg Am, 2013;95:385-92

10. **Berger RA, Sanders SA, Thill ES, Della Valle C, et al.** Newer anesthesia and rehabilitation protocols enable outpatient hip replacement in selected patients. Clin Orthop Relat Res 2009;467: 1424-1430

11. **Kolisek FR, McGrath MS, Jessup NM, Mont MA, et al.** Comparison of outpatient vs inpatient total knee arthroplasty. Clin Orthop Relat Res 2009;467:1438-1442

12. **Dorr LD, Thomas DJ, Zhu J, Long WT, et al.** Outpatient total hip arthroplasty. J Arthroplasty 2010;25:501-506

13. **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.

Orthopaedic Surgeon Modularity Utilization and Surgical Technique Considerations in the Face of Implant Corrosion*

ABSTRACT

The use of modular femoral components for total hip arthroplasty (THA) allows surgeons to adjust leg lengths, restore anatomy, and improve stability through alterations in femoral offset, neck length, and version; however, corrosion, fretting, and fatigue failure have raised concerns about these implants. To determine surgeons' opinions and trends regarding the use of modularity in THA, during 2013 and 2014 surveys were sent to AAOS fellows to investigate the use of modularity in THA. The survey included questions regarding technique and basic science knowledge of modular components. Results from 2013 and 2014 were compared to evaluate trends in modular component use. Ninety-nine surgeons (2013) and 106 surgeons (2014) responded, more than 93% of whom routinely perform THA. Over 50% of respondents were fellowship trained. Most respondents (> 87%) in both years reported that they had used a modular implant, either when absolutely necessary (<5% of time) or routinely (>50% of time). From 2013 to 2014, the routine use of modular implants decreased. In 2014, a higher percentage of surgeons reported concerns over debris and stem breakage and more chose ceramic heads over metal heads. Most respondents reported locking the femoral head with one or more forceful hits. When corrosion was noted on the taper during revision cases, most surgeons retained the femur while cleaning the taper with either a sponge or bovie scratch pad. Some respondents applied an additional metal taper sleeve between the damaged taper and the new femoral head; 93.9% of respondents reported cleaning and drying the taper prior to head insertion. These results demonstrate that modular implants are widely used in THA, either occasionally or routinely. The number of surgeons routinely using modular implants remains high, making education regarding debris production and breakage with modular stems a necessity.

KEYWORDS: total hip arthroplasty, modular components, usage trends, technique

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INTRODUCTION

The development of modular femoral components for total hip arthroplasty (THA) has allowed surgeons to intraoperatively adjust leg lengths, restore anatomy, and improve stability through changes in femoral offset, neck length, and version; however, corrosion, fretting, and fatigue failure with dual modular components have raised concerns about these implants. Increased revision rates have been reported with some dual-taper modular-neck femoral components for THA[1,2,3], raising questions about whether adding modularity is necessary, or even desirable, in THA and TKA surgery. If long-term outcomes are not improved, we should rethink the directions that implant designs are taking and whether newer designs need more stringent guidance and post-market surveillance. For example, post-market research identified the interface of modular-neck femoral components with the tapered junction in the Stryker Rejuvenate system as a potential source of metal fretting and crevice corrosion, leading to adverse local tissue reactions and device failure. In 2012, citing the risk of fretting and corrosion associated with the Rejuvenate and ABG II modular-neck hip stems, Stryker issued a voluntary recall of both stems[4]. DePuy, in 2010, issued a recall of both of its ASR hip systems, citing higher-than-normal failure rates due to implant loosening, implant erosion,

and metallosis[5].

Surgeons today have increased access to modular options for primary arthroplasty procedures, but the frequency of modular implant use is relatively unknown. As modular component use increases, the need for surgeon education also increases. We proposed to investigate surgeons' opinions and trends regarding the use of modularity in THA.

METHODS

During 2013 and 2014, the AAOS survey system was used to investigate fellows' perceptions and experiences regarding the use of modularity in THA. A total of 604 fellows were invited to participate (99 fellows participated in 2013 and 106 in 2014). Participants were first asked if they perform joint reconstruction surgery. Those who performed total joint reconstruction surgery were then asked questions regarding society memberships, fellowship training, and their use of implants that use modularity with a metal-metal taper junction. The surgeons who did use modular metal-metal components were then asked to continue the survey.

Participants who reported using modular implants were then asked about the frequency of modular component use, and their knowledge on modular implant production of metal particulate debris was tested. Surgeons also were asked how they lock femoral heads onto metal tapers and how they deal with obvious fretting and corrosion debris on a well-fixed stem during revision procedures.

Several true/false questions were included in the survey which aimed at investigating participants' knowledge regarding the interchangeability of varying components and alloys, particulate debris with single compared to dual modular components, debris generation from the use of varying modular alloys, and tissue reaction from generation of metal debris. Participants also were asked how they prepare the taper junction before femoral head impaction.

Finally, participants were asked how their use of modular implants has changed over the past 12 months. Specifically, they were asked if their use of femoral heads larger than 36 mm has decreased, if their use of modularity has decreased, and if their use of ceramic heads has increased because of concerns regarding modularity reported in the literature.

RESULTS

Of the 604 surgeons invited to participate in the survey during 2013 and 2014, 99 responded in 2013 and 106 surgeons in 2014. In 2013, 93% of the respondents reported performing joint reconstruction surgery, which increased to 99% in 2014. Only those who performed total joint reconstruction procedures proceeded with the rest of the survey. In 2013, 38 of the respondents belonged to a joint reconstruction subspecialty society while in 2014 58 of the 106 respondents belonged to a society. Almost all respondents who belonged to a society were members of the American Association of Hip and Knee Surgeons (AAHKS). Over half—50.5% in 2013 and 61.9% in 2014—of those who performed total joint reconstructions were fellowship trained. Finally, of those surgeons performing total joint reconstruction, 87% (2013) and 94.3% (2014) used some type of modular implant with a metal/metal taper junction.

When questioned regarding the frequency of modular implant use, 29.6% (2013) and 40.4% (2014) of respondents used modularity only when necessary, while 45.7% (2013) and 36.4% (2014) routinely used a modular taper junction. The remaining surgeons used modularity infrequently (19.8% in 2013 and 14.1% in 2014) or on a semi-routine basis (4.9% in 2013 and 9.1% in 2014).

Respondents were asked about the potential hazards of using modular implants: 54.3% (2013) and 38.4% (2014) reported that negligible particulate debris was produced by metal taper junctions, and 35.8% (2013) and 40.4% (2014) agreed that a modular metal taper junction is a weak link in the reconstructive device. When asked if modular metal taper junctions were a source of osteolysis that could jeopardize implant survival, 97.5% (2013) and 93.9% (2014) of respondents agreed. Finally, 7.4% (2013) and 15.2% (2014) of surgeons agreed that the amount of debris generated from a metal taper modular junction is of major concern, thus causing the respondents to seldom use modularity.

Respondents to the 2014 survey were asked about which method they use to lock a femoral head to the stem-taper junction: 25% reported using one heavy impaction force in line with the taper neck, and 68% reported using several mallet hits in line with the taper neck. The remaining respondents (5%) reported that they did not pay attention to the direction of the impacted force because of a minimally invasive approach or other various reasons. Most respondents (93.9%) also reported that they clean and dry the taper junction before impacting it on the femoral head.

Respondents to the 2014 survey were asked about their preferred method for addressing taper corrosion debris during revision procedures: 17.2% reported cleaning the taper with a bovie scratch pad and placing

Table 1: Responses to True/False Questions in 2013 and 2014 (% of respondents)

	Question # 1		Question # 2		Question # 3		Question # 4	
	2013	2014	2013	2014	2013	2014	2013	2014
True	22.2	22.2	3.7	2.0	13.6	7.1	30.9	24.1
False	77.8	77.8	96.3	98.0	86.4	92.9	69.1	75.8

Question 1: Modular metal taper junctions are standardized and interchangeable between manufacturers as long as the taper is of the same measure.
Question 2: During a hip reconstruction procedure, using multiple metal taper junctions produces the same amount of debris as the same construct with one modular taper, since they are subjected to the same loads.
Question 3: The wear debris and corrosion generated by a metal modular taper junction is only of concern when two dissimilar alloys are used.
Question 4: In a metal/metal articulating THA the modular head neck taper junction does not significantly contribute to the generation of metal wear debris or acute local tissue reaction.

a new femoral head on the femoral stem, 19.2% reported revising well-fixed femoral stems with obvious corrosion debris, 33.3% reported cleaning the taper with a laparotomy sponge and placing a new femoral head on the taper, and 30.3% reported using a metal taper sleeve between the damaged taper and a new femoral head.

Respondents in both 2013 and 2014 were asked a series of true/false questions concerning their knowledge of the basic science of modular implants **(Table 1)** and three questions true/false questions regarding how their use of modular implants has changed over the 12 months prior to completion of the survey **(Table 2)**.

DISCUSSION

The use of modular implant designs in primary and revision THA has become commonplace because of the intraoperative flexibility they provide. A modular head-neck junction allows customization of leg length, offset, and version, as well as the use of varying metallic or ceramic head options. The component taper also allows for bearing replacement in the presence of wear [6]. While modularity provides many benefits to the surgeon and patient, it is not without its unique disadvantages. Taper corrosion, fretting, wear, and implant fracture are known complications inherent in modular implant designs. Modularity also contributes to additional risks such as elevated serum ion levels and local tissue reactions.

The modular taper articulation in total hip arthroplasty has been found to be a significant generator of metal wear debris[1,7,8]. Micromotion associated with loading (fretting) leads to crevice corrosion of the taper surface[9]. This component wear has several important consequences. In a study of 114 metal-on-metal THAs, Meyer et al. found evidence of corrosion at the cone/taper interface that caused implant instability and loosening in 94% of patients[10]. This taper junction fretting and corrosion can be significant enough to lead to early implant failure. Molloy et al. reviewed 15 patients who had a Stryker ABG II dual modular hip system[11]. Seven patients showed evidence of medial calcar erosion, elevated cobalt-ion levels, and local soft-tissue reaction at a mean follow-up of 42.3 months. These patients eventually required revision arthroplasty. The component was subsequently recalled by the manufacturer and is no lon-

Table 2: Responses to True/False Questions Regarding Previous 12-Month Use of Modular THA Components (percentage of respondents)

	Question # 1		Question # 2		Question # 3	
	2013	2014	2013	2014	2013	2014
True	56.8	58.6	45.7	50.5	43.2	55.6
False	43.2	41.4	54.3	49.5	56.8	44.4

Question 1: I have decreased the use of head sizes > 36 mm in my practice due to literature reports about corrosion of metal taper modular junctions.

Question 2: I have decreased the use of modular femoral stems and necks in my practice due to literature reports about corrosion of metal taper modular junctions.

Question 3: I have increased the use of ceramic heads in my practice due to literature reports about corrosion of metal taper modular junctions.

ger in production. Significant corrosion has been found to occur in both mixed metal couples and similar metal couples[12], and the amount of metal debris generated is increased when multiple modular interfaces are present within an implant. The use of alternative bearings such as ceramic heads has been shown to decrease fretting at taper junctions[7,13].

The generation of metal debris from taper corrosion has been shown to have important local soft-tissue as well as systemic consequences. Locally deposited metal debris can lead to local soft-tissue destruction or pseudotumor formation[8,14,15]. Metal ion release from modular tapers also is likely the primary contributor to elevated serum ion levels in patients with THA. Levine et al. found elevated serum metal levels in THA patients for as many as 10 years postoperatively[16]. The clinical significance of increased serum metal concentrations is, however, unclear at this time.

Femoral component Morse tapers are made in various sizes, angles, and surface finishes specific to each implant. Combining stem and head implants from different manufacturers should be avoided because of the risk of component mismatch. The presence of biologic debris such as fat or blood in the taper junction has been shown to increase the risk of component dissocation[17]. Care should be taken to clean the taper interfaces before impaction of the femoral head component.

Although modularity provides many advantages in implant placement and customization, it has not been shown to decrease the rate of total hip revision[1], Our survey reflects a gradual recognition of both the advantages and shortcomings of modular total hip implants. It also highlights the need for continued surgeon education and rigorous clinical testing of modular designs. Surgeons need to understand the risks and benefits of implant modularity before widely adopting these implants in their practice.

REFERENCES

1. **Mihalko, W.M., Wimmer, M.A., Pacione, C.A., Laurent, M.P., Murphy, R.F., and Rider, C.**, "How Have Alternative Bearings and Modularity Affected Revision Rates in Total Hip Arthroplasty?" Clin. Orthop. Relat. Res., Vol. 472, 2014, pp. 3747-3758.
2. **Australian Orthopaedic Association National Joint Replacement Registry.** Annual Report 2013. Available at: https://aoanjrr.dmac.adelaide.edu.au/annual-reports-2013. Accessed 11/01/2014.
3. **Australian Orthopaedic Association National Joint Replacement Registry.** Supplementary Report: Metal on Metal Total Conventional Hip Arthroplasty, 2013. Available at: https://aoanjrr.dmac.adelaide.edu.au/annual-reports-2013. Accessed 11/01/2014
4. **http://www.recallcenter.com/stryker/.** Accessed 11/14/2014.
5. **http://www.drugwatch.com/depuy-hip/replacement.php.** Accessed 11/14/2014.
6. **Srinivasan, A., Jung, E., and Levine, B.R.**, "Modularity of the Femoral Component in Total Hip Arthroplasty," J. Am. Acad. Orthop. Surg., Vol. 20, 2012, pp. 214-222.
7. **Kurtz, S.M., Kocagöz, S.B., Hanzlik, J.A., Underwood, R.., Gilbert, J.L., MacDonald, D.W., Lee, G.C., Mont M.A., Kraay, M.J., Klein G.R., Parvizi, J., and Rimnac, C.M.**, "Do Ceramic Femoral Heads Reduce Taper Fretting Corrosion in Hip Arthroplasty? A Retrieval Study," Cli.n Orthop. Relat. Res., Vol. 471, 2013, pp. 3270-3282.
8. **Cook, R.B., Bolland, B.J., Wharton, J.A., Tilley. S., Latham, J.M., and Wood, R,J.**, "Pseudotumour Formation Due to Tribocorrosion at the Taper Interface of Large Diameter Metal-on-polymer Modular Total Hip Replacements," J. Arthroplasty, Vol. 28, 2013, pp. 1430-1436.
9. **Goldberg, J.R., and Gilbert, J.L.**, "In Vitro Corrosion Testing of Modular Hip Tapers," J. Biomed. Mater. Res. B. Appl. Biomater., Vol. 64, 2003, pp. 78-93.
10. **Meyer, H., Mueller, T., Goldau, G., Chamaon, K., Ruetschi, M., and Lohmann, C.H.**, "Corrosion at the Cone/taper Interface Leads to Failure of Large-diameter Metal-on-metal Total Hip Arthroplasties," Clin. Orthop. Relat. Res., Vol. 470, 2012, pp. 3101–3108.
11. **Molloy, D.O., Munir, S., Jack, C.M., Cross, M.B., Walter, W.L., and Walter, W.K., Sr.**, "Fretting and Corrosion in Modular-neck Total Hip Arthroplasty Femoral stems," J. Bone Joint Surg. Am., Vol. 96, 2014, pp. 488-493.
12. **Gilbert, J.L., Buckley, C.A., and Jacobs J.J.**, "In Vivo Corrosion of Modular Hip Prosthesis Components in Mixed and Similar Metal Combinations. The Effect of Crevice, Stress, Motion, and Alloy Coupling," J. Biomed. Mater. Res., Vol. 27, 1993, pp. 1533–1544.
13. **Hallab, N.J., Messina, C., Skipor, A., and Jacobs, J.J.**, "Differences in the Fretting corrosion of Metal-metal and Ceramic-metal Modular Junctions of Total Hip Replacements," J. Orthop. Res., Vol. 22, 2004, pp. 250-259.
14. **Cooper, H.J., Urban, R.M., Wixson, R.L., Meneghini, R.M., and Jacobs, J.J.**, "Adverse Local Tissue Reaction Arising From Corrosion at the Femoral Neck-body Junction in a Dual-taper Stem With a Cobalt-chromium Modular Neck," J. Bone Joint Surg. Am., Vol. 95, 2013, pp. 865-872.
15. **Gill, I.P., Webb, J., Sloan, K., and Beaver, R.J.**, "Corrosion at the Neck-stem Junction as a Cause of Metal Ion Release and Pseudotumour Formation," J. Bone Joint Surg. Br., Vol. 94, 2012, pp. 895-900.
16. **Levine, B.R., Hsu, A.R., Skipor, A.K., Hallab, N.J., Paprosky, W.G., Galante, J.O., and Jacobs, J.J.**, "Ten-year Outcome of Serum Metal Ion Levels After Primary Total Hip Arthroplasty: A Concise Follow-up of a Previous Report," J. Bone Joint Surg. Am., Vol. 95, 2013, pp. 512-518.
17. **Lavernia, C.J., Baerga, L., Barrack, R.L., Tozakoglou, E., Cook, S.D., Lata, L., and Rossi, M.D.**, "The effects of Blood and Fat on Morse Taper Disassembly Forces," Am. J. Orthop., Vol. 38, 2009, pp. 187-190.

NOT CITED

1. **Berry, D. J.**, "Utility of Modular Implants in Primary Total Hip Arthroplasty," J. Arthroplasty Vol. 29, 2014, pp. 657-658.
2. **Omlor, G.W., Kretzer, J.P., Reinders, J., Streit, M.R., Bruckner, T., Gotterbarm, T., Aldinger, P.R., and Merle, C.**, "In Vivo Serum Titanium Ion Levels Following Modular Neck Total Hip Arthroplasty--10 Year Results in 67 Patients," Acta Biomaterials, Vol. 9, 2013, pp. 626278-82.
3. **Kretzer, J.P., Jakubowitz, E., Krachler, M., Thomsen, M., and Heisel, C.**, "Metal Release and Corrosion Effects of Modular Neck Total Hip Arthroplasty," Int .Orthop., Vol. 33, 2009, pp. 1531–1536.
4. **Kop, A.M., and Swarts, E.**," Corrosion of a Hip Stem With a Modular Neck Taper Junction: A Retrieval Study of 16 Cases," J. Arthroplasty, Vol. 24, 2009, pp. 1019–1023.
5. **Bobyn, J.D., Tanzer, M., Krygier, J.J., Dujovne, A.R., and Brooks, C.E.**, "Concerns With Modularity in Total Hip Arthroplasty," Clin. Orthop. Relat. Res., Vol. 298, 1994, pp. 27–36.

Psychosocial Risk Factors of Postoperative Pain in Ankle and Hindfoot Reconstruction

Introduction: With the possibility of patient pain and satisfaction scores affecting reimbursement, there is increased awareness of pain as a complication. The purpose of this study was to examine medical, social, and psychological factors associated with pain after elective ankle and hindfoot reconstruction.

Methods: After IRB approval, 139 cases (132 patients) of total ankle replacement, ankle fusion, and/or hindfoot fusion over a 3-year period were identified. All operations were performed by one of three fellowship-trained foot and ankle surgeons. Retrospective chart review determined patient demographics, medical comorbidities, and associated surgical procedures. Specific pre-operative factors including age, sex, body mass index, etiology, diabetes, tobacco use, alcohol use greater than two or more drinks per day, chronic pain disorder, mood disorder, and any pre-operative narcotic use 3 months prior to surgery were examined. Narcotic usage was tracked through initial and subsequent post-operative prescriptions in the electronic medical record and linked narcotic database within a 2-year follow-up period. Primary outcomes were cumulative amount of narcotic prescribed (morphine milligram equivalent dose) in the initial 90-day post-operative period, need for continued narcotics beyond 90 days, and VAS pain score at minimum one year follow up. Bivariate and multivariate logistic and linear regression were used, in addition to student's T-test and Fisher's exact test for continuous and categorical data. P-values less than 0.05 were considered significant.

Results: The average amount of narcotic prescribed in the initial 90 days after surgery was 1711 mg (morphine equivalent) and 37% required narcotic prescriptions past 90 days. Pre-operative narcotic use (76%; OR=7.67, 95% CI (2.36-24.91), $p<0.01$), chronic pain disorder (93%; OR=7.83, 95% CI (1.35-45.44), $p=0.02$), and mood disorder (77%; OR=10.67, 95% CI (3.46-32.83), $p<0.01$) were risk factors for continued narcotic use past 90 days in multivariate analysis. Tobacco use (4659 mg; $\beta=0.205$, $p=0.01$) and chronic pain disorder (5713 mg; $\beta=0.40$, $p<0.01$) were risk factors for increased initial post-operative narcotic use in a multivariate model. 91 patients (94 feet, 68.9%) responded with VAS pain score at mean 2.7 years follow up. Average VAS was 2.14. Mood disorder was a risk factor for increased VAS (3.87; $\beta=0.37$, $p<0.01$) in multivariate analysis. Age, sex, BMI, etiology, alcohol use, and diabetes were not associated with increased post-operative pain.

Discussion and Conclusion: Patients who were being treated for chronic pain pre-operatively, had been diagnosed with a mood disorder, had been prescribed any amount of narcotics pre-operatively, or used tobacco products had an increased risk for pain post-operatively. As more emphasis is placed on patient outcomes and satisfaction, appropriate counseling is necessary regarding pain expectations after surgery. The presence of risk factors should prompt physicians to discuss modified pain management strategies before surgery.

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REFERENCES

1. **Morris BJ, Mir HR.** The opioid epidemic: impact on orthopaedic surgery. J Am Acad Orthop Surg. 2015 May;23(5):267-71.
2. **Devin CJ, Lee DS, Armaghani SJ, Bible J, Shau DN, Martin PR, Ehrenfeld JM.** Approach to Pain Management in Chronic Opioid Users Undergoing Orthopaedic Surgery. J Am Acad Orthop Surg. 2014 Oct;22(10):614-622. Review.
3. **Volkow ND, McLellan TA, Cotto JH, Karithanom M, Weiss SR: Characteristics of opioid prescriptions in 2009.** JAMA 2011;305(13):1299-1301.
4. **Owen GT, Burton AW, Schade CM, Passik S: Urine drug testing: Current recommendations and best practices.** Pain Physician 2012;15(3 suppl):ES119-ES133.
5. **Menendez ME, van Dijk CN, Ring D.** Who leaves the hospital against medical advice in the orthopaedic setting? Clin Orthop Relat Res. 2015 Mar;473(3):1140-9.
6. **Wang J, Liu GT, Mayo HG, Joshi GP.** Pain Management for Elective Foot and Ankle Surgery: A Systematic Review of Randomized Controlled Trials. J Foot Ankle Surg. 2015 Jul-Aug;54(4):625-35.
7. **Helmerhorst GT, Vranceanu AM, Vrahas M, Smith M, Ring D: Risk factors for continued opioid use one to two months after surgery for musculoskeletal trauma.** J Bone Joint Surg Am 2014;96(6):495-499.
8. **Chapman CR, Davis J, Donaldson GW, Naylor J,Winchester D: Postoperative pain trajectories in chronic pain patients undergoing surgery: The effects of chronic opioid pharmacotherapy on acute pain.**J Pain 2011;12(12):1240-1246.
9. **Armaghani SJ, Lee DS, Bible JE, Archer KR, Shau DN, Kay H, Zhang C, McGirt MJ, Devin CJ.** Preoperative opioid use and its association with perioperative opioid demand and postoperative opioid independence in patients undergoing spine surgery. Spine (Phila Pa 1976). 2014 Dec 1;39(25):E1524-30.
10. **Lawrence JT, London N, Bohlman HH, Chin KR.** Preoperative narcotic use as a predictor of clinical outcome: results following anterior cervical arthrodesis. Spine (Phila Pa 1976). 2008 Sep 1;33(19):2074-8.
11. **Pivec R, Issa K, Naziri Q, Kapadia BH, Bonutti PM, Mont MA.** Opioid use prior to total hip arthroplasty leads to worse clinical outcomes. Int Orthop. 2014 Jun;38(6):1159-65.
12. **Desai VN, Cheung EV.** Postoperative pain associated with orthopedic shoulder and elbow surgery: a prospective study. J Shoulder Elbow Surg. 2012 Apr;21(4):441-50.
13. **Zywiel MG, Stroh DA, Lee SY, Bonutti PM, Mont MA.** Chronic opioid use prior to total knee arthroplasty. J Bone Joint Surg Am. 2011 Nov 2;93(21):1988-93.
14. **Singh JA, Lewallen DG.** Predictors of pain medication use for arthroplasty pain after revision total knee arthroplasty. Rheumatology (Oxford). 2014 Oct;53(10):1752-8.
15. **Singh JA, Lewallen DG.** Medical and psychological comorbidity predicts poor pain outcomes after total knee arthroplasty. Rheumatology (Oxford). 2013 May;52(5):916-23.
16. **Singh JA, Lewallen DG.** Predictors of use of pain medications for persistent knee pain after primary Total Knee Arthroplasty: a cohort study using an institutional joint registry. Arthritis Res Ther. 2012 Nov 16;14(6):R248.
17. **Singh JA, O'Byrne MM, Harmsen WS, Lewallen DG.** Predictors of moderate-severe functional limitation 2 and 5 years after revision total knee arthroplasty. J Arthroplasty. 2010 Oct;25(7):1091-5, 1095.e1-4.
18. **Singh JA, Lewallen D.** Predictors of pain and use of pain medications following primary Total Hip Arthroplasty (THA): 5,707 THAs at 2-years and 3,289 THAs at 5-years. BMC Musculoskelet Disord. 2010 May 13;11:90.
19. **Singh JA, Lewallen D.** Age, gender, obesity, and depression are associated with patient-related pain and function outcome after revision total hip arthroplasty. Clin Rheumatol. 2009 Dec;28(12):1419-30.
20. **Singh JA, Gabriel S, Lewallen D.** The impact of gender, age, and preoperative pain severity on pain after TKA. Clin Orthop Relat Res. 2008 Nov;466(11):2717-23.
21. **Manchikanti L, Singh A: Therapeutic opioids: A ten-year perspective on the complexities and complications of the escalating use, abuse, and nonmedical use of opioids.** Pain Physician 2008;11 (2 suppl):S63-S88.
22. **Edlund MJ, Martin BC, Fan MY, Devries A, Braden JB, Sullivan MD.** Risks for opioid abuse and dependence among recipients of chronic opioid therapy: results from the TROUP study. Drug Alcohol Depend. 2010;112:90–98.
23. **Edlund MJ, Steffick D, Hudson T, Harris KM, Sullivan M.** Risk factors for clinically recognized opioid abuse and dependence among veterans using opioids for chronic non-cancer pain. Pain. 2007;129:355–362.
24. **Rice JB, White AG, Birnbaum HG, Schiller M, Brown DA, Roland CL.** A model to identify patients at risk for prescription opioid abuse, dependence, and misuse. Pain Med. 2012;13:1162–1173.
25. **Sullivan MD, Edlund MJ, Zhang L, Unutzer J, Wells KB.** Association between mental health disorders, problem drug use, and regular prescription opioid use. Arch Intern Med. 2006;166: 2087–2093.
26. **White AG, Birnbaum HG, Schiller M, Tang J, Katz NP.** Analytic models to identify patients at risk for prescription opioid abuse. Am J Manag Care. 2009;15:897–906.
27. **Fishbain DA: Polypharmacy treatment approaches to the psychiatric and somatic comorbidities found in patients with chronic pain.** Am J Phys Med Rehabil 2005; 84(3, suppl)S56-S63.
28. **Armaghani SJ, Lee DS, Bible JE, Archer KR, Shau DN, Kay H, Zhang C, McGirt MJ, Devin CJ.** Preoperative narcotic use and its relation to depression and anxiety in patients undergoing spine surgery. Spine (Phila Pa 1976). 2013 Dec 1;38(25):2196-200.
29. **Ishikawa SN, Murphy GA, Richardson EG.** The effect of cigarette smoking on hindfoot fusions. Foot Ankle Int. 2002;23(11):996-998.
30. **Chalayon O, Wang B, Blankenhorn B, Jackson JB 3rd, Beals T, Nickisch F, Saltzman CL.** Factors Affecting the Outcomes of Uncomplicated Primary Open Ankle Arthrodesis. Foot Ankle Int. 2015 May 20.
31. **Krannitz KW, Fong HW, Fallat LM, Kish J.** The effect of cigarette smoking on radiographic bone healing after elective foot surgery. J Foot Ankle Surg. 2009;48(5):525-527.

The Effect of Obesity on Forefoot Surgery*

BACKGROUND: Forefoot surgery is typically elective so it is important to define risk factors to educate patients on potential complications. The purpose of this study was to determine if obesity is an independent risk factor that contributes to increased complication rates after forefoot surgery.

METHODS: A retrospective review of records for 633 patients who had forefoot surgery at one institution between 2008 and 2010 was performed. All patients who currently smoked or smoked in the past were excluded to eliminate a confounding factor, as smoking is known to increase complication rates, leaving 427 patients for inclusion, 299 non-obese (BMI <30) and 128 obese (BMI> 30). Medical records were reviewed for the occurrence of complications, including nonunion, delayed union, delayed wound healing, infection and persistent pain.

RESULTS: The overall complication rate was 9% with similar rates between obese (10%) and non-obese patients (9%). The only specific complication approaching significance (p=0.13 was a higher rate of infection in obese patients (4 % vs. 1%) which could be attributed to the higher percentage of diabetic patients in the obese group. Diabetic patients, regardless of weight, had significantly higher rates of infection (p=0.03) with a trend towards higher rates of overall complications and delayed wound healing (p=0.08 and p=0.06 respectively).

CONCLUSIONS: Obesity was not shown to lead to higher complications after forefoot surgery. Diabetes was associated with significantly higher rates of infection, regardless of weight. Though not significant, there was a trend towards higher rates of overall complications and delayed wound healing in diabetic patients as well.

LEVEL OF EVIDENCE: Level III, retrospective, comparative study

KEY WORDS: Forefoot surgery; Obesity; Complications; Diabetes

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Obesity is a rising epidemic in the United States with nearly 78 million adults and 13 million children dealing with its health effects. One in three Americans is now considered obese, which is defined as having a body mass index greater than 30. Reports have shown that obesity in adults more than doubled from 13 percent in 1962 to 35 percent in 2006. These rising numbers are putting an increasing strain on our healthcare system, with more than 190 billion being spent a year on weight-related medical bills. [18] Not only does obesity increase your risk to develop life-threatening diseases such as type 2 diabetes, cancer, and heart disease, it also damages the musculoskeletal system.[14,18] Excess weight places higher biomechanical load on our joints, leading to osteoarthritis at younger ages and increasing risk for injuries. The odds of sustaining a musculoskeletal injury is 48 percent higher for obese people compared to people of normal weight. [14] There is also a negative impact on bone and soft tissue metabolism leading to increased pro-inflammatory cytokines and higher rates of osteoporosis, fractures, and wound healing complications.[13]

There has been extensive research into the effects of obesity as it relates to orthopaedic outcomes. The majority of complications relate to increased infection rates, thromboembolic events, and problems with wound healing.[1,3,4,5,7,8,11,16,211] Why obese patients are more susceptible is complex and multifactorial. Local

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conditions at the wound, associated systemic diseases and factors directly altering the immune response all play a role. An obese patient's surgical site typically is in a state of relative hypoperfusion secondary to increased adipose tissue and wound tension. This may lead to poor delivery of antibiotics and reduced availability of oxygen.[1,6] Increased adipose tissue also leads to increased levels of secreted bioactive molecules including cytokines, chemokines and hormone-like factors, collectively known as adipokines. Many of these adipokines have a deleterious effect on the immune system, as they have been linked to a state of chronic low grade inflammation that is believed to influence the healing process.[6]

Successful outcomes in forefoot surgery typically requires the relief of persistent pain, healing of the wound in a timely manner, bony union in the case of osteotomies, and return to pre-surgical level of function. Many of these patients are obese and it is unknown whether this adds any additional risk to their surgical outcome. Obesity has been linked to higher perioperative complication rates in many other orthopaedic subspecialties including total joints, trauma, pediatrics, spine, and sports surgery.[3,4,5,7,8,11,12,15,16,19,211] Obese patients tend to have a multitude of comorbidities that may independently increase risks and confound outcomes.[14] The purpose of this study was to investigate whether obesity alone is an independent risk factor increasing the rate of complications following forefoot surgery. We hypothesized that obese patients would have a higher complication rate than non-obese patients after surgery of the forefoot, particularly rates of infection and wound dehiscence.

MATERIALS AND METHODS

This study was approved by our institution's Institutional Review Board before data collection began. All patients who had forefoot surgery for whom body mass index could be determined from the medical record were included. A CPT code search for all forefoot operative procedures performed between 2008 and 2010 was used to compile a list of patients for a retrospective medical record review.

All surgeries were performed by three fellowship-trained orthopaedic foot and ankle surgeons. Medical records were reviewed to determine patient demographics, including age, sex, and presence of comorbidities. Comorbidities recorded were those that were known to have a negative impact on operative outcomes, including diabetes mellitus, rheumatoid arthritis, peripheral vascular disease, peripheral neuropathy, and chronic steroid use as detailed on the intake history and physical. All patients had palpable pulses in the operative foot before surgery or vascular consultation was obtained before any surgical intervention. Weight and height was determined from the intake history at initial visit and patients were classified as obese or non-obese based on their body mass index.

Patients with a body mass index less than 30 were considered non-obese. Patients with a body mass index greater than or equal to 30 were considered obese. All patients who currently smoked or had smoked in the past were excluded as this has been found to be an independent risk factor for complications in forefoot surgery.[2] The type of forefoot surgery was similar among each group. Correction of hallux valgus and/or hammertoes consisted of approximately 50% of the surgeries within each group. Medical records were reviewed from the immediate post-operative visit through the latest follow-up visit. The length of follow-up was recorded for each patient.

Outcome measures were complications that occurred including nonunion, infection, delayed wound healing, delayed union, and persistent pain as detailed by the surgeon in the medical record. The presence of each complication was recorded to allow calculation of total complications and complication rate. Nonunion, delayed wound healing, and delayed union were considered to be present when the primary surgeon had documented each in the medical record during a follow-up visit. Infection was considered to be present when documented by the primary surgeon at follow-up and treated with antibiotics. Persistent pain was defined as pain significant enough to be reported by the patient as leaving him or her dissatisfied with the outcome at latest follow-up in the absence of any other complication.

To account for patients who had more than one complication and to avoid artificial inflation of the complication rate, the rate was calculated as the number of patients with any complication divided by the total number of patients. A power analysis using a beta of 20% and a p-value of 0.05 was performed, as were a chi-square analysis and Fisher's exact test with a p-value of less than 0.05 indicating significance. Relative risk also was calculated.

RESULTS

The retrospective review of CPT codes identified 633 patients who had forefoot procedures between 2008 and

2010. All patients who currently smoked or smoked in the past were excluded to eliminate a confounding factor, as smoking is known to increase complication rates. This left 427 patients for inclusion, 299 non-obese (BMI <30) and 128 obese (BMI> 30). The average age of the 348 females and 79 males was 53.5 years. The obese group had a higher percentage of diabetic patients ($p<0.001$) but otherwise the groups were similar in the percentage of those with rheumatoid arthritis, steroid use, peripheral vascular disease and neuropathy.

The overall complication rate of forefoot surgery at our institution was found to be 9%, with similar rates among the obese (10%) and non-obese groups (8 %). The most common complications were persistent pain (4%), infection (2%) and delayed wound healing (1%). While the overall complication rates in both groups were similar, we did find that diabetic patients were twice as likely to experience a complication compared to non-diabetics, though this number only approached significance ($p=0.09$).

Diabetics were also found to have higher rates of infection (9% vs. 2%) and delayed wound healing (6 % vs. 1%) when compared to non-diabetic patients ($p=0.03$ and $p=0.06$ respectively). Complication rates in diabetic patients were independent of weight. The rates were similar in obese diabetic patients (17%) compared to normal weight diabetics (18%).

Obese patients had a 3 times higher rate of infection compared to patients of normal weight. This approached significance ($p=0.13$) but could be attributed to the higher percentage of diabetic patients within the obese group. When controlling for diabetes, the overweight group had infection rates similar to the normal weight groups (2% vs. 1%), while patients who were diabetic and overweight had infection rates of 13 %.

DISCUSSION

Obesity has commonly been associated with increased complication rates after orthopaedic surgery. The negative effect of BMI on surgical morbidity has been studied extensively in the total joint, spine and trauma literature but there are only a few studies in the foot and ankle literature and none to our knowledge looking at obesity's effect on forefoot surgery. There are many theories as to why obesity may lead to higher complication rates including technical difficulty secondary to larger soft tissue envelopes, nonoptimal wound healing environments, longer operative times and inability to mobilize effectively in the postoperative period. These reasons have lead to conclusions that obesity results in higher rates of infection, thromboembolic events and decreased functional outcomes after specific types of orthopaedic surgery.[1,3,4,5,6,7,8,11,12,16] Collins et al. showed that obese patients undergoing hip arthroscopy were 11.1 times more likely to have a complication, specifically, higher rates of deep vein thrombosis and worsening pain. They found the surgery to be much more technically challenging due to body habitus which led to significantly longer operative times as well.[3] Patel et al. showed an increase in significant complications after elective spine fusions in obese patients with a 14% rate in patients with BMI<25 and a 36% rate in patients with BMI>40. These complications were independent of associated co-morbidities such as diabetes and hypertension.[15] Namba et al. prospectively looked at the incidence of obesity and its effect on perioperative morbidity in patients undergoing total hip and knee arthroplasty. They found that obese patients were significantly younger and more likely to have comorbidities such as diabetes and hypertension. The odds ratio was 6.7 times higher risk of infection in obese total knee arthroplasty patients and 4.2 times higher in total hip arthroplasty patients.[12]

Obesity is a complex issue though, as many of these patients have confounding comorbidities that may actually contribute to their higher complications rates after surgery. Our question was to whether obesity was an independent risk factor that leads to more complications and our data indicated that it was not. This is in contrast to our hypothesis and the initial trend seen during the literature search. Upon closer examination, we found that our data mirrored the results of other similar studies involving the foot and ankle region. Markdana-Kivi et al presented a case series study on 36 patients evaluating the effect of obesity on the arthroscopic findings and the functional outcome after arthroscopic treatment of anterolateral impingement syndrome of the ankle. They showed that the presence of obesity had no effect on the functional outcome scores at one year follow-up and that regardless of weight, arthroscopic treatment for impingement was equally effective.[10] Strauss et al. found no difference in time to union, incidence of complications or level of function after operatively treated ankles fractures in a cohort of obese (99 patients with BMI>30) and non-obese patients (180 patients with BMI <30). They did find that obese patients had more severe fractures and a higher number of co-morbidities,

but concluded that obese patients should be treated in line with standard protocol, keeping in mind any known associated comorbidities.[17]

London et al. compared the rates of postoperative complications in obese and non-obese patients following elbow, forearm, and hand surgery. Their case control study included 436 patients with a BMI>35 and 433 patients with a BMI<30 who were frequency matched by type of surgery, age and sex. The overall complication rate was 8.7% with similar rates between obese and non-obese (8.5% and 9.0%).[9] Many of the reasons that they theorize for similar complications rates between the groups can be extrapolated to forefoot surgery as well. First, many of these surgeries are short, performed under regional block and should not significantly affect mobility, as most patients are able to weight bear to tolerance afterwards or at least weightbear through their heel. This may significantly cut down on the rate of thromboembolic events, more commonly seen after more extensive lower extremity surgeries. Second, wound complications in obese patients are often seen after deep dissections that can lead to increased rates of hematoma, seroma or infection. The forefoot has limited subcutaneous fat even in the most obese patients so they should be more protected from these problems as well.

We did find that diabetes mellitus was an independent risk factor associated with significantly higher rates of infection and a trend towards higher overall rates of complication and delayed wound healing. This correlates with the findings of other authors who have shown increased complications and infections in complicated diabetics undergoing foot and ankle surgery. Wukich et al. retrospectively reviewed 1000 patients following foot and ankle surgery and showed that diabetic patients had an infection rate of 13.2% compared to 2.8% in non-diabetics. After removing diabetics with neuropathy, there was no longer a significant risk of infection. They concluded that complicated diabetic patients had a greater risk of developing postoperative infections and that HbA1C > 8% was independently associated with surgical site infections.[20] SooHoo et al. demonstrated that complicated diabetes was a strong predictor of short term complications following open reduction internal fixation for ankle fractures, with an odds ratio of 2.3 ($p<0.001$).[22]

The primary limitation of this study is its retrospective nature. All past medical history was obtained from a self-reported patient questionnaire filled out at their initial visit, which could lead to omissions of co-morbidities or medication use. There may also be a tendency to neglect listing peripheral vascular disease and neuropathy, two diagnoses included in our data, as these may not be known by the patient or may be seen as complications of a broader disease such as diabetes, rather than a stand-alone disease process. We also have no knowledge as to the severity of diabetes in most cases unless it was mentioned specifically in the physician's note. Therefore we are unable to determine if all diabetic patients are at greater risk of infection after forefoot surgery or just complicated diabetics, as demonstrated in other studies.

Though we have a large number of patients overall, we are limited by the small number of total complications (n=39), as this is the actual sample size that we are trying to analyze. This limitation introduces the possibility of a type II error. On the other hand, there were trends seen in diabetic patients undergoing forefoot surgery, such as increased complication rates and delayed wound healing, that could be statistically significant if this study had a higher power. Also, our sample size allows us to only analyze two groups (obese vs. non-obese). Further stratification may show a dose dependent type higher complication rate in the super-obese group but we were limited in the fact that we only had 14 patients with a BMI>40.

Our management of forefoot conditions is similar for obese and non-obese patients, as these results concluded there was no significant difference in the complication rates between the two groups. Though pre-operative counseling may not specifically address risks of obesity in forefoot surgery, we do often encourage preoperative weight loss as this will have a beneficial effect for the patient as a whole.

REFERENCES

1. **Anaya, DA, Dellinger EP.** The obese surgical patient: A susceptible host for infection. Surgical Infections. 2006 Oct.
2. **Bettin CC, Gower K, McCormick K, Wan JY, Ishikawa SN, Richardson DR, Murphy GA.** Cigarette smoking increases complication rate in forefoot surgery. FAI. 2015 Jan 12.
3. **Collins JA, Beutel BG, Garofolo G, Youm T.** Correlation of obesity with patient-reported outcomes and complications after hip arthroscopy. Arthroscopy. 2015 Jan.
4. **D'Apuzzo MR, Novicoff WM, Browne JA.** Morbid Obesity independently impacts complications, mortality, and resource use after TKA. Clin Orthop Relat Res. 2015 Jan.

5. **Dowsey MM, Choong PF.** Obesity is a major risk factor for prosthetic infection after primary hip arthroplasty. Clin Orthop Relat Res. 2008 Jan.

6. **Guo S and LA Dipietro.** Factors affecting wound healing. J Dent Res. 2010 Mar; 89 (3): 219-229.

7. **Haverkamp D et al.** Obesity in total hip arthroplasty—does it really matter? A meta-analysis. Acta Orthop. 2011 Aug.

8. **Kerkhoffs GM et al.** The influence of obesity on the complication rate and outcome of total knee arthroplasty: a meta-analysis and systematic literature review. J Bone Joint Surg AM. 2012 Oct 17.

9. **London DA et al.** The impact of obesity on complications of elbow, forearm, and hand surgeries. J Hand Surg Am. 2014 Aug.

10. **Mardani-Kivi M et al.** Effect of obesity on arthroscopic treatment of anterolateral impingement syndrome of the ankle. J Foot Ankle Surg. 2015 Jan-Feb.

11. **McGuire KJ et al.** The effect of high obesity on outcomes of treatment for lumbar spinal conditions: subgroup analysis of the spine patient outcomes research trial. Spine (Phila Pa 1976). 2014 Nov 1.

12. **Namba RS et al.** Obesity and perioperative morbidity in total hip and total knee arthroplasty patients. J Arthroplasty. 2005 Oct.

13. **Obalum DC, Fiberesima F, Eyesan SU, Ogo CN, Nzew C, Mijinyawa M.** A review of obesity and orthopaedic surgery: the critical issues. Niger Postgrad Med J. 2012 Sep; 19 (3): 175-180.

14. **Obesity linked to increased risk for orthopaedic conditions and surgical complications.** October 20, 2014. http://newsroom.aaos.org/media-resources/Press-releases/obesity-link-to-increased-risk-for-orthopaedic-conditions-and-surgical-complications.htm

15. **Patel N, Bagan B, Vadera S, Maltenfort MG, Deutsch H, Vaccaro AR, Harrop J, Sharan A, Ratliff JK.** Obesity and spine surgery: relation to perioperative complications. J Neurosurg Spine. 2007 Apr; 6(4): 291-7.

16. **Rana AR et al.** Childhood obesity: A risk factor injuries observed at one level 1 trauma center. J Pediatr Surg. 2009 Aug.

17. **Strauss EJ, Frank JB, Walsh M, Koval KJ, Egol KA.** Does Obesity influence the outcome after the operative treatment of ankle fractures? J Bone Joint Surg Br. 2007 Jun; 89 (6): 794-8

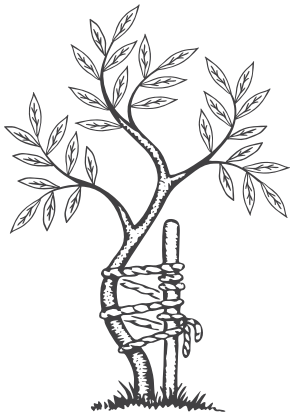
18. **Understanding the American Obesity Epidemic.** March 14, 2014. http://www.heart.org/HEARTORG/GettingHealthy/WeightManagement/Obesity/Understanding-the-American-Obesity-Epidemic_UCM_461650_Article.jsp

19. **Weinlein, JC, Deaderick S, Murphy RF.** Morbid Obesity increases the risk for systemic complications in patients with femoral shaft fractures. J Orthop Trauma. 2015 Mar.

20. **Wukich DK et al.** Postoperative infection rates in Foot and Ankle surgery: a comparison of patients with and without diabetes mellitus. J Bone Joint Surg Am. 2010 Feb.

21. **Yuan K and Chen HL.** Obesity and surgical site infections risk in orthopedics: a meta-analysis. Int J Surg. 2013.

22. **SooHoo NF et al.** Complication rates following open reduction and internal fixation of ankle fractures. J Bone Joint Surg Am. 2009 May.



CAMPBELL CLINIC STAFF RESEARCH

Preoperative Narcotic and Alcohol Use Are Risk Factors for Complication in Ankle and Hindfoot Reconstruction

Introduction: Predictors of complications after foot and ankle surgery have been well documented; however, some potentially confounding medical and psychological diagnoses have not been assessed regarding their relationship to outcomes. The purpose of this study was to examine medical, social, and psychological factors associated with complications and reoperations after elective ankle and hindfoot reconstruction.

Methods: After IRB approval, 139 cases (132 patients) of total ankle replacement, ankle fusion, and/or hindfoot fusion with a minimum 2-year follow-up were identified. All operations were performed by one of three fellowship-trained foot and ankle surgeons. Retrospective chart review determined patient demographics, medical comorbidities, and associated surgical procedures. Specific pre-operative factors examined were age, sex, body mass index, etiology, diabetes, tobacco use, alcohol use greater than two or more drinks per day, chronic pain disorder, mood disorder, and any pre-operative narcotic use 3 months before surgery. Primary outcomes included complications and reoperations. A major complication was defined as infection, nonunion, or failure requiring revision or reoperation; otherwise, the complication was considered minor. Bivariate and multivariate logistic regression were used, in addition to student's T-test and Fisher's exact test, for continuous and categorical data, respectively. P-values less than 0.05 were considered significant.

Results: The overall complication rate was 28%. Minor complication rate was 23% and major complications occurred in 6.5%. Including elective implant removal, reoperation rate was 17%. Alcohol use (53%; OR=3.87, 95% CI (1.17-12.84), p=0.03) and pre-operative narcotic use (40%; OR=2.63, 95% CI (1.21-5.75), p=0.02) were risk factors for complications in a multivariate model. Delayed wound healing was significantly more frequent in alcohol users (31%, p=0.03), and deep infection (6%, p=0.045) and nonunion (24%, p=0.046) were significantly more frequent with pre-surgery narcotic use. Older patients were less likely to undergo reoperation (OR=0.97, 95% CI (0.94-0.995), p=0.02). Age, sex, body mass index, etiology, diabetes, mood disorder, and chronic pain disorder were not associated with increased complications.

Discussion and Conclusion: Patients who consumed two or more drinks of alcohol per day or had been prescribed any amount of narcotic within 3 months prior to surgery were at increased risk for complications. Surgeons should be aware of these factors and counsel patients before surgery.

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REFERENCES

1. **Patton D, Kiewiet N, Brage M.** Infected total ankle arthroplasty: risk factors and treatment options. Foot Ankle Int. 2015 Jun;36(6):626-34.
2. **Kessler B, Sendi P, Graber P, et al.** Risk factors for periprosthetic ankle joint infection: a case-control study. J Bone Joint Surg Am. 2012;94(20):1871-1876.
3. **Knecht SI, Estin M, Callaghan JJ, et al.** The Agility total ankle arthroplasty: seven to sixteen-year follow-up. J Bone Joint Surg Am. 2004;86-A(6):1161-1171.
4. **Wukich DK, Mallory BR, Suder NC, Rosario BL.** Tibiotalocalcaneal arthrodesis using retrograde intramedullary nail fixation: comparison of patients with and without diabetes mellitus. J Foot Ankle Surg. 2015 May 23.
5. **Chalayon O, Wang B, Blankenhorn B, Jackson JB 3rd, Beals T, Nickisch F, Saltzman CL.** Factors affecting the outcomes of uncomplicated primary open ankle arthrodesis. Foot Ankle Int. 2015 May 20.
6. **Collman DR, Kaas MH, Schuberth JM.** Arthroscopic ankle arthrodesis: factors influencing union in 39 consecutive patients. Foot Ankle Int. 2006;27(12):1079-1085.
7. **Ishikawa SN, Murphy GA, Richardson EG.** The effect of cigarette smoking on hindfoot fusions. Foot Ankle Int. 2002;23(11):996-998.
8. **Krannitz KW, Fong HW, Fallat LM, Kish J.** The effect of cigarette smoking on radiographic bone healing after elective foot surgery. J Foot Ankle Surg. 2009;48(5):525-527.

9. **Mann RA, Rongstad KM.** Arthrodesis of the ankle: a critical analysis. Foot Ankle Int. 1998;19(1):3-9.
10. **Perlman MH, Thordarson DB.** Ankle fusion in a high risk population: an assessment of nonunion risk factors. Foot Ankle Int. 1999;20(8):491-496.
11. **Gross CE, Green CL, DeOrio JK, Easley M, Adams S, Nunley JA 2nd.** Impact of diabetes on outcome of total ankle replacement. Foot Ankle Int. 2015 May 6.
12. **Schipper ON, Jiang JJ, Chen L, Koh J, Toolan BC.** Effect of diabetes mellitus on perioperative complications and hospital outcomes after ankle arthrodesis and total ankle arthroplasty. Foot Ankle Int. 2015;36(3):258-267.
13. **Goldstein DT, Durinka JB, Martino N, Shilling JW.** Effect of preoperative hemoglobin A(1c) level on acute postoperative complications of total joint arthroplasty. Am J Orthop (Belle Mead NJ). 2013;42(10):E88-E90.
14. **Singh JA, Lewallen DG.** Diabetes: a risk factor for poor functional outcome after total knee arthroplasty. PLoS One. 2013;8(11):e78991.
15. **Tsang ST, Gaston P.** Adverse peri-operative outcomes following elective total hip replacement in diabetes mellitus: a systematic review and meta-analysis of cohort studies. Bone Joint J. 2013;95B(11):1474-1479.
16. **Werner BC, Burrus MT, Looney AM, Park JS, Perumal V, Cooper MT.** Obesity is associated with increased complications after operative management of end-stage ankle arthritis. Foot Ankle Int. 2015 Mar 12.
17. **Choi WJ, Lee JS, Lee M, Park JH, Lee JW.** The impact of diabetes on the short to mid-term outcome of total ankle replacement. Bone Joint J. 2014 Dec;96-B(12):1674-80.
18. **Chahal J, Stephen DJ, Bulmer B, Daniels T, Kreder HJ.** Factors associated with outcome after subtalar arthrodesis. J Orthop Trauma. 2006 Sep;20(8):555-61.
19. **Frey C, Halikus NM, Vu-Rose T, Ebramzadeh E.** A review of ankle arthrodesis: predisposing factors to nonunion. Foot Ankle Int. 1994 Nov;15(11):581-4.
20. **Morris BJ, Mir HR.** The opioid epidemic: impact on orthopaedic surgery. J Am Acad Orthop Surg. 2015 May;23(5):267-71.
21. **Devin CJ, Lee DS, Armaghani SJ, Bible J, Shau DN, Martin PR, Ehrenfeld JM.** Approach to pain management in chronic opioid users undergoing orthopaedic surgery. J Am Acad Orthop Surg. 2014 Oct;22(10):614-622. Review.
22. **Lavernia CJ, Villa JM, Iacobelli DA.** What is the role of mental health in primary total knee arthroplasty? Clin Orthop Relat Res. 2015 Jan;473(1):159-63.
23. **Armaghani SJ, Lee DS, Bible JE, Shau DN, Kay H, Zhang C, McGirt MJ, Devin CJ.** Increased Preoperative Narcotic Use and its Association with Postoperative Complications and Length of Hospital Stay in Patients Undergoing Spine Surgery. J Spinal Disord Tech. 2014 Jun 5.
24. **Lee D, Armaghani S, Archer KR, Bible J, Shau D, Kay H, Zhang C, McGirt MJ, Devin C.** Preoperative Opioid Use as a Predictor of Adverse Postoperative Self-Reported Outcomes in Patients Undergoing Spine Surgery. J Bone Joint Surg Am. 2014 Jun 4;96(11):e89.
25. **Pivec R, Issa K, Naziri Q, Kapadia BH, Bonutti PM, Mont MA.** Opioid use prior to total hip arthroplasty leads to worse clinical outcomes. Int Orthop. 2014 Jun;38(6):1159-65.
26. **Singh JA, Lewallen DG.** Depression in primary TKA and higher medical comorbidities in revision TKA are associated with suboptimal subjective improvement in knee function. BMC Musculoskelet Disord. 2014 Apr 11;15:127.
27. **Blackburn J, Qureshi A, Amirfeyz R, Bannister G.** Does preoperative anxiety and depression predict satisfaction after total knee replacement? Knee. 2012 Oct;19(5):522-4.
28. **Browne JA, Sandberg BF, D'Apuzzo MR, Novicoff WM.** Depression is associated with early postoperative outcomes following total joint arthroplasty: a nationwide database study. J Arthroplasty. 2014 Mar;29(3):481-3.
29. **Lawrence JT, London N, Bohlman HH, Chin KR.** Preoperative narcotic use as a predictor of clinical outcome: results following anterior cervical arthrodesis. Spine (Phila Pa 1976). 2008 Sep 1;33(19):2074-8.
30. **Zywiel MG, Stroh DA, Lee SY, Bonutti PM, Mont MA.** Chronic opioid use prior to total knee arthroplasty. J Bone Joint Surg Am. 2011 Nov 2;93(21):1988-93.
31. **Singh JA, Lewallen D.** Age, gender, obesity, and depression are associated with patient-related pain and function outcome after revision total hip arthroplasty. Clin Rheumatol. 2009 Dec;28(12):1419-30.
32. **Owen GT, Burton AW, Schade CM, Passik S: Urine drug testing: Current recommendations and best practices.** Pain Physician 2012;15(3 suppl):ES119-ES133.
33. **Menendez ME, van Dijk CN, Ring D.** Who leaves the hospital against medical advice in the orthopaedic setting? Clin Orthop Relat Res. 2015 Mar;473(3):1140-9.
34. **Manchikanti L, Singh A: Therapeutic opioids: A ten-year perspective on the complexities and complications of the escalating use, abuse, and nonmedical use of opioids.** Pain Physician 2008;11 (2 suppl):S63-S88.
35. **Mulligan RP, McCarthy K, Grear BJ, Richardson DR, Ishikawa SN, Murphy GA.** Psychosocial risk factors of post-operative pain in ankle and hindfoot reconstruction. – in submission.
36. **Friday, KE; Howard, GA: Ethanol inhibits human bone cell proliferation and function in vitro.** Metabolism. 40:562 –565, 1991.
37. **Easley, M; Trnka, HJ; Schon, LC; et al.**: Isolated subtalar arthrodesis. J Bone Joint Surg Am. 82:613, 2000.
38. **Cobb, TK; Gabrielsen, TA; Campbell, DC; et al.**: Cigarette smoking and non-union after ankle arthrodesis. Foot Ankle Intl. 15(2):64 –7, 1994.

Vitamin D Supplementation and Awareness in Patients Presenting to an Orthopaedic Foot and Ankle Clinic

Background: Vitamin D deficiency has been implicated in delayed bone healing, stress fractures, and bone pain, but there is limited information about patient awareness of vitamin D. This study was conducted to determine the level of awareness of vitamin D and the rate of vitamin D supplementation in patients presenting to a foot and ankle clinic.

Methods: New patients presenting to our foot and ankle fellowship-trained staff were asked about vitamin D supplementation and related factors. They also were asked if they were aware that vitamin D deficiency could cause delayed bone healing, stress fractures, and bone pain and whether this information made them more likely to use vitamin D supplements. They were contacted at an average of 47 days (range 21-81 days) after their office visit to determine rates of vitamin D supplementation.

Results: At the initial visit 46.8% of the 359 patients reported taking some form of vitamin D. Previous diagnoses of vitamin D deficiency and stress fracture were present in 21.1% and 17.4% of patients, respectively. Prior to their visit, 40.2% of patients knew the importance of vitamin D for bone health, while 79.3% stated the new information made them more likely to take vitamin D supplements. At follow-up 58.1% of 199 patients were taking vitamin D; 43.2% of patients recalled their doctor discussing vitamin D with them.

Conclusion: Awareness of vitamin D among patients presenting to a foot and ankle clinic is low. Patients who recall discussing vitamin D with their surgeon are more likely to use vitamin D supplements.

Level of Evidence: Level IV – case series

Key Words: Vitamin D, bone health, foot and ankle

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REFERENCES

1. **Brinker MR, O'Connor DP, Monla YT, Earthman TP.** Metabolic and endocrine abnormalities in patients with nonunions. J Orthop Trauma 2007; 21:557-570.
2. **Cranney A, Weiler HA, O'Donnell S, Puil L.** Summary of evidence-based review on vitamin D efficacy and safety in relation to bone health. Am J Clin Nutr 2008; 88:513S-519S.
3. **Doetsch AM, Faber J, Lynnerup N, Wätjen I, Bliddal H, Danneskiold-Samsøe B.** The effect of calcium and vitamin D3 supplementation on the healing of the proximal humerus fracture: a randomized placebo-controlled study. Calcif Tissue Int 2004; 75:183-188.
4. **Givon U, Friedman E, Reiner A, Vered I, Finestone A, Shemer J.** Stress fractures in the Israeli defense forces from 1995 to 1996. Clin Orthop Relat Res 2000; 373:277-232.
5. **Heidari B, Shirvani JS, Firouzjahi A, Heidari P, Hajian-Tilaki KO.** Association between nonspecific skeletal pain and vitamin D deficiency. Int J Rheum Dis 2010; 13:340-346.
6. **Jones BH, Thacker SB, Gilchrist J, Kimsey CD Jr, Sosin DM.** Prevention of lower extremity stress fractures in athletes and soldiers: a systematic review. Epidemiol Rev 2002; 24:228-247.
7. **Lappe J, Cullen D, Haynatzki G, Recker R, Ahlf R, Thompson K.** Calcium and vitamin D supplementation decreases incidence of stress fractures in female navy recruits. J Bone Miner Res 2008; 23:741-749.
8. **McCabe MP, Smyth MP, Richardson DR.** Current concept review: vitamin D and stress fractures. Foot Ankle Int 2012; 33:526-533.
9. **Ruohola JP, Laaksi I, Ylikomi T, Haataja R, Mattila VM, Sahi T, Tuohimaa P, Pihlajamäk H.** Association between serum 25(OH)D concentrations and bone stress fractures in Finnish young men. J Bone Miner Res 2006; 21:1483-1488.
10. **Smith JT, Halim K, Palms DA, Okike K, Bluman EM, Chiodo CP.** Prevlanece of vitamin D deficiency in patients with foot and ankle injuries. Foot Ankle Int 2014; 35:8-13.
11. **Bogunovic L, Kim AD, Beamer BS, Nguyen J, Lane JM.** Hypovitaminosis D in patients scheduled to undergo orthopaedic surgery: a single-center analysis. J Bone Joint Surg Am 2010; 92:2300-2304.
12. **Glowacki J, Hurwitz S, Thronhill TS, Kelly M, LeBoff MS.** Osteoporosis and vitamin-D deficiency among postmenopausal women with osteoarthritis underling total hip arthroplasty. J Bone Joint Surg Am 2003; 85:2171-2377.
13. **Nawabi DH, Chin KF, Keen RW, Haddad FS.** Vitamin D deficiency in patients with osteoarthritis undergoing total hip replacement: a cause for concern? J Bone Joint Surg Br 2010; 92:496-499.
14. **Stoker GE, Buchowski JM, Bridwell KH, Lenke LG, Riew KD, Zebala LP.** Preoperative vitamin D status of adults undergoing surgical spinal fusion. Spine (Phila Pa 1976) 2013; 38:507-515.

15. **Mithal A, Wahl DA, Bonjour JP, Burckhardt P, Dawson-Hughes B, Eisman JA, El-Hajj Fuleihan G, Josse RG, Lips P, Morales-Torres J; IOF Committee of Scientific Advisors (CSA) Nutrition Working Group.** Global vitamin D status and determinants of hypovitaminosis D. Osteoporos Int 2009; 20:1807-1820.
16. **Holick MF.** Vitamin D deficiency. N Eng J Med 2007; 357:266-281.
17. **Ni Chróinin D, Glavin P, Power D.** Awareness of osteoporosis, risk and protective factors and own diagnostic status: a cross-sectional study. Arch Osteoporos 2013; 8:117.
18. **Alemu E, Varnam R.** Awareness of vitamin D deficiency among at-risk patients. BMC Res Notes 2012; 5:17.
19. **Kung AW, Lee KK.** Knowledge of vitamin D and perceptions and attitudes toward sunlight among Chinese middle-aged and elderly women: a population survey in Hong Kong. BMC Public Health 2006; 6:226.

Adolescent Idiopathic Scoliosis Treated with Simultaneous Translation on Two Rods (ST2R) with Preoperative, Postoperative, and Follow-up Evaluation by EOS 3D Imaging: A Pilot Study

ABSTRACT

Background: Simultaneous translation with 2 rods (ST2R) is a relatively new technique for the correction of adolescent idiopathic scoliosis (AIS), and to date has been reported only by its developer and with only radiographic evaluation of the correction obtained.

Purpose: To evaluate preoperative, postoperative, and follow-up 3D spinal and pelvic parameters using EOS 3D imaging in patients who had ST2R corrective posterior spinal surgery for AIS.

Methods: This study included 5 patients, who had surgical correction of Lenke 1 or 2 AIS with the ST2R technique. The preoperative average Cobb angle of the 5 patients was 72.4 ° ± 19.4. Low-dose standing biplanar radiographs were obtained to evaluate several spinal and pelvic parameters preoperatively (5 patients), immediately postoperatively (4 patients), and at follow-up (4 patients). One operator performed the 3D reconstructions (total of 13 reconstructions).

Results: The mean number of levels fused was 11.2° ± 2.0. The number of pedicle screw used for constructs averaged 19.2° ± 3.06 (1.75 density screw per vertebra). The Cobb angle values were significantly changed by the operation (75° ± 21 to 28° ± 7, p = 0.009), but no other values were significantly altered. The maximal apical axial change at junctional region was 32.8° (absolute value) and the minimal apical axial change at apical region was 4.8° (absolute value). The intervertebral rotation difference in the axial plane was larger near the apical region (T8-T9), from 2.1° ± 2.7 to -14° ± 6.9, and smaller near the junctional region (T12-L1), from -2.6° ± 2.9 to -1.1° ± 8.4.

Conclusion: This pilot study suggests that corrective posterior spinal surgery for AIS using ST2R can achieve 3D correction of the spine and some additional intervertebral axial rotation correction, with little deterioration during follow-up. Preoperative, postoperative, and follow-up evaluation of spinal and pelvic parameters can be accurately evaluated with EOS low-dose 3D imaging.

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INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a structural spinal deformity with unknown etiopathogenesis that affects about 1% to 3% of children between the ages of 10 and 16 years[1,2,3,4]. Severe morphologic changes, such as rib cage and pelvic asymmetry, may develop among affected individuals[5,6]. Although conventionally diagnosed and classified based on two-dimensional x-ray projections of the spine, AIS is a three-dimensional deformity that affects all three planes (coronal, sagittal, and transverse) of the vertebrae[6,7,8,9]. The simultaneous translation on 2 rods (ST2R) technique was developed to achieve three-dimensional correction of spinal deformities, including scoliosis and kyphosis. ST2R pulls the spine toward the pre-contoured rods, as opposed to pushing down or leveraging on the spine. Clement et al.[13,14] demonstrated superior sagittal correction with ST2R reduction compared to cantilever reduction.

Traditionally, the Cobb method has been the stan-

Figure 1: EOS Imaging System

dard method to quantitate the degree of deformity[10]. This angle is based on sagittal and coronal radiographic views, but it does not adequately portray the 3D nature of scoliosis because it overlooks the rotational component[11]. Thus, 3D models have been used to better evaluate spinal deformities[9]. Magnetic resonance imaging (MRI) and computerized tomography (CT) show the complete 3D geometry of the spine, but they are performed with the patient supine, which modifies the curvature[12,9]. Also, CT exposes young patients to high radiation.

EOS (EOS Imaging, Paris, France) is a fairly new development that can avoid some of the problems associated with other imaging methods. It is a low-dose X-ray device that creates a 3D reconstruction of the spine from biplanar (lateral and posteroanterior) images taken simultaneously **(Figure 1)**[11,12]. Because it automatically records many different spinal and pelvic parameters, EOS is especially helpful for evaluation of changes in spinal deformity after surgery.

The objective of this study was to compare preoperative, postoperative, and follow-up 3D spinal and pelvic parameters using EOS imaging of patients who had corrective (ST2R) instrumentation and fusion for AIS.

METHODS

Patients

Following institutional review board approval, 5 consecutive patients who had surgical correction of AIS (Lenke type 1 or 2) with the ST2R technique were retrospectively studied. Four patients with a minimum of 8-months follow-up were included. Patients were evaluated preoperatively, in the early postoperative period (within 6 weeks), and at the latest follow-up. None of the patients had prior spinal surgery.

Surgical Technique

For the ST2R reduction maneuver, two 6.0-mm titanium rods are first bent according to the desired sagittal profile, and then attached to the anchors with threaded polyaxial screw extensions and claws. Two proximal nuts are tightened on the threaded extension to lock rotation of the rods. Gradual and alternative tightening of the nuts on the threaded rods pulls the vertebrae back toward the rods (translation maneuver), resulting in a reduction in the coronal plane and the restoration of kyphosis. Contrary to other techniques, which persuade the rod to approach the anchorages, ST2R pulls back the vertebrae toward the rods, and the forces are distributed among all vertebrae with anchorages. No distraction techniques were used.

Reconstruction Process

Full 3D images of the spine were reconstructed (total 13 reconstructions) by a trained observer. The preliminary step was the identification of a segment on the sacral endplate and two spheres around the femoral heads in the acetabulum, which permitted the creation of a 'patient frame' that was compatible with the reference axis used by the SRS for classification of AIS [15]. The spinal curve, the T1 upper endplate and the L5 lower endplate were then digitized and used as predictors to statistically estimate the other descriptors of the parametric spine 3D-model. A highly detailed 3D model was generated then projected on both X-rays so that the operator could verify and, if necessary, perform fine adjustments of the position and shape of each reconstructed vertebra (T1–L5)[16] **(Figure 2)**.

Method of Evaluation

Several spinal and pelvic parameters were measured preoperatively, postoperatively, and at the latest follow-up. Although all five patients had preoperative measurements, only four had immediate postoperative, and latest follow-up measurements. The parameters include major and minor Cobb angle, T1/T12 and T4/T12 kyphosis, L1/L5 and L1/S1 lordosis, apical vertebral rotation (AVR), pelvic incidence, sacral slope, and sagittal pelvic tilt. Additionally, intervertebral axial rotation was measured.

The kyphosis was defined as the angle between vectors normal to the endplates when projected into the local sagittal (xz) plane. Similarly, the local coro-

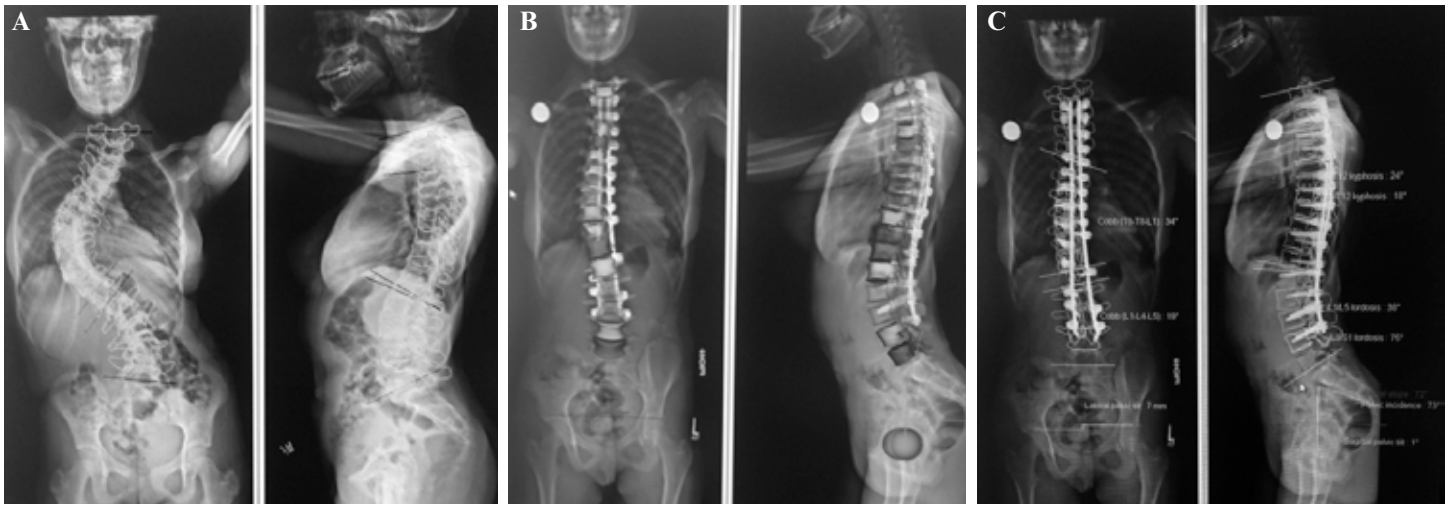

Figure 2: Illustrative Case: Preoperative (A) and Postoperative (B) radiographs and 3-Dimensional Reconstruction (C) of a 12-year old patient corrected using the ST2R technique.

nal Cobb angle of each vertebra and disc was defined as the angle between vectors normal to the endplates when projected into the local coronal (yz) plane[17].

Apical vertebral rotation was defined as the angle between projections of the x-axis of the apical vertebra and the x-axis of the global spinal reference frame onto the XY plane of the global spinal reference frame. The intervertebral axial rotation used the same projection concept. Clockwise rotation was defined as positive, using the anteroposterior view[17].

The intervertebral rotation in the axial plane between adjacent vertebrae was defined as the angle between adjacent y-axes projected on the subjacent local coordinate x– y plane[18].

Statistical Analysis

Two-tailed paired t-test was used to compare 1) preoperative and postoperative and 2) postoperative and latest follow-up measurements. A p value <0.05 was considered to be significant. All statistical analyses were conducted using the software SAS version 9.3 (SAS Institute Inc, Cary, NC, USA).

RESULTS

Population

The average age of the two female and three male patients was 15 years and 6 months (range: 13-19 years); three had Lenke type 1 curves and two had Lenke type 2 curves. Frontal and lateral EOS 3D images were captured for each of the 5 patients preoperatively, for four patients immediately postoperatively (images unavailable for patient #2), and for four patients at latest postoperative follow-up (images unavailable for patient #5), giving full sets of images for three patients.

All patients had structural thoracic curves and two had structural (thoraco) lumbar curvature on the basis of bending criteria. Three patients had preoperative Cobb angles between 50 and 65 degrees, and two had severe curves with Cobb angles of more than 65 degrees.

The average number of days between the first examination and surgery was 56 days; between surgery and postoperative immediate examination, 25 days; and between surgery and latest follow-up, 328 days.

Operative Procedure

The mean number of levels fused was 11.2° ± 2.0. The number of pedicle screw used for constructs averaged 19.2° ± 3.06 (1.75 density screw per vertebra). Poliaxial screw constructs were used for all 5 patients. The apical vertebra was instrumented with two pedicle screws in all cases.

Spinal and Pelvic Parameters

The anatomic landmarks were clearly distinguishable by varying the luminosity and contrast to optimally reveal the vertebrae and pelvis. In particular, the superior endplate of T1 and the femoral heads were visible in all cases. Consequently, the 10 radiologic parameters were measurable in all 5 patients. We compared preoperative and immediate postoperative measurements in 4 subjects[1,3,4,5], and immediate postoperative and latest follow-up measurements in 3 sub-

Table 1: Mean Values (degrees) of deformity parameters pre- and immediately post-operatively (4 patients)

	Preoperative (Mean ± SD)	Immediate Postoperative (Mean ± SD)	p
Major Cobb(°)	75 ± 21	28 ± 7	0.009
Minor Cobb(°)	35 ± 18	25 ± 3	0.22
Kyphosis (T1/T12) (°)	32 ± 7.5	28 ± 7	0.56
Kyphosis (T4/T12) (°)	31 ± 30	22 ± 8	0.52
Lordosis (L1/L5) (°)	48 ± 22	41 ± 8	0.60
Lordosis (L1/S1) (°)	77 ± 25	81 ± 10	0.76
Apical Vertebral Rotation (AVR) (°)	-5.4 ± 17	6.5 ± 25	0.31
Pelvic Incidence(°)	76 ± 4	82 ± 6	0.16
Sacral Slope(°)	71 ± 5	73 ± 4	0.65
Sagittal Pelvic Tilt(°)	4.9 ± 4	8.5 ± 7	0.33

jects[1,3,4]. The mean values of the spinal and pelvic parameters of the series are summarized in **Table 1** and **Table 2** at various follow up intervals. The Cobb angle values were significantly changed by the operation (75° ± 21 to 28° ± 7, p = 0.009), but no significant changes occurred at the latest follow-up **(Figure 2)**. Apical vertebral derotation failed to reach statistical significance.

DISCUSSION

With this study, we attempted to quantify the multi-planar correction capabilities of ST2R spinal system using EOS imaging and SterEOS reconstruction software. Although the interpretation of the results is difficult because of the small number of patients, it provided interesting preliminary information to warrant further study.

Table 2: Mean Values (degrees) of deformity parameters between immediate post-operative and 1-year follow up (3 patients)

	Immediate Postoperative (Mean ± SD)	Final Follow Up (Mean ± SD)	p
Major Cobb(°)	29 ± 7	38 ± 7	0.16
Minor Cobb(°)	25 ± 3	27 ± 6	0.76
Kyphosis (T1/T12) (°)	27 ± 8	30 ± 6	0.12
Kyphosis (T4/T12) (°)	22 ± 10	24 ± 10	0.67
Lordosis (L1/L5) (°)	41 ± 10	40 ± 5	0.91
Lordosis (L1/S1) (°)	81 ± 12	77 ± 3	0.76
Apical Vertebral Rotation (AVR) (°)	13 ± 26	-3 ± 43	0.25
Pelvic Incidence(°)	83 ± 7	81 ± 2	0.65
Sacral Slope(°)	73 ± 5	69 ± 5	0.40
Sagittal Pelvic Tilt(°)	10 ± 8	12 ± 6	0.19

The number of levels fused (11.2° ± 2.0) compared with thoracic and lumbar curves was similar to the average published. All of the patients in this study required fusion at least to the level of L2 to stabilize the curves and avoid distal junctional kyphosis[19].

A significant decrease in Cobb angle was observed between preoperative and immediate postoperative measurements, but not in kyphosis and lordosis (L1-L5). There was a non-significant increase in Cobb angle at the latest follow-up, probably caused by biomechanical adjustments during the healing process[19]. Winter et al. expressed concern about over-correction in the attempt to obtain a few supplemental degrees of coronal reduction and suggested that it is more important to obtain a balanced fusion[20]. The pelvic parameters showed the same relation during follow-up with no significant difference.

In the present study, reconstructed models from images obtained by an EOS imaging system enabled accurate measurement of the axial profile (apical vertebral rotation). Furthermore, it became possible to measure not only the axial AVR, but also that of each intervertebral segment.

We had some limitations in our study. This is pilot study with a very small sample size, and there was no control group of nonscoliotic patients. The corrections obtained with PASS LP instrumentation MEDICREA® simultaneous translation on 2 rods (ST2R) will need to be compared in the future to other reduction techniques assessed with low dose stereoradiography[19]. Although the follow-up period was short (9 months), it is generally accepted that loss of correction after fusion in AIS primarily occurs during the first postoperative year and that results of spine surgery can be reliably evaluated radiologically after a minimum follow-up of 2 years[22]. The measurements obtained with the EOS system were not compared

to another imaging method, since the purpose of the study was not to evaluate the reliability of stereoradiography, which has already been reported previously in AIS[23]. Finally, this was a purely radiolographic study; no functional score was used to evaluate the clinical outcome of these patients.

CONCLUSIONS

This pilot study suggests that corrective ST2R spinal surgery for AIS is able to achieve 3D correction of the spine and some additional intervertebral axial rotation correction, with little deterioration during the follow-up period, and that EOS imaging is effective for evaluation of this 3D correction.

REFERENCES

1. **Weinstein SL, Dolan LA, Cheng JC, Danielsson A, Morcuende JA.** Adolescent idiopathic scoliosis. Lancet. 2008 May 3;371(9623):1527-37.
2. **Lowe TG, Edgar M, Margulies JY, Miller NH, Raso VJ, Reinker KA, Rivard CH.**Etiology of idiopathic scoliosis: current trends in research. J Bone Joint Surg Am. 2000 Aug;82-A(8):1157-68.
3. **Burwell RG.** Aetiology of idiopathic scoliosis: current concepts. Pediatr Rehabil. 2003 Jul-Dec;6(3-4):137-70.
4. **Kane WJ.** Scoliosis prevalence: a call for a statement of terms. Clin Orthop Relat Res. 1977 Jul-Aug;(126):43-6.
5. **Stokes IA, Dansereau J, Moreland MS.** Rib cage asymmetry in idiopathic scoliosis. J Orthop Res. 1989;7(4):599-606.
6. **Begon M, Scherrer SA, Coillard C, Rivard CH, Allard P.** Three-dimensional vertebral wedging and pelvic asymmetries in the early stages of adolescent idiopathic scoliosis. Spine J. 2015 Mar 1;15(3):477-86.
7. **Hattori T, Sakaura H, Iwasaki M, Nagamoto Y, Yoshikawa H, Sugamoto K.** In vivo three-dimensional segmental analysis of adolescent idiopathic scoliosis. Eur Spine J. 2011 Oct;20(10):1745-50.
8. **Sangole AP, Aubin CE, Labelle H, Stokes IA, Lenke LG, Jackson R, Newton P.** Three-dimensional classification of thoracic scoliotic curves. Spine (Phila Pa 1976). 2009 Jan 1;34(1):91-9.
9. **Kadoury S, Labelle H.** Classification of three-dimensional thoracic deformities in adolescent idiopathic scoliosis from a multivariate analysis. Eur Spine J. 2012 Jan;21(1):40-9.
10. **Morrissy RT, Goldsmith GS, Hall EC, Kehl D, Cowie GH.** Measurement of the Cobb angle on radiographs of patients who have scoliosis. Evaluation of intrinsic error. J Bone Joint Surg Am. 1990 Mar;72(3):320-7.
11. **Ilharreborde B, Dubousset J, Le Huec JC.** Use of EOS imaging for the assessment of scoliosis deformities: application to postoperative 3D quantitative analysis of the trunk. Eur Spine J. 2014 Jul;23 Suppl 4:S397-405.
12. **Glaser DA, Doan J, Newton PO.** Comparison of 3-dimensional spinal reconstruction accuracy: biplanar radiographs with EOS versus computed tomography. Spine (Phila Pa 1976). 2012 Jul 15;37(16):1391-7.
13. **Kuklo TR, Potter BK, Polly DW, Jr.**, Lenke LG. Monaxial versus multiaxial thoracic pedicle screws in the correction of adolescent idiopathic scoliosis. Spine (Phila Pa 1976). Sep 15 2005;30(18):2113-2120.
14. **Clement J-L, Chau E, Vallade M-J, Geoffray A.** Simultaneous translation on two rods is an effective method for correction of hypokyphosis in AIS: radiographic results of 24 hypokyphotic thoracic scoliosis with 2 years minimum follow-up. European Spine Journal. Jul 2011;20(7):1149-1156.
15. **Sangole A, Aubin CE, Labelle H, Lenke L, Jackson R, Newton P, Stokes IA (2010) The central hip vertical axis: a reference axis for the scoliosis research society three dimensional classification of idiopathic scoliosis.** Spine (Phila Pa 1976) 35:E530–E53.
16. **Al-Aubaidi Z, Lebel D, Oudjhane K, Zeller R.** Three-dimensional imaging of the spine using the EOS system: is it reliable? A comparative study using computed tomography imaging. J Pediatr Orthop B. 2013 Sep;22(5):409-12.
17. **Newton PO, Fujimori T, Doan J, Reighard FG, Bastrom TP, Misaghi A.** Defining the "Three-Dimensional Sagittal Plane" in Thoracic Adolescent Idiopathic Scoliosis. J Bone Joint Surg Am. 2015 Oct 21;97(20):1694-701.
18. **Hattori T, Sakaura H, Iwasaki M, Nagamoto Y, Yoshikawa H, Sugamoto K.** In vivo three-dimensional segmental analysis of adolescent idiopathic scoliosis. Eur Spine J. 2011 Oct;20(10):1745-50.
19. **Ilharreborde B, Steffen JS, Nectoux E, Vital JM, Mazda K, Skalli W, Obeid I (2011) Angle measurement reproducibility using EOS three-dimensional reconstructions in adolescent idiopathic scoliosis treated by posterior instrumentation.** Spine (Phila Pa 1976) 36:E1306–E1313
20. **Winter RB, Lonstein JE, Denis F (2007) How much correction is enough? Spine 32:2641–2643**
21. **Schlösser TP(1), van Stralen M, Brink RC, Chu WC, Lam TP, Vincken KL, Castelein RM, Cheng JC.** Three-dimensional characterization of torsion and asymmetry of the intervertebral discs versus vertebral bodies in adolescent idiopathic scoliosis.Spine (Phila Pa 1976). 2014 Sep 1;39(19):E1159-66.
22. **Remes V, Helenius I, Schlenzka D, Yrjonen T, Ylikoski M, Poussa M (2004) Cotrel-Dubousset (CD) or Universal Spine System (USS) instrumentation in adolescent idiopathic scoliosis (AIS): comparison of midterm clinical, functional, and radiologic outcomes.** Spine 29:2024–2030
23. **Ilharreborde B, Sebag G, Skalli W, Mazda K.** Adolescent idiopathic scoliosis treated with posteromedial translation: radiologic evaluation with a 3D low-dose system. Eur Spine J. 2013 Nov;22(11):2382-91.

Cervical Spine Trauma Immobilization Protocols in Young Children. How Often Are These Safety Protocols Followed?

Background: Children have a larger head to torso size ratio than adults. Positioning them on a standard flat backboard during computed tomography (CT) examination will place the cervical spine in a flexed position.

Methods: Patients < 7 years old who had a CT of the cervical spine as part of a trauma evaluation were included. Head positioning was determined by measuring the vertical displacement of the occipital protuberance above the plane of the posterior aspect of the thorax on the CT scout view.

Results: A total of 158 CT scans were obtained, of which 135 (85%) were adequate for review. Of these, 66 (49%) had the occipital protuberance elevated above the level of the posterior thorax, indicating a relative hyperflexion of the cervical spine.

Conclusions: Despite having a cervical immobilization protocol and positioning devices, 49% of children presenting to a pediatric level 1 trauma center were not positioned correctly for CT imaging. Constant review and education of health care providers is needed to ensure that cervical spine immobilization protocols are followed in order to prevent unwanted cervical flexion in the young child with suspected cervical spine trauma.

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INTRODUCTION

Children less than 8 years old have a larger head to torso ratio compared to adults. As a result, positioning them on a standard flat backboard for transport and CT imaging results in cervical spine flexion. This is undesirable in the setting of cervical spine trauma as flexion may lead to further spinal cord compromise or inaccurate diagnosis of spine trauma. To achieve neutral cervical spine positioning in children less than 8 years old, Herzenberg et al recommended using a pediatric backboard with either an occipital recess or a pad to elevate the chest relative to the head[1] **(Figure 1)**.

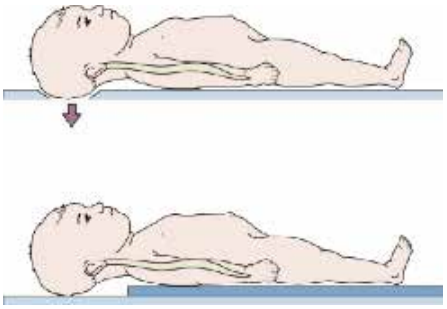

Figure 1: Illustrations representing the two proper methods of positioning a pediatric trauma patient for CT scanning of the cervical spine. Figure 1A (top) demonstrates an occipital protuberance relief hole in the back board while Figure 1B (bottom) demonstrates elevation of the torso above the level of the occipital protuberance. (Used with permission from: Dorman JP: Evaluation of Children With Suspected Cervical Spine Injury, in Beaty JH:(ed): Instructional Course Lectures 51. Rosemont, IL, American Academy of Orthopaedic Surgeons, 2002, pp 401-409.)

This study seeks to determine how often children presenting to a level 1 trauma center emergency department with suspected cervical trauma have correct cervical spine positioning during CT imaging.

MATERIALS AND METHODS

After IRB approval, a retrospective review was conducted of CT scans of the cervical spine in children 7 years

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Figure 2: CT scout image demonstrates improper positioning with vertical displacement of the occipital protuberance above the plane of the posterior chest.

old and younger presenting to the emergency department with suspected cervical spine trauma. The study was limited to CT scans from January 1, 2009 to December 31, 2014. Effectiveness of immobilization protocols during CT examination was determined by measuring the vertical displacement of the occipital protuberance above the plane of the posterior chest. The vertical displacement was measured by drawing a horizontal line from the most dependent part of the chest on the scout lateral radiograph in the CT scanner and recording the displacement of the occipital protuberance above or below this line. Vertical displacement of the occipital protuberance above the plane of the posterior chest indicated relative cervical flexion and incorrect positioning **(Figure 2)**, whereas displacement of the occipital protuberance below the plane of the posterior chest indicated correct positioning **(Figure 3)**.

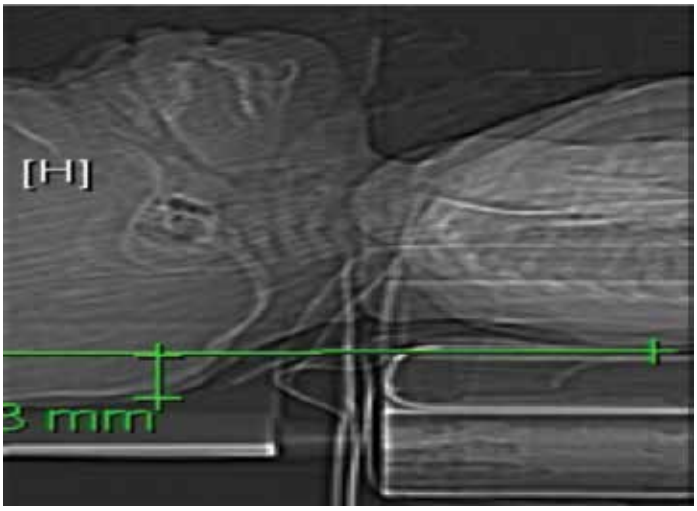

Figure 3: CT scout image demonstrates proper positioning with vertical displacement of the occipital protuberance below the plane of the posterior chest.

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No external funding was obtained for this project.

RESULTS

A total of 158 CT scans were reviewed, of which 23 were excluded due to inability to adequately visualize the occipital protuberance or the posterior chest. Of the remaining 135 CT scans, 66 (49%) had the occipital protuberance elevated above the posterior chest indicative of cervical hyperflexion and incorrect positioning (mean displacement 2.0 cm anterior with a range of 0.5-3.4 cm). On the contrary, 69 (51%) were found to have the occipital protuberance below the posterior chest indicating correct positioning, with a mean displacement of 1.1cm posterior and a range of 0.2-4.2cm.

DISCUSSION

Despite having a cervical immobilization protocol in place at a level 1 trauma center, 49% of children presenting to the ED with cervical spine trauma were found to be in cervical flexion, indicative of incorrect positioning.

It must be noted that the measured vertical displacement in our study does not directly indicate whether a split mat or occipital recess pillow was used. It only indicates whether the patient is improperly positioned in cervical flexion. We can infer two etiologies of the improper positioning: 1) lack of adherence to immobilization protocols 2) immobilization protocols are inadequate in achieving a neutral cervical position.

Previous studies have suggested that immobilization protocols do not completely remove the risk of improper positioning. Pediatric cervical spine immobilization techniques by Curran et al showed that despite documented use of backboards with towels to elevate the chest above the head, 55% of patients were still found to have cervical kyphosis or lordosis greater than 5 degrees[2]. Regardless of the efficacy of technique in achieving neutral cervical positioning, the health care provider doing the immobilization should ultimately provide proper immobilization by ensuring the patient's external meatus is posterior to the shoulder for immobilization[3].

CONCLUSION

In addition to review of immobilization protocols, constant education of health care providers is also needed to ensure that cervical spine immobilization protocols are followed to prevent undesirable cervical flexion.

REFERENCES

1. **Herzenberg J.**E., Hensinger R.N, Dedrick D.K., and Phillips W.A.: Emergency transport and position of young children who have an injury of the cervical spine. The standard backboard may be hazardous. J Bone Joint Surg Am 1989; 71: pp. 15-22
2. **Curran C.**, Dietrich A.M., Bowman M.J., et al: Pediatric cervical spine immobilization: achieving neutral position? J Trauma 1995; 39: pp. 729-732
3. **Mencio, G.** (2014). Fractures of the Spine. In Green's Skeletal Trauma in Children (Fifth ed., p. 273).
4. **Nypaver M.**, and Treloar D.: Neutral cervical spine positioning in children. Ann Emerg Med 1994; 23: pp. 208-211
5. **Zaahid, P.**, Shepherd, M., & Lamont, T. (2010). Achieving a neutral cervical spine position in suspected spinal cord injury in children analyzing the use of a thoracicelevation device for imaging the cervical spine in paediatric patients. Emergency Medicine Journal, 27(8), 573-576. Retrieved September 20, 2014.
6. **Theodore, N.**, Hadley M.,Aarabi B., Dhall S. (2013). Prehospital Cervical Spinal Immobilization after Trauma. Neurosurgery Journal. 72(3), 23-34.
7. **Boswell, H.**, Dietrich, A., Shiels, W., King, D., Ginn-Pease, M. Accuracy of visual determination of neutral position of the immobilized pediatric cervical spine. Pediatric Emergency Care, 17(1), 10-14.

Comparison of Axillary Lateral Radiography with Computed Tomography in the Preoperative Characterization of Glenohumeral Wear Patterns and the Effects of Body Mass Index on Quality of Imaging

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Background: Pre-operative imaging is critical in shoulder arthroplasty for understanding pathoanatomy and to prepare for glenoid component placement. Both axillary lateral radiographs and computed tomography (CT) have been advocated to guide pre-operative planning. The purpose of this study was to evaluate and compare preoperative axillary lateral radiographs and axial CT slices for classification and measurement of glenoid wear, glenoid version, and glenohumeral subluxation as well as to determine the influence of body mass index on characterization of glenoid wear patterns.

Methods: Following Institutional Review Board approval, the axillary lateral radiographs and CT imaging of 88 consecutive patients who underwent shoulder arthroplasty for the diagnosis of glenohumeral osteoarthritis were reviewed. Patient demographics were obtained from chart review. The best preoperative axillary lateral radiograph for glenoid visualization, taken with a standardized institutional protocol, and best representative axial CT image of glenoid wear and glenohumeral subluxation were obtained. All radiographs and CT images were deidentified and randomized prior to evaluation. Seven blinded observers reviewed the images to classify glenoid wear (Walch and Mayo classifications) and glenohumeral subluxation (Mayo classification). Glenoid version measurements were made using Friedman's technique. After a minimum two week period, the same observers repeated the process to obtain intra and interobserver reliability. Statistical analysis was performed to obtain Cohen's kappa, Fleiss' kappa, intraclass correlation coefficients, and t-test and F-test probabilities. Kappa values greater than 0.8 were considered to indicate substantial agreement, values between 0.6-0.8 good agreement, values between 0.4-0.6 fair agreement and values less than 0.4 were considered to indicate poor agreement. Differences with $p<0.05$ were considered statistically significant.

Results: Of the 88 shoulders reviewed, 58 (66%) radiographs and 84 (95%) CT scans were of sufficient quality to perform each classification by all evaluators ($p<0.0001$). The average body mass index (BMI) of patients whose x-rays could not be entirely evaluated by each observer was 37 (vs 31, $p=0.0003$). The average BMI of the four CT scans that could not be fully classified was 51 (vs 32, $p<0.0001$). For measurement of glenoid version, 69 (78%) radiographs and all 88 CT scans were sufficient for evaluation by all observers ($p<0.0001$).

Kappa values for intraobserver reliability for the Walch, Mayo glenoid wear, and Mayo subluxation classification on axillary lateral radiographs were 0.42, 0.46, and 0.47, and 0.50, 0.49 and 0.41 for CT imaging; all indicating fair agreement. Kappa values for interobserver reliability for the Walch, Mayo glenoid wear, and Mayo subluxation classifications on axillary lateral radiographs were 0.28, 0.21, and 0.21, and 0.27, 0.23, and 0.19 for CT imaging; all indicating poor agreement.

The intraobserver reliability for measurement of glenoid version using x-ray was 0.66 (good agreement) and 0.88 (substantial agreement) for CT scan. The interobserver reliability for measurement of glenoid version using x-ray was 0.56 (fair agreement) and 0.78 (good agreement) for CT scan.

Conclusions: When readable, axillary lateral radiographs and axial CT imaging demonstrated similar intra- and interobserver agreement for all classifications of glenoid wear and glenohumeral subluxation in this study. However, CT imaging was significantly more likely to provide sufficient characterization of glenohumeral wear patterns by multiple observers; as over 1/3 of axillary lateral films were inadequate for classification and 22% were inadequate for version measurements. For axillary lateral and CT images that were unable to be fully evaluated, increased body mass index factored significantly in the observers' ability to judge classifications, likely due to projection of the axillary soft tissue. Precise characterization of glenoid wear by measurement of glenoid version was more reliable with CT imaging.

REFERENCES

1. **Bishop JY, Jones GL, Rerko MA, Donaldson C; MOON Shoulder Group.** 3-D CT is the most reliable imaging modality when quantifying glenoid bone loss. Clin Orthop Relat Res. 2013 Apr; 471(4): 1251-6. http://dx.doi.org/10.1007/s11999-012-2607-x
2. **Bokor DJ, O'Sullivan MD, Hazan GJ.** Variability of measurement of glenoid version on computed tomography scan. J Shoulder Elbow Surg 1999; 8:595-8. http://dx.doi.org/10.1016/s1058-2746(99)90096-4
3. **Bryce CD, Davison AC, Lewis GS, Wang L, Flemming DJ, Armstrong AD.** Two-dimensional glenoid version measurements vary with coronal and sagittal scapular rotation. J Bone Joint Surg Am. 2010 Mar; 92(3): 692-9. http://dx.doi.org/10.2106/jbjs.i.00177
4. **Budge MD, Lewis GS, Schaefer E, Coquia S, Flemming DJ, Armstrong AD.** Comparison of standard two-dimensional and three dimensional corrected glenoid version measurements. J Shoulder Elbow Surg 2011; 20:577-83. http://dx.doi.org/10.1016/j.jse.2010.11.003
5. **Elsharkawi M, Cakir B, Reichel H, Kappe T.** Reliability of radiologic glenohumeral osteoarthritis classifications. J Shoulder Elbow Surg 2013; 22:1063-1067. http://dx.doi.org/10.1016/j.jse.2012.11.007
6. **Farron A, Terrier A, Buchler P.** Risks of loosening of a prosthetic glenoid implanted in retroversion. J Shoulder Elbow Surg 2006; 15:521-6. http://dx.doi.org/10.1016/j.jse.2005.10.003
7. **Friedman R J, Hawthorne KB, Genez BM: The use of computerized tomography in the measurement of glenoid version.** J Bone Joint Surg Am 74:1032, 1992
8. **Gupta AK, Chalmers PN, Rahman Z, Bruce B, Harris JD, McCormick F, Abrams GD, Nicholson GP.** Reverse total shoulder arthroplasty in patients of varying body mass index. J Shoulder Elbow Surg. 2014 Jan; 23(1): 35-42. http://dx.doi.org/10.1016/j.jse.2013.07.043
9. **Hendel MD, Bryan JA, Barsoum WK, Rodriguez EJ, Brems JJ, Evans PJ, Iannotti JP.** Comparison of patient-specific instruments with standard surgical instruments in determining glenoid component position: a randomized prospective clinical trial. J Bone Joint Surg Am. 2012 Dec 5; 94(23): 2167-75. http://dx.doi.org/10.2106/jbjs.k.01209
10. **Hoenecke HR Jr, Hermida JC, Flores-Hernandez C, D'Lima DD.** Accuracy of CT-based measurements of glenoid version for total shoulder arthroplasty. J Shoulder Elbow Surg 2010; 19:166-71. http://dx.doi.org/10.1016/j.jse.2009.08.009
11. **Hopkins AR, Hansen UN, Amis AA, Emery R.** The effects of glenoid component alignment variations on cement mantle stresses in total shoulder arthroplasty. J Shoulder Elbow Surg 2004; 13:668-75. http://dx.doi.org/10.1016/j.jse.2004.04.008
12. **Jain NB, Guller U, Pietrobon R, Bond TK, Higgins LD.** Comorbidities increase complication rates in patients having arthroplasty. Clin Orthop Relat Res. 2005 Jun;(435): 232-8. http://dx.doi.org/10.1097/01.blo.0000156479.97488.a2
13. **Kwon YW, Powell KA, Yum JK, Brems JJ, Iannotti JP.** Use of three-dimensional computed tomography for the analysis of the glenoid anatomy. J Shoulder Elbow Surg 2005; 14:85-90. http://dx.doi.org/10.1016/j.jse.2004.04.011
14. **Landis JR, Koch GG.** An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. Biometrics 1977; 33:363-74. http://dx.doi.org/10.2307/2529786
15. **Landis JR, Koch GG.** The measurement of observer agreement for categorical data. Biometrics 1977; 33:159-74.
16. **Li X, Williams PN, Nguyen JT, Craig EV, Warren RF, Gulotta LV.** Functional outcomes after total shoulder arthroplasty in obese patients. J Bone Joint Surg Am. 2013 Nov 6; 95(21): e160. http://dx.doi.org/10.2106/jbjs.l.01145
17. **Linberg CJ, Sperling JW, Schleck CD, Cofield RH.** Shoulder arthroplasty in morbidly obese patients. J Shoulder Elbow Surg. 2009 Nov-Dec; 18(6): 903-6. http://dx.doi.org/10.1016/j.jse.2009.02.006
18. **Nowak DD, Gardner TR, Bigliani LU, Levine WN, Ahmad CS.** Interobserver and intraobserver reliability of the Walch classification in primary glenohumeral arthritis. J Shoulder Elbow Surg. 2010 Mar; 19(2): 180-3. http://dx.doi.org/10.1016/j.jse.2009.08.003
19. **Nyffeler RW, Jost B, Pfirrmann CW, Gerber C.** Measurement of glenoid version: conventional radiographs versus computed tomography scans. J Shoulder Elbow Surg. 2003 Sep-Oct; 12(5): 493-6. http://dx.doi.org/10.1016/s1058-2746(03)00181-2
20. **Pappou I, Virani NA, Clark R, Cottrell BJ, Frankle MA.** Outcomes and Costs of Reverse Shoulder Arthroplasty in the Morbidly Obese: A Case Control Study. J Bone Joint Surg Am. 2014 Jul 16; 96(14): 1169-1176. http://dx.doi.org/10.2106/jbjs.m.00735
21. **Randelli M, Gambrioli PL: Gleno-humeral osteometry by computed tomography in normal and unstable shoulders.** Clin Orthop 208:15 I, 1986
22. **Raymond AC, McCann PA, Sarangi PP.** Magnetic resonance scanning vs. axillary radiography in the assessment of glenoid version for osteoarthritis. J Shoulder Elbow Surg. 2013 Aug; 22(8): 1078-83. http://dx.doi.org/10.1016/j.jse.2012.10.036
23. **Rerko MA, Pan X, Donaldson C, Jones GL, Bishop JY.** Comparison of various imaging techniques to quantify glenoid bone loss in shoulder instability. J Shoulder Elbow Surg. 2013 Apr; 22(4): 528-34. http://dx.doi.org/10.1016/j.jse.2012.05.034
24. **Rouleau DM, Kidder JF, Pons-Villanueva J, Dynamidis S, Defranco M, Walch G.** Glenoid version: how to measure it? Validity of different methods in two-dimensional computed tomography scans. J Shoulder Elbow Surg. 2010 Dec; 19(8): 1230-7. http://dx.doi.org/10.1016/j.jse.2010.01.027
25. **Scalise JJ, Codsi MJ, Brems JJ, Iannotti JP.** Inter-rater reliability of an arthritic glenoid morphology classification system. J Shoulder Elbow Surg. 2008 Jul-Aug; 17(4):575-7. http://dx.doi.org/10.1016/j.jse.2007.12.006
26. **Scalise JJ, Codsi MJ, Bryan J, Brems JJ, Iannotti JP.** The influence of three-dimensional computed tomography images of the shoulder in preoperative planning for total shoulder arthroplasty. J Bone Joint Surg Am. 2008 Nov; 90(11): 2438-45. http://dx.doi.org/10.2106/jbjs.g.01341
27. **Shapiro TA, McGarry MH, Gupta R, Lee YS, Lee TQ.** Biomechanical effects of glenoid retroversion in total arthroplasty. J Shoulder Elbow Surg 2007; 16:90-5. http://dx.doi.org/10.1016/j.jse.2006.07.010
28. **Sperling JW, Cofield RH, Rowland CM.** Neer hemiarthroplasty and Neer total shoulder arthroplasty in patients fifty years old or less. Long-term results. J Bone Joint Surg Am 1998; 80:464-73.
29. **Sperling JW, Cofield RH, Schleck CD, Harmsen WS.** Total shoulder arthroplasty versus hemiarthroplasty for rheumatoid arthritis of the shoulder: results of 303 consecutive cases. J Shoulder Elbow Surg. 2007 Nov-Dec; 16(6): 683-90. http://dx.doi.org/10.1016/j.jse.2007.02.135
30. **Sperling JWC, R.**H., Rowland CM. Minimum 15 year follow-up of Neer hemiarthroplasty and total shoulder arthroplasty in patients fifty years old and less. New Orleans, LA: 2003. p. 543.
31. **Throckmorton TW, Zarkadas PC, Sperling JW, Cofield RH.** Pegged versus keeled glenoid components in total shoulder arthroplasty. J Shoulder Elbow Surg. 2010 Jul;19(5):726-33. http://dx.doi.org/10.1016/j.jse.2009.10.018
32. **Torchia ME, Cofield RH, Settergren CR.** Total shoulder arthroplasty with the Neer prosthesis: long-term results. J Shoulder Elbow Surg 1997; 6:495-505.
33. **Walch G, Badet R, Boulahia A, Khoury A.** Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty 1999; 14:756-60.
34. **Walch G, Boulahia A, Boileau P, Kempf JF.** Primary glenohumeral osteoarthritis: clinical and radiographic classification. The Aequalis Group. Acta Orthop Belg. 1998; 64 Suppl 2:46-52.
35. **Walch G, Moraga C, Young A, Castellanos-Rosas J.** Results of anatomic nonconstrained prosthesis in primary osteoarthritis with biconcave glenoid. J Shoulder Elbow Surg 2012; 21:1526-33. http://dx.doi.org/10.1016/j.jse.2011.11.030
36. **Walch G, Vezeridis PS, Boileau P, Deransart P, Chaoui J.** Three-dimensional planning and use of patient-specific guides improve glenoid component position: an in vitro study. J Shoulder Elbow Surg. 2015 Feb; 24(2): 302-9. http://dx.doi.org/10.1016/j.jse.2014.05.029

Comparison of Outcomes of Reverse Total Shoulder Arthroplasty in Patients Younger than 65 Years to Those in Patients Older than 65 Years

Background: Younger patients with reverse total shoulder arthroplasty (RTSA) are believed to have higher activity levels that place higher stresses across the prosthesis, increasing the risk of failure, but there is little information to support or refute this supposition. The purpose of this study was to define the patient-reported activity levels of patients younger and older than 65 years who had RTSA and to evaluate any differences between the groups.

Methods: Forty-six patients with primary RTSA answered a questionnaire regarding their activity levels. Data were categorized and tabulated according to pain, range of motion, strength, and activity level (low, medium, and high demand). Fisher's exact test, chi square test, and independent t-test statistical analyses were performed. Differences with $p<0.05$ were considered statistically significant.

Results: Seventeen patients younger than 65 years (average 57.7) and 29 older than 65 (average 75.2) were included. No significant differences were found for range of motion, strength, or number of activities; 47% of younger patients and 44% of older patients reported high-demand activities ($p=0.64$); 24% of younger patients and 37% of older patients reported medium-demand use ($p=0.30$). Patients younger than 65 were more likely to require narcotic pain medication ($p=0.03$) and to be disabled ($p=0.0001$).

Conclusion: These data provide initial evidence that commonly held concerns about higher activity levels among younger patients placing excessive demands on the RTSA prosthesis may not be as important as currently thought. Rather, patients seem to self-regulate their activities to minimize pain and maximize essential functions after surgery.

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REFERENCES

1. **Beaton D, Richards RR.** Assessing the reliability and responsiveness of 5 shoulder questionnaires. J Shoulder Elbow Surg 1998; 7:565-572. doi:10.1016/S1058-2746(98)90002-7
2. **Cazeneuve JF, Cristofari DJ.** Long term functional outcome following reverse shoulder arthroplasty in the elderly. Orthop Traumatol Surg Res 2011; 97:583-589. doi:10.1016/j.otsr.2011.03.025
3. **Flury MP, Frey P, Goldhahn J, Schwyzer HK, Simmen BR.** Reverse shoulder arthroplasty as a salvage procedure for failed conventional shoulder replacement due to cuff failure-midterm results. Int Orthop 2010;35:53-60. doi:10.1007/s00264-010-0990-z
4. **Henn III RF, Ghomrawi H, Rutledge JR, Mazumdar M, Mancuso CA, Marx RG.** Preoperative patient expectations of total shoulder arthroplasty. J Bone Joint Surg Am 2011; 93:2110–2115. doi: 10.2106/JBJS.J.01114
5. **IBM Corp.** Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp
6. **Johnson MH, Paxton ES, Green A.** Shoulder arthroplasty options in young (<50 years old) patients: review of current concepts. J Shoulder Elbow Surg 2015; 24:317-e25. doi: 10.1016/j.jse.2014.09.029
7. **Kempton LB, Ankerson E, Wiater JM.** A complication-based learning curve from 200 reverse shoulder arthroplasties. Clin Orthop Relat Res 2011; 469: 2496-2504. doi: 10.1007/s11999-011-1811-4
8. **Lawrence TM, Ahmadi S, Sanchez-Sotelo J, Sperling JW, Cofield RH.** Patient reported activities after reverse shoulder arthroplasty: part II. J Shoulder Elbow Surg 2012; 21:1464-1469. doi:10.1016/j.jse.2011.11.012
9. **Leung B, HorodyskiMB, Struk AM, Wright TW.** Functional outcome of hemiarthroplasty compared to reverse total shoulder arthroplasty in the treatment of rotator cuff tear arthropathy. J Shoulder Elbow Surg 2012; 21:319-323. doi:10.1016/j.jse.2011.05.023
10. **Levy JC, Virani N, Pupello D, Frankle M.** Use of the reverse shoulder prosthesis for the treatment of failed hemiarthroplasty in patients with glenohumeral arthritis and rotator cuff deficiency. J Bone Joint Surg Br 2007; 89:189-95. doi:10.1302/0301-620X.89B2.18161
11. **Magnussen RA, Mallon WJ, Willems WJ, Moorman CT.** Long-term activity restrictions after shoulder arthroplasty: an international survey of experienced shoulder surgeons. J Shoulder Elbow Surg 2011; 20:281-9. doi:10.1016/j.jse.2010.07.021
12. **Merolla G, Porcellini G.** Reverse shoulder arthroplasty in patients aged sixty years old or younger: are we really doing the best? Transl Med UniSa 2014; 9:66-67.
13. **Mulieri P, Dunning P, Klein S, Pupello D, Frankle M.** Reverse shoulder arthroplasty for the treatment of irreparable rotator cuff tear without glenohumeral arthritis. J Bone Joint Surg Am 2010; 92:2544-2556. doi:10.2106/JBJS.I.00912
14. **Raiss P, Rettig O, Wolf S, Loew M, Kasten P.** Range of Motion of shoulder and elbow in activities of daily life in 3D motion analysis. Z Orthop Unfall 2007; 145:493-498. doi: 10.1055/s-2007-965468

15. **Sanchez-Sotelo J.** Reverse total shoulder arthroplasty. In: Morrey BF, editor. Joint replacement arthroplasty: basic science, elbow and shoulder. Philadelphia: Wolters Kluwer; 2011. p. 277.

16. **Schwartz DG, Cottrell BJ, Teusink MJ, Clark RE, Downes KL, Tannenbaum RS, et al.** Factors that predict postoperative motion in patients treated with reverse shoulder arthroplasty. J Shoulder Elbow Surg 2014; 23:1289-1295. doi: 10.1016/j.jse.2013.12.032

17. **Sershon RA, Van Thiel GS, Lin EC, McGill KC, Cole BJ, Verma NN, et al.** Clinical outcomes of reverse total shoulder arthroplasty in patients aged younger than 60 years. J Shoulder Elbow Surg 2014; 23:395-400. doi:10.1016/j.jse.2013.07.047

18. **Smith AM, Barnes SA, Sperling JW, Farrell CM, Cummings JD, Cofield RH.** Patient and physician assessed shoulder function after arthroplasty. J Bone Joint Surg Am 2006; 88:508-513. doi: 10.2106/JBJS.E.00132

19. **Throckmorton TW.** Shoulder and elbow arthroplasty. Canale ST, Beaty JH, editors. Campbell's Operative Orthopaedics, 12th Edition. Philadelphia: Elsevier; 2013. p. 532-534.

20. **Wall B, Nove-Josserand L, O'Connor DP, Edwards TB, Walch G.** Reverse total shoulder arthroplasty: a review of results according to etiology. J Bone Joint Surg Am 2007; 89:1476-1485. doi: 10.2106/JBJS.F.00666

21. **Wiater BP, Boone CR, Koueiter DM, Wiater JM.** Early outcomes of staged bilateral reverse total shoulder arthroplasty: a case-control study. Bone Joint J 2013; 95:1232-1238. doi:10.1302/0301-620X.95B9

22. **Willis M, Min W, Brooks J, Mulieri P, Walker M, Pupello D, et al.** Proximal humeral malunion treated with reverse shoulder arthroplasty. J Shoulder Elbow Surg 2012; 21:507-513. doi:10.1016/j.jse.2011.01.042

23. **Yang JS, Keener JD, Yamaguchi K, Chen J, Stobbs-Cucchi, Patton R, et al.** Reliability of patient self-assessment of shoulder range of motion and strength after shoulder arthroplasty. J Shoulder Elbow Surg 2015;2 4:1-10. doi: 10.1016/j.jse.2014.08.025

24. **Zarkadas PC, Throckmorton T, Dahm DL, Sperling J, Scleck CD, Cofield R, Patient reported activities after shoulder replacement: total and hemiarthroplasty.** J Shoulder Elbow Surg 2011; 20:273-280. doi:10.1016/j.jse.2010.06.007

Generic Targeting Guides Place Revision Glenoid Components in More Anatomic Version than Traditional Techniques

Background: Glenoid component positioning in revision shoulder arthroplasty is difficult due to distorted anatomic landmarks and significant scarring in and around the glenoid vault. However, accurate glenoid component placement remains an important goal, particularly in the revision setting. The purpose of this study was to compare post-operative glenoid component version in revision total shoulder arthroplasty (TSA) and reverse total shoulder arthroplasty (RTSA) using traditional instrumentation compared with a generic reusable glenoid targeting guide.

Methods: The post-operative radiographs of 50 shoulders undergoing revision shoulder arthroplasty were retrospectively reviewed in a randomized fashion by an independent reviewer not involved with the surgical cases and without knowledge of operative technique. Twenty one components were placed using traditional instrumentation and the remaining twenty nine were placed with a targeting guide placed down the anterior glenoid neck to direct guidewire placement in anatomic version. Using Friedman's technique, glenoid component version was measured on the best available post-operative axillary lateral radiograph. Absolute deviation of implant placement from anatomic version was calculated. Statistical analysis was performed using t-tests and F-tests. Differences with $p<0.05$ were considered statistically significant.

Results: The average deviation in component version from anatomic for the traditional technique group was 8 degrees, compared to 5 degrees in the targeting guide group ($p=0.03$). In revision to TSA, the average deviation in version was 10 degrees in the traditional group and 3 degrees in the targeting guide group ($p=0.01$). There was not a significant difference in revision to RTSA, with an average deviation in version of 8 degrees in the traditional group and 6 degrees in the targeting guide group ($p=0.45$).

Glenoid components in obese patients (BMI>30, 58% of patients) were in more anatomic version following placement with the targeting guide when compared to traditional instrumentation (5 degrees vs 9 degrees, $p=0.04$). There were no significant differences between techniques in glenoids with greater than 15 degrees of pre-operative retroversion, TSA conversion to RSTA, or arthroplasty in the setting of prior proximal humerus fixation.

Conclusions: In the revision arthroplasty setting, glenoid components placed with the generic targeting guide were significantly more accurate in version when compared to traditional instrumentation, particularly when revising to anatomic TSA. The targeting guide was also useful in the obese population, which was over half of our cohort. This suggests that excess soft tissue, whether post-traumatic scarring or secondary to obesity, can make glenoid placement using traditional techniques more prone to error.

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REFERENCES

1. **Alentorn-Geli E, Samitier G, Torrens C, Wright TW.** Reverse shoulder arthroplasty. Part 2: Systematic review of reoperations, revisions, problems, and complications. Int J Shoulder Surg. 2015 Apr-Jun;9(2):60-7.
2. **Gonzalez JF, Alami GB, Baque F, Walch G, Boileau P.** Complications of unconstrained shoulder prostheses. J Shoulder Elbow Surg. 2011 Jun;20(4):666-82.
3. **Zumstein MA, Pinedo M, Old J, Boileau P.** Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: a systematic review. J Shoulder Elbow Surg. 2011 Jan;20(1):146-57.
4. **Papadonikolakis A, Neradilek MB, Matsen FA 3rd.** Failure of the glenoid component in anatomic total shoulder arthroplasty: a systematic review of the English-language

literature between 2006 and 2012. J Bone Joint Surg Am. 2013 Dec 18;95(24):2205-12.

5. **Rasmussen JV.** Outcome and risk of revision following shoulder replacement in patients with glenohumeral osteoarthritis. Acta Orthop Suppl. 2014 Jun;85(355):1-23.
6. **Hasan SS, Leith JM, Campbell B, Kapil R, Smith KL, Matsen FA.** Characteristics of unsatisfactory shoulder arthroplasties. J Shoulder Elbow Surg 2002;11:431-41. doi:10.1067/mse.2002.125806
7. **Hennigan SP, Iannotti JP.** Instability after prosthetic arthroplasty of the shoulder. Orthop Clin North Am 2001;32:649-59.
8. **Iannotti JP, Spencer EE, Winter U, Deffenbaugh D, Williams GR.** Prosthetic positioning in total shoulder arthroplasty. J Shoulder Elbow Surg 2005;14:1115-21.
9. **Nyffeler RW, Sheikh R, Atkinson TS, Jacob HAC, Favre P, Gerber C.** Effects of glenoid component version on humeral head displacement and joint reaction forces: An experimental study. J Shoulder Elbow Surg 2006;15:625-9.
10. **Spencer EE, Kambic H, Valdevit A, Iannotti JP.** The effect of humeral component anteversion on shoulder stability with glenoid component retroversion. J Bone Joint Surg Am 2005;87A:808-14.
11. **Kwon YW, Powell KA, Yum JK, Brems JJ, Iannotti JP.** Use of three dimensional computed tomography for the analysis of the glenoid anatomy. J Shoulder Elbow Surg 2005;14:85-90.
12. **Churchill RS, Brems JJ, Kotschi H.** Glenoid size, inclination, and version: An anatomic study. J Shoulder Elbow Surg 2001;10:327-32.
13. **Codsi MJ, Bennetts C, Gordiev K, Boeck DM, Kwon YW, Brems JJ,et al.** Normal glenoid vault anatomy and validation of a novel glenoid implant shape. J Shoulder Elbow Surg 2008;17:471-8.
14. **Ganapathi AM, McCarron JA, Chen X, Iannotti JP.** Predicting normal glenoid version from the pathologic scapula: A comparison of four methods in 2D and 3D models. J Shoulder Elbow Surg 2011;20:234-44.
15. **Budge MD, Lewis GS, Schaefer E, Coquia S, Flemming DJ, Armstrong AD.** Comparison of standard two-dimensional and three dimensional corrected glenoid version measurements. J Shoulder Elbow Surg 2011;20:577-83.
16. **Hoenecke HR Jr, Hermida JC, Flores-Hernandez C, D'Lima DD.** Accuracy of CT-based measurements of glenoid version for total shoulder arthroplasty. J Shoulder Elbow Surg 2010;19:166-71.
17. **Walch G, Vezeridis PS, Boileau P, Deransart P, Chaoui J.** Three-dimensional planning and use of patient-specific guides improve glenoid component position: an in vitro study. J Shoulder Elbow Surg. 2015 Feb;24(2):302-9.
18. **Hendel MD, Bryan JA, Barsoum WK, Rodriguez EJ, Brems JJ, Evans PJ, Iannotti JP.** Comparison of patient-specific instruments with standard surgical instruments in determining glenoid component position: a randomized prospective clinical trial. J Bone Joint Surg Am. 2012 Dec 5;94(23):2167-75.
19. **Rerko MA, Pan X, Donaldson C, Jones GL, Bishop JY.** Comparison of various imaging techniques to quantify glenoid bone loss in shoulder instability. J Shoulder Elbow Surg. 2013 Apr;22(4):528-34.
20. **Bishop JY, Jones GL, Rerko MA, Donaldson C; MOON Shoulder Group.** 3-D CT is the most reliable imaging modality when quantifying glenoid bone loss. Clin Orthop Relat Res. 2013 Apr;471(4):1251-6.
21. **Bryce CD, Davison AC, Lewis GS, Wang L, Flemming DJ, Armstrong AD.** Two-dimensional glenoid version measurements vary with coronal and sagittal scapular rotation. J Bone Joint Surg Am. 2010 Mar;92(3):692-9.
22. **Scalise JJ, Codsi MJ, Bryan J, Brems JJ, Iannotti JP.** The influence of three-dimensional computed tomography images of the shoulder in preoperative planning for total shoulder arthroplasty. J Bone Joint Surg Am. 2008 Nov;90(11):2438-45.
23. **Nguyen D, Ferreira LM, Brownhill JR, King GJ, Drosdowech DS, Faber KJ, et al.** Improved accuracy of computer assisted glenoid implantation in total shoulder arthroplasty: an in-vitro randomized controlled trial. J Shoulder Elbow Surg 2009;18:907-14.
24. **Verborgt O, De Smedt T, Vanhees M, Clockaerts S, Parizel PM, Van Glabbeek F.** Accuracy of placement of the glenoid component in reversed shoulder arthroplasty with and without navigation. J Shoulder Elbow Surg 2011;20:21-6.
25. **Levy JC, Everding NG, Frankle MA, Keppler LJ.** Accuracy of patient-specific guided glenoid baseplate positioning for reverse shoulder arthroplasty. J Shoulder Elbow Surg. 2014 Oct;23(10):1563-7.
26. **Kircher J, Wiedemann M, Magosch P, Lichtenberg S, Habermeyer P.** Improved accuracy of glenoid positioning in total shoulder arthroplasty with intraoperative navigation: a prospective-randomized clinical study. J Shoulder Elbow Surg 2009;18:515-20.
27. **Friedman R J, Hawthorne KB, Genez BM: The use of computerized tomography in the measurement of glenoid version.** J Bone Joint Surg Am 74:1032, 1992
28. **Previous study reference**
29. **Iannotti JP, Greeson C, Downing D, Sabesan V, Bryan JA.** Effect of glenoid deformity on glenoid component placement in primary shoulder arthroplasty. J Shoulder Elbow Surg. 2012 Jan;21(1):48-55.
30. **Gupta AK, Chalmers PN, Rahman Z, Bruce B, Harris JD, McCormick F, Abrams GD, Nicholson GP.** Reverse total shoulder arthroplasty in patients of varying body mass index. J Shoulder Elbow Surg. 2014 Jan; 23(1): 35-42.
31. **Jain NB, Guller U, Pietrobon R, Bond TK, Higgins LD.** Comorbidities increase complication rates in patients having arthroplasty. Clin Orthop Relat Res. 2005 Jun;(435): 232-8.
32. **Li X, Williams PN, Nguyen JT, Craig EV, Warren RF, Gulotta LV.** Functional outcomes after total shoulder arthroplasty in obese patients. J Bone Joint Surg Am. 2013 Nov 6; 95(21): e160.
33. **Linberg CJ, Sperling JW, Schleck CD, Cofield RH.** Shoulder arthroplasty in morbidly obese patients. J Shoulder Elbow Surg. 2009 Nov-Dec; 18(6): 903-6.
34. **Pappou I, Virani NA, Clark R, Cottrell BJ, Frankle MA.** Outcomes and Costs of Reverse Shoulder Arthroplasty in the Morbidly Obese: A Case Control Study. J Bone Joint Surg Am. 2014 Jul 16; 96(14): 1169-1176.
35. **Nyffeler RW, Jost B, Pfirrmann CW, Gerber C.** Measurement of glenoid version: conventional radiographs versus computed tomography scans. J Shoulder Elbow Surg. 2003 Sep-Oct;12(5):493-6.
36. **Ho JC, Youderian A, Davidson IU, Bryan J, Iannotti JP.** Accuracy and reliability of postoperative radiographic measurements of glenoid anatomy and relationships in patients with total shoulder arthroplasty. J Shoulder Elbow Surg. 2013 Aug;22(8):1068-77.

Is a Generic Targeting Guide Useful for Glenoid Component Placement in Shoulder Arthroplasty?*

ABSTRACT

Background: This study compared postoperative glenoid component version using traditional instrumentation or a generic glenoid targeting guide during total or reverse total shoulder arthroplasty.

Methods: Glenoid component version was measured on postoperative radiographs of 184 shoulders (traditional 109; targeting guide 75). Demographics, preoperative imaging, and operative technique were identified from medical records. Absolute deviation from neutral version and standard deviations (SDs) were calculated.

Results: Average mean ± SD deviation in component version for the traditional technique group was 10 ° ± 7° compared with 9° ± 6 ° for the targeting guide group (P= .37; SD P=.12). No significant difference was noted based on operation, body mass index, preoperative version, or operative indication. For the last 30 shoulders in the targeting group, absolute mean deviation was 6° compared with 11° in the first 30 of that group (P<.01) and 10° in the entire traditional group (P=.01). The SD in the last 30 shoulders in the targeting group was 5° compared with 7° in the first 30 in that group (P=.04) and 7° in the traditional group (P<.01).

Conclusions: No significant difference in component accuracy was noted between the 2 techniques. The narrower SD in the targeting group, although not statistically significant, suggests less glenoid placement in the extremes of version. A learning curve was noted with the targeting guide, with significantly improved accuracy in later patients.

Levels of evidence: Level III, Retrospective Cohort Design, Treatment study.

Keywords: Glenoid; version; targeting; total shoulder arthroplasty

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INTRODUCTION

Shoulder arthroplasty has proven to be an effective treatment for patients with degenerative shoulder conditions, but success often is related to glenoid component orientation and survival.[6,14,26] Excessive glenoid retroversion may cause glenoid component loosening and humeral head subluxation or dislocation.[9,11,16,23,27] Often the surgeon is able to identify glenoid wear and plan for eccentric reaming or bone grafting preoperatively, but intraoperative landmarks may be distorted and cause uncertainty with glenoid version correction. Increased glenoid bone loss makes proper component placement much more difficult. Normal glenoid version varies widely in the population, within a range of about 20°.[4,5,8,18] However, without knowing the patient's native orientation, the goal for glenoid version in arthroplasty is typically perpendicular to the plane of the scapula or "neutral" version.

Traditional techniques of accurately preparing the glenoid and placement of the component have been inconsistent.[16] Recent literature supports the use of the three-dimensional computed tomography (CT) scanning and production of custom alignment guides, but at many institutions this is either cost prohibitive for the patient, or the technology is lacking. [1,2,3,10,13,17,18,19,21,24,25,28,29] As a

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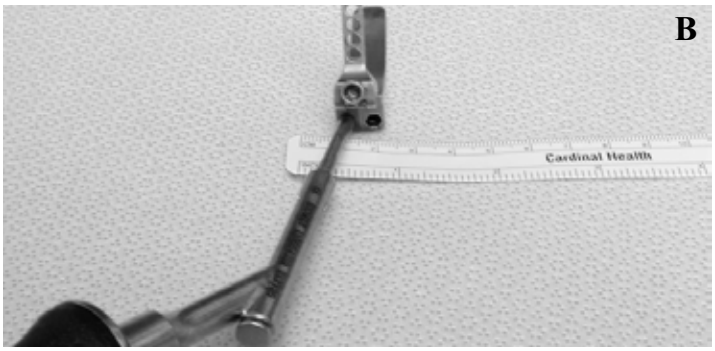

Figures 1A & 1B: Generic targeting guide for glenoid component positioning.

result, commercially available, noncustom and reusable targeting guides have been created to assist with component positioning **(Figure 1A)**. Appropriate alignment is obtained by placing the guide down the anterior glenoid neck, which directs guidewire placement.

The purpose of this study was to compare postoperative glenoid component version after using traditional instrumentation or a generic glenoid targeting guide during total shoulder arthroplasty (TSA) and reverse total shoulder arthroplasty (RTSA).

MATERIALS AND METHODS

A retrospective review of 184 patients who underwent primary shoulder arthroplasty, including TSA and RTSA, was conducted to assess postoperative glenoid version, using 1of 2 glenoid component positioning techniques. Patients were included over a 4-year period, from 2009 to 2013. Exclusion criteria were revision shoulder arthroplasty and glenoid bone grafting, which directly affects postoperative glenoid version and confounds the contribution of the positioning technique.

All TSAs in this series were performed by a single surgeon (T.W.T), and 1 of 2 techniques was used to prepare the glenoid with the goal of placing components in neutral version: the traditional technique or a generic targeting guide. The traditional technique involves using preoperative CT imaging to assess glenoid wear and anatomic landmarks intraoperatively to estimate anatomic version. A pencil tipped burr is used in the center of the glenoid articular surface to "sound the vault" and ensure that the trajectory of the centering pin does not exit the glenoid neck anteriorly or posteriorly. The generic reusable targeting guide uses an anterior flange placed down the anterior glenoid neck to direct guidewire placement in anatomic version. The flange acts similar to an anterior cruciate ligament guide in that its tip contacts the base of the glenoid vault and allows the guide to reference the scapular body to obtain pin placement in neutral version **(Figure 1B)**. The surgeon had gained prior experience with the guide in a cadaver laboratory setting and then adopted it into regular practice.

In patients with significant glenoid erosion in whom implants were unsupported on native bone after reaming, RTSA components were placed with the goal of 50% cortical contact on native bone. These patients were included in the study, but patients with structural bone grafting used in anatomic TSA were excluded. The traditional method was used in the first 109 patients in this series until the reusable targeting guide was introduced and used in the final 75 patients.

An independent reviewer not involved with any of the operations and without knowledge of the operative technique randomly assessed postoperative axillary lateral radiographs. Axillary lateral radiographs were obtained with the patient supine and the arm abducted between 60° and 90°. The X-ray beam was projected through the axilla superiorly towards a cassette placed horizontally above the shoulder. All radiographs were obtained by a licensed radiology technician. Fluoroscopic positioning was not used. Images were reviewed retrospectively with this standardized axillary lateral technique. Radiographs with full view of the scapular body as well as the glenoid vault and implants were considered adequate and were available in all patients. Anatomic total shoulder implants employed a porous titanium central post that was used to assess glenoid component version, and the RTSA baseplates were placed with a center screw that allowed measurement of component version (Comprehensive Shoulder System, Biomet, Inc, Warsaw, IN). The Friedman technique was used to measure glenoid component version on the best available postoperative radiograph.[7]

Electronic medical records were then reviewed for each patient to obtain demographics (sex, age, and body mass index [BMI][20]), assess preoperative imaging, and identify the operative technique.

Table I: Demographics

	TOTAL	TRADITIONAL	GUIDE	p-value
Total	184	109 (59.2%)	75 (40.8%)	
Men	77 (41.8%)	46 (42.2%)	31 (41.3%)	1.00
Age	66.2 (27 - 90)	69.1 (47 - 90)	61.9 (27 - 80)	<0.01
BMI	30.6 (15.8 - 55.1)	29.6 (15.8 - 55.1)	32.1 (17.2 - 50.5)	0.01
Right shoulder	97 (52.7%)	56 (51.4%)	41 (54.7%)	0.76
30 BMI or greater	88 (47.8%)	43 (39.4%)	45 (60%)	0.01
40 BMI or greater	17 (9.2%)	7 (6.4%)	10 (13.3%)	0.12
Pre-op retroversion (degrees)	11 (-12 - 44)	10.7 (-7 - 44)	11.4 (-12 - 32)	0.64
Absolute pre-op version (degrees)	11.5 (0 - 44)	11.2 (0 - 44)	12.1 (0 - 32)	0.45
More than 15 degrees pre-op retroversion	47 (25.5%)	26 (23.9%)	21 (28.0%)	0.61
Indication				
Osteoarthritis	94 (51.1%)	52 (47.7%)	42 (56.0%)	0.30
Inflammatory arthritis	10 (5.4%)	6 (5.5%)	4 (5.3%)	1.00
Cuff pathology	41 (22.3%)	27 (24.8%)	14 (18.7%)	0.37
Trauma/Post-trauma	32 (17.4%)	21 (19.3%)	11 (14.7%)	0.55
Other	7 (3.8%)	3 (2.8%)	4 (5.3%)	0.43
Procedure				
Total shoulder arthroplasty	114 (62.0%)	64 (58.7%)	50 (66.7%)	0.28
Reverse total shoulder arthroplasty	70 (38.0%)	45 (41.3%)	25 (33.3%)	0.28
Post-op anteversion	31 (16.8%)	13 (11.9%)	18 (24.0%)	0.04

Average absolute deviation from neutral version and standard deviations (SDs) were calculated between techniques overall and based on demographics and preoperative imaging. Statistical analysis was performed using SPSS 22 software (IBM, Armonk, NY). Means were compared with t tests and SDs were compared with *F* tests. *P* values of <0.5 were considered statistically significant.

RESULTS

The study included 184 consecutive patients (77 men and 107 women) undergoing primary shoulder arthroplasty. Of the total number of arthroplasties, 114 were anatomic TSA and 70 were RTSA. There was no difference in distribution of operations (TSA compared with RTSA) between technique groups. There was no difference in sex between technique groups. Patient demographics are summarized in Table I. The average age was significantly different between the groups, with the targeting guide group on younger by an average of 7 years. Almost half of the patients in the study were clinically obese (BMI > than 30 kg/m2), and 9% had a BMI > 40 kg/m2. The difference between groups was statistically significant, with more obese patients in the targeting group (**see Table I**).

More than 25% of patients had a preoperative retroversion of more than 15°. The average absolute preoperative glenoid retroversion was 11.5° (range, 0° - 44°), with no difference between technique groups. More than half of the patients had a primary diagnosis of osteoarthritis.

The average mean ± SD deviation in component version from neutral for the traditional technique group was 10° ± 7° compared with 9° ± 6 ° in the targeting guide group, which was not significant (**Table II**). Glenoid components placed with the targeting guide also were more likely to be placed in slight anteversion (18 of 75 [24%]) compared with the traditional technique (13 of 109 [12%]; *P*=.04). There was no statistically significant difference in the SD between groups (*P*=.12). Differences in deviation from neutral version based on arthroplasty type (TSA vs RTSA), BMI, preoperative retroversion, or operative indication also did not reach statistical significance (**see Table II**).

Table III documents the mean degree differences and variances. The difference in absolute mean deviation in version from anatomic for the first 30 shoulders compared with the last 30 in the targeting group was statistically significant (*P*=.002). This was also true when the last 30 in the targeting group were compared with

the all-traditional group (P=.014). The SD in the last 30 shoulders in the targeting group was 5° compared with 7° in the first 30 in the targeting group (P=.04) and 7° in the traditional group (P=.006).

In the 47 glenoids with more than 15° of preoperative retroversion, absolute mean deviation from anatomic version in the traditional group (26 shoulders) was 13° compared with 11° in the targeting group (21 shoulders), which was not significant. Accuracy was improved when preoperative version was less than 15° in both the traditional (8° vs 13°, P<.01) and targeting (7° vs 11°, P=.03) groups. The results were not significantly different between procedures performed. A significant difference in results with the targeting guide also was not demonstrated in patients with a BMI of greater than 30 kg/m2.

DISCUSSION

Methods to accurately place the glenoid component in shoulder arthroplasty continue to evolve. Although many agree traditional techniques may be inferior, this is the first study to our knowledge comparing a traditional free-hand technique with a reusable, nonpatient-specific targeting guide. We did not find a significant difference in postoperative version in our series overall. Although a narrower SD was noted in the targeting guide group, which may indicate less glenoid placement in the extremes of version, this finding was not statistically significant.

Our most notable finding in this study is the apparent learning curve with use of the targeting guide. The average deviation from neutral version in the final 30 glenoids using the guide was significantly improved compared with the first 30 glenoids using this technique (6° compared with 11°). The final 30 glenoids also were placed with significantly improved accuracy compared with the traditional instrumentation group (6° compared with 10°).

Previous studies have shown traditional instrumentation techniques place the glenoid component less accurately in as much as 13° average deviation from anatomic version in 1 study.[10,15,17,21,28] Cadaver and in vivo models of patient-specific instrumentation (PSI) have demonstrated glenoid placement in more anatomic version.[10,17,21,19,28] After a learning curve, the generic targeting guide used in this study placed glenoid components on average within 6° of neutral version, which is close but not equal to the range of reported results for PSI.

Traditional instrumentation techniques have been shown to be particularly poor in restoring anatomic version of the glenoid in patients with moderate to severe glenoid deformity.[15] In contrast, a strong benefit of PSI is correction of significant glenoid wear patterns. Hendel et al.10 found the greatest advantage of PSI in patients with greater than 16° of retroversion. Average postoperative deviation in their traditional group was 10° compared to 1.2° using PSI technology (P<.001). Similar improvements were not seen with the generic targeting guide in this study because there was no difference in glenoid component accuracy between the groups when preoperative retroversion was greater than 15°. However, our study may have been underpowered to show a statistically significant difference in this subset.

The advantages of the generic guide include that it is easily attainable, reusable, and less expensive than PSI; however, a learning curve was present, which low-volume shoulder arthroplasty surgeons may not be able to ascend in a short period of time. Nevertheless, the re-

Table II: Results

	TRADITIONAL (mean degrees)	GUIDE (mean degrees)	p-value	TRADITIONAL (variance)	GUIDE (variance)	p-value
Overall	10 ± 7.4	9 ± 6.2	0.37	54	39	0.12
TSA	11 ± 8.2	10 ± 6.8	0.80	68	47	0.17
RTSA	8 ± 5.7	7 ± 4.5	0.44	33	20	0.21
>=15 degrees pre-op	13 ± 9.6	11 ± 6.9	0.47	92	48	0.14
<15 degrees pre-op	8 ± 6.0	7 ± 5.6	0.53	36	32	0.72
>=30 BMI	11 ± 7.6	9 ± 6.4	0.22	58	41	0.26
<30 BMI	9 ± 7.0	8 ± 5.9	0.56	50	34	0.28
>=40 BMI	13 ± 9.6	10 ± 6.7	0.40	92	45	0.32
OA	11 ± 8.5	10 ± 7.0	0.66	73	48	0.18
Cuff pathology	9 ± 5.4	7 ± 4.5	0.22	29	21	0.54
Trauma	9 ± 6.8	8 ± 4.5	0.81	47	20	0.17
Final 30 patients	8 ± 6.0	6 ± 4.6	0.24	36	22	0.18

Table III: Results

MEAN (degrees)					VARIANCE		
Last 30 Guide		All Traditional		p-value	Last 30 Guide	All Traditional	p-value
6	± 4.6	10	± 7.3	0.014	22	54	0.006
First 30 Guide		Last 30 Guide		p-value	First 30 Guide	Last 30 Guide	p-value
11	± 6.9	6	± 4.6	0.002	48	22	0.04
TSA Guide		RTSA Guide		p-value	TSA	RTSA	p-value
10	± 6.8	7	± 4.5	0.09	47	20	0.03
Pre-op version >=15 Guide		<15 Guide		p-value	Pre-op version >=15 Guide	<15 Guide	p-value
11	± 6.9	7	± 5.6	0.03	48	32	0.26
Pre-op version >=15 Traditional		<15 Traditional		p-value	Pre-op version >=15 Traditional	<15 Traditional	p-value
13	± 9.6	8	± 6.0	0.005	92	36	0.002
BMI >=30		<30		p-value	BMI >=30	<30	p-value
9	± 6.4	8	± 5.9	0.13	41	34	0.31

sults during this study period were not worse than those using the traditional technique, and accuracy with the generic guide improved with time until a significant difference was noted after the learning curve was completed. The learning curve with PSI is likely shorter and may convey an advantage for low-volume surgeons, but in environments where PSI is not available, we suggest that a generic guide may offer a reasonable alternative to traditional glenoid preparation methods.

Our study has notable weaknesses. This is a retrospective case series reviewing 2 glenoid preparation methods performed by a single surgeon. A large proportion of 1 technique was done early in the series, followed by a change in practice, which introduces the possibility of experience bias. Results could have improved because of increased surgeon familiarity with other aspects of the procedure, thereby improving glenoid component positioning. Although postoperative imaging was evaluated by an independent, blinded reviewer experienced with radiographic measurements, reliability was not established by comparing his results to those of another reviewer. Finally, the difficulties of measuring glenoid version on axillary lateral radiographs have been established in previous literature.[22] Soft-tissue projection, restricted shoulder motion, and operator experience all contribute to variable image quality and out-of-plane radiographs. Nevertheless, Ho et al.[12] found moderate agreement between postoperative axillary lateral radiographs and CT and supported this modality as an appropriate measure of glenoid version.

CONCLUSIONS

Our study did not find an overall improvement in glenoid component accuracy using a generic targeting guide; however, this most likely is attributed to a learning curve inherent in a new operative technique. With further experience, the generic targeting guide was accurate and reproducible in later patients, resulting in significant improvements in glenoid component placement compared with traditional instrumentation, although it did not achieve the accuracy reported with PSI. Further comparative studies may assess the utility of targeting guides in primary and revision shoulder arthroplasty and the cost-effectiveness of various techniques in patients with severe glenoid wear patterns.

DISCLAIMER

The authors, their immediate families, and any research foundations 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. **Bishop JY, Jones GL, Rerko MA, Donaldson C; MOON Shoulder Group.** 3-D CT is the most reliable imaging modality when quantifying glenoid bone loss. Clin Orthop Relat Res. 2013 Apr;471(4):1251-1256. doi: 10.1007/s11999-012-2607-x
2. **Bryce CD, Davison AC, Lewis GS, Wang L, Flemming DJ, Armstrong AD.** Two-dimensional glenoid version measurements vary with coronal and sagittal scapular rotation. J Bone Joint Surg Am. 2010 Mar;92(3):692-699. doi: 10.2106/JBJS.I.00177
3. **Budge MD, Lewis GS, Schaefer E, Coquia S, Flemming DJ, Armstrong AD.** Comparison of standard two-dimensional and three dimensional corrected glenoid version measurements. J Shoulder Elbow Surg 2011;20:577-583. doi: 10.1016/j.jse.2010.11.003
4. **Churchill RS, Brems JJ, Kotschi H.** Glenoid size, inclination, and version: An anatomic study. J Shoulder Elbow Surg 2001;10:327-332.
5. **Codsi MJ, Bennetts C, Gordiev K, Boeck DM, Kwon YW, Brems JJ,et al.** Normal glenoid vault anatomy and validation of a novel glenoid implant shape. J Shoulder Elbow Surg 2008;17:471-478. doi: 10.1016/j.jse.2007.08.010
6. **Farron A, Terrier A, Buchler P.** Risks of loosening of a prosthetic glenoid implanted in retroversion. J Shoulder Elbow Surg 2006;15:521-526. Dx.doi.org/10.1016/j.jse.2005.10.003
7. **Friedman R J, Hawthorne KB, Genez BM: The use of computerized tomography in the measurement of glenoid version.** J Bone Joint Surg Am 74:1032, 1992.
8. **Ganapathi AM, McCarron JA, Chen X, Iannotti JP.** Predicting normal glenoid version from the pathologic scapula: A comparison of four methods in 2D and 3D models. J Shoulder Elbow Surg 2011;20:234-244. doi: 10.1016/j.jse.2010.05.024
9. **Hasan SS, Leith JM, Campbell B, Kapil R, Smith KL, Matsen FA.** Characteristics of unsatisfactory shoulder arthroplasties. J Shoulder Elbow Surg 2002;11:431-441. doi:10.1067/mse.2002.125806
10. **Hendel MD, Bryan JA, Barsoum WK, Rodriguez EJ, Brems JJ, Evans PJ, Iannotti JP.** Comparison of patient-specific instruments with standard surgical instruments in determining glenoid component position: a randomized prospective clinical trial. J Bone Joint Surg Am. 2012 Dec 5;94(23):2167-2175. doi: 10.2106/JBJS.K.01209.
11. **Hennigan SP, Iannotti JP.** Instability after prosthetic arthroplasty of the shoulder. Orthop Clin North Am 2001;32:649-659.
12. **Ho JC, Youderian A, Davidson IU, Bryan J, Iannotti JP.** Accuracy and reliability of postoperative radiographic measurements of glenoid anatomy and relationships in patients with total shoulder arthroplasty. J Shoulder Elbow Surg. 2013 Aug;22(8):1068-1077. doi: 10.1016/j.jse.2012.11.015
13. **Hoenecke HR Jr, Hermida JC, Flores-Hernandez C, D'Lima DD.** Accuracy of CT-based measurements of glenoid version for total shoulder arthroplasty. J Shoulder Elbow Surg 2010;19:166-171. doi: 10.1016/j.jse.2009.08.009.
14. **Hopkins AR, Hansen UN, Amis AA, Emery R.** The effects of glenoid component alignment variations on cement mantle stresses in total shoulder arthroplasty. J Shoulder Elbow Surg 2004;13:668-675. dx.doi.org/10.1016/j.jse.2004.04.008
15. **Iannotti JP, Greeson C, Downing D, Sabesan V, Bryan JA.** Effect of glenoid deformity on glenoid component placement in primary shoulder arthroplasty. J Shoulder Elbow Surg. 2012 Jan;21(1):48-55. Dx.doi.org/10.1016/j.jse.2011.02.011
16. **Iannotti JP, Spencer EE, Winter U, Deffenbaugh D, Williams GR.** Prosthetic positioning in total shoulder arthroplasty. J Shoulder Elbow Surg 2005;14:1115-1121. dx.doi.org/10.1016/j.jse.2004.09.026
17. **Kircher J, Wiedemann M, Magosch P, Lichtenberg S, Habermeyer P.** Improved accuracy of glenoid positioning in total shoulder arthroplasty with intraoperative navigation: a prospective-randomized clinical study. J Shoulder Elbow Surg 2009;18:515-520. doi: 10.1016/j.jse.2009.03.014.
18. **Kwon YW, Powell KA, Yum JK, Brems JJ, Iannotti JP.** Use of three dimensional computed tomography for the analysis of the glenoid anatomy. J Shoulder Elbow Surg 2005;14:85-90. Dx.doi.org/10.1016/j.jse.2004.04.011
19. **Levy JC, Everding NG, Frankle MA, Keppler LJ.** Accuracy of patient-specific guided glenoid baseplate positioning for reverse shoulder arthroplasty. J Shoulder Elbow Surg. 2014 Oct;23(10):1563-1567. doi: 10.1016/j.jse.2014.01.051
20. **Linberg CJ, Sperling JW, Schleck CD, Cofield RH.** Shoulder arthroplasty in morbidly obese patients. J Shoulder Elbow Surg. 2009 Nov-Dec;18(6):903-906. doi: 10.1016/j.jse.2009.02.006.
21. **Nguyen D, Ferreira LM, Brownhill JR, King GJ, Drosdowech DS, Faber KJ, et al.** Improved accuracy of computer assisted glenoid implantation in total shoulder arthroplasty: an in-vitro randomized controlled trial. J Shoulder Elbow Surg 2009;18:907-914. doi: 10.1016/j.jse.2009.02.022.
22. **Nyffeler RW, Jost B, Pfirrmann CW, Gerber C.** Measurement of glenoid version: conventional radiographs versus computed tomography scans. J Shoulder Elbow Surg. 2003 Sep-Oct;12(5):493-496. Dx.doi.org/10.1016/s1058-2746(03)00181-2
23. **Nyffeler RW, Sheikh R, Atkinson TS, Jacob HAC, Favre P, Gerber C.** Effects of glenoid component version on humeral head displacement and joint reaction forces: An experimental study. J Shoulder Elbow Surg 2006;15:625-629. Dx.doi.org/10.1016/j.jse.2005.09.016
24. **Rerko MA, Pan X, Donaldson C, Jones GL, Bishop JY.** Comparison of various imaging techniques to quantify glenoid bone loss in shoulder instability. J Shoulder Elbow Surg. 2013 Apr;22(4):528-534. doi: 10.1016/j.jse.2012.05.034.
25. **Scalise JJ, Codsi MJ, Bryan J, Brems JJ, Iannotti JP.** The influence of three-dimensional computed tomography images of the shoulder in preoperative planning for total shoulder arthroplasty. J Bone Joint Surg Am. 2008 Nov;90(11):2438-2445. doi: 10.2106/JBJS.G.01341.
26. **Shapiro TA, McGarry MH, Gupta R, Lee YS, Lee TQ.** Biomechanical effects of glenoid retroversion in total arthroplasty. J Shoulder Elbow Surg 2007;16:90-95. Dx.doi.org/10.1016/j.jse.2006.07.010
27. **Spencer EE, Kambic H, Valdevit A, Iannotti JP.** The effect of humeral component anteversion on shoulder stability with glenoid component retroversion. J Bone Joint Surg Am 2005;87A:808-14. Dx.doi.org/10.2106/jbjs.c.00770
28. **Verborgt O, De Smedt T, Vanhees M, Clockaerts S, Parizel PM, Van Glabbeek F.** Accuracy of placement of the glenoid component in reversed shoulder arthroplasty with and without navigation. J Shoulder Elbow Surg 2011;20:21-26. doi: 10.1016/j.jse.2010.07.014.
29. **Walch G, Vezeridis PS, Boileau P, Deransart P, Chaoui J.** Three-dimensional planning and use of patient-specific guides improve glenoid component position: an in vitro study. J Shoulder Elbow Surg. 2015 Feb;24(2):302-309. doi: 10.1016/j.jse.2014.05.029.

Reliability Testing for Three Classifications of Glenohumeral Rheumatoid Arthritis

Background: Several radiographic classifications exist for glenohumeral wear patterns found in rheumatoid arthritis. To date, no published data exists confirming the reliability of the Neer, Levigne, or Myoshi classifications. We proposed to examine the intra- and inter-observer agreement of these systems to determine which scheme is most reliable for classification.

Methods: Four orthopaedic surgeons with fellowship level training in upper extremity disorders and four orthopaedic trainees examined 53 radiographs of rheumatoid shoulders and classified them according to the three radiographic schemes. After a minimum two week interval, each observer repeated the classification process. Intra-observer agreement was calculated using weighted Cohen's kappa values. Inter-observer agreement was quantified using weighted Conger's kappa values. Altman's benchmark scale was used with Kappa values from 0.81 – 1.00 considered very good agreement, values between 0.61-0.8 good agreement, values between 0.4-0.6 moderate agreement, values between 0.21-0.4 fair agreement and values less than 0.2 were considered to indicate poor agreement.

Results: The Levigne classification demonstrated good intra-observer agreement (k=0.80) and good inter-observer agreement (k=0.64). The Neer classification scheme demonstrated good intra-observer agreement (k=0.61) and moderate inter-observer agreement (k=0.50). Finally, the Myoshi classification scheme was also found to have good intra-observer agreement (k=0.66) and fair inter-observer agreement (k=0.37). There were no differences in intra-observer reliability between trainees and fellowship-trained physicians.

Conclusions: We found the Levigne classification to have good intra- and inter-observer reliability in this study. In contrast, the Neer and Myoshi classifications both demonstrated good intra-observer reliability with moderate and fair inter-observer agreement, respectively. While all systems demonstrated reasonable overall reliability, these data suggest the Levigne system may be most reliable for classification of rheumatoid arthritis affecting the glenohumeral joint. Level of training did not impact the ability of observers to reliably judge rheumatoid wear patterns with these classification systems.

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REFERENCES

1. **Kanazawa T, Nishino J, Tohma S, Tanaka S.** Analysis of the affected joints in rheumatoid arthritis patients in a large Japanese cohort. Mod Rheumatol. 2012;23(1):44–49. doi:10.1007/s10165-012-0636-7.
2. **Scott DL, Smith C, Kingsley G.** Joint damage and disability in rheumatoid arthritis: an updated systematic review. Clin Exp Rheumatol. 2003;21(5 Suppl 31):S20–7.
3. **Fauci AS.** Harrison's Principles of Internal Medicine. 2008.
4. **van der Zwaal P, Pijls BG, Thomassen BJW, Lindenburg R, Nelissen RGHH, van de Sande MAJ.** The natural history of the rheumatoid shoulder: a prospective long-term follow-up study. Bone Joint J. 2014;96-B(11):1520–1524. doi:10.1302/0301-620X.96B11.34133.
5. **Kim SH, Wise BL, Zhang Y, Szabo RM.** Increasing Incidence of Shoulder Arthroplasty in the United States. J Bone Joint Surg Am. 2011;93(24). doi:10.2106/JBJS.J.01994.
6. **Mertelsmann-Voss C, Lyman S, Pan TJ, Goodman SM, Figgie MP, Mandl LA.** US Trends in Rates of Arthroplasty for Inflammatory Arthritis Including Rheumatoid Arthritis, Juvenile Idiopathic Arthritis, and Spondyloarthritis. Arthritis & Rheumatology. 2014;66(6):1432–1439. doi:10.1002/art.38384.
7. **MD EF, MD DZ, MD LK, MD NFS.** Factors predicting complication rates after primary shoulder arthroplasty. Journal of Shoulder and Elbow Surgery. 2011;20(4):557–563. doi:10.1016/j.jse.2010.11.005.
8. **Hirooka A, Wakitani S, Yoneda M, Ochi T.** Shoulder destruction in rheumatoid arthritis Classification and prognostic signs in 83 patients followed 5–23 years. Acta Orthop. 2009;67(3):258–263.
9. **Evaluation of surgeries for rheumatoid shoulder based on the destruction pattern.** J Rheumatol. 1999;26(1):41–46.
10. **Hermann KGA, Backhaus M, Schneider U, et al.** Rheumatoid arthritis of the shoulder joint: Comparison of conventional radiography, ultrasound, and dynamic contrast-enhanced magnetic resonance imaging. Arthritis & Rheumatism. 2003;48(12):3338–3349. doi:10.1002/art.11349.

11. **Kidder JF, Rouleau DM, DeFranco MJ, Pons Villanueva J, Dynamidis S.** Revisited: Walch classification of the glenoid in glenohumeral osteoarthritis. Shoulder & Elbow. 2012;4(1):11–15. doi:10.1111/j.1758-5740.2011.00151.x.
12. **Rouleau M, Kidder J, de Villanueva JP, Dynamidis S, De Franco M, Walch G.** 172 – Revisited: Reliability of the Walch Classification of the Glenoid in Glenohumeral Osteoarthritis Dominique. J Bone Joint Surg Br. 2011;93-B(SUPP IV):588–588.
13. **Miyoshi N, Suenaga N, Katayama K, Oizumi N, Yamaguchi H, Matsuno T.** Radiological classification of glenoid deformity in rheumatoid arthritis. Int J Rheumatol. 2011;2011(7):239894–6. doi:10.1155/2011/239894.
14. **Walch G, Boileau P.** Shoulder Arthroplasty. Springer Science & Business Media; 1999.
15. **Neer CS.** II Shoulder Reconstruction/Ch. S. Neer II. Philadelphia: WB Saunders Company; 1990.
16. **Kelly IG.** Unconstrained shoulder arthroplasty in rheumatoid arthritis. Clin Orthop Relat Res. 1994.
17. **Lévigne C, Franceschi JP.** Rheumatoid Arthritis of the Shoulder: Radiological Presentation and Results of Arthroplasty. In: Shoulder Arthroplasty. Berlin, Heidelberg: Springer Berlin Heidelberg; 1999:221–230. doi:10.1007/978-3-642-58365-0_24.
18. **Oizumi N, Suenaga N, Fukuda K, Minami A.** Massive rotator cuff tears repaired on top of humeral head by McLaughlin's procedure. Journal of Shoulder and …. 2007.
19. **Iannotti JP, McCarron J, Raymond CJ, et al.** Agreement study of radiographic classification of rotator cuff tear arthropathy. J Shoulder Elbow Surg. 2010;19(8):1243–1249. doi:10.1016/j.jse.2010.02.010.
20. **Blonna D, Zarkadas PC, Fitzsimmons JS, O'Driscoll SW.** Validation of a photography-based goniometry method for measuring joint range of motion. J Shoulder Elbow Surg. 2012;21(1):29–35. doi:10.1016/j.jse.2011.06.018.
21. **Altman DG.** Mathematics for Kappa. Practical statistics for medical research; 1991.
22. **Bruynesteyn K, van der Heijde D, Boers M, van der Linden S, Lassere M, van der Vleuten C.** The Sharp/van der Heijde method out-performed the Larsen/Scott method on the individual patient level in assessing radiographs in early rheumatoid arthritis. Journal of clinical epidemiology. 2004;57(5):502–512. doi:10.1016/j.jclinepi.2003.10.014.
23. **Larsen A.** A radiological method for grading the severity of rheumatoid arthritis. Scand J Rheumatol. 1975.
24. **Scalise JJ, Codsi MJ, Brems JJ, Iannotti JP.** Inter-rater reliability of an arthritic glenoid morphology classification system. Journal of Shoulder and Elbow Surgery. 2008;17(4):575–577. doi:10.1016/j.jse.2007.12.006.
25. **MD ME, MD BC, MD HR, MD TK.** Reliability of radiologic glenohumeral osteoarthritis classifications. Journal of Shoulder and Elbow Surgery. 2013;22(8):1063–1067. doi:10.1016/j.jse.2012.11.007.
26. **MD DDN, MCE TRG, MD LUB, MD WNL, MD CSA.** Interobserver and intraobserver reliability of the Walch classification in primary glenohumeral arthritis. Journal of Shoulder and Elbow Surgery. 2010;19(2):180–183. doi:10.1016/j.jse.2009.08.003.
27. **Panchani S, Reading J, Mehta J.** Inter and intra-observer reliability in assessment of the position of the lateral sesamoid in determining the severity of hallux valgus. Foot (Edinb). 2015. doi:10.1016/j.foot.2015.10.001.
28. **Koo H.** Interobserver Reliability of the Young-Burgess and Tile Classification Systems for Fractures of the Pelvic Ring. Journal orthopedic trauma. 2008:1–6.
29. **Nowak DD, Gardner TR, Bigliani LU, Levine WN, Ahmad CS.** Interobserver and intraobserver reliability of the Walch classification in primary glenohumeral arthritis. Journal of Shoulder and Elbow Surgery. 19(2):180–183.

Combined ACL and ALL Reconstructions in Patients with a Grade III Pivot Shift: Technique and Early Outcomes

Background: The anterolateral ligament (ALL) has been identified as an important structure involved in internal tibial rotational stability. There have been a limited number of studies recognizing its importance as a knee stabilizer when anatomically reconstructed in combination with a ruptured anterior cruciate ligament (ACL). To our knowledge this study is the first to provide early outcomes on a subset of patients with an ACL deficient knee exhibiting grade III pivot shift preoperatively.

Methods: Inclusion criteria were patients who underwent combined ACL and ALL reconstruction during the year 2015. All patients exhibited a grade III pivot shift under anesthesia prior to the procedure. Patellar tendon autograft was used for ACL reconstructions. Hamstring autograft was used for ALL reconstructions.

Results: A total of 17 patients underwent combined ACL and ALL reconstruction. Patient ages ranged from 15-40 years old with an average of 22.2 years. Mean follow up from time of surgery was 6 months. Average time from surgery to full range of motion was 7.6 weeks (range 3-12 weeks). 16 patients were found to have no pivot shift on exam at latest follow up. One patient exhibited a grade 1 pivot glide. There were no wound complications.

Conclusion: This study illustrates what we believe to be a useful technique when reconstructing anterior cruciate ligaments in patients found to have a grade III pivot shift preoperatively. The combination of the ALL reconstruction in conjunction with ACL reconstruction not only allows for increased knee anterolateral rotational stability in selected patients, it appears to do so without increasing complication rates of traditional ACL reconstructions. Long term and comparative follow up studies are still needed to provide a definitive answer on the results of combined ACL and ALL reconstructions.

Study design: Retrospective case series, Level IV

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REFERENCES

1. **Hewison CE, Tran MN, Kaniki N, Remtulla A, Bryant D, Getgood AM.** Lateral Extra-articular Tenodesis Reduces Rotational Laxity When Combined With Anterior Cruciate Ligament Reconstruction: A Systematic Review of the Literature. Arthroscopy. 2015 Oct;31(10):2022-34. doi: 10.1016/j.arthro.2015.04.089. Epub 2015 Jun 24.
2. **Dodds AL, Gupte CM, Neyret P, Williams AM, Amis AA.** Extra-articular techniques in anterior cruciate ligament reconstruction: a literature review. J Bone Joint Surg Br. 2011 Nov;93(11):1440-8. doi: 10.1302/0301-620X.93B11.27632.
3. **Lubowitz JH, Provencher MT, Brand JC, Rossi MJ.** The knee anterolateral ligament. Arthroscopy. 2014 Nov;30(11):1385-8. doi: 10.1016/j.arthro.2014.08.007. Epub 2014 Oct 23.
4. **Bonasia DE, D'Amelio A, Pellegrino P, Rosso F, Rossi R.** Anterolateral Ligament of the Knee: Back to the Future in Anterior Cruciate Ligament Reconstruction. Orthop Rev (Pavia). 2015 Jun 11;7(2):5773. doi: 10.4081/or.2015.5773. eCollection 2015.
5. **Van der Watt L, Khan M, Rothrauff BB, Ayeni OR, Musahl V, Getgood A, Peterson D.** The structure and function of the anterolateral ligament of the knee: a systematic review. Arthroscopy. 2015 Mar;31(3):569-82.e3. doi: 10.1016/j.arthro.2014.12.015.
6. **Tavlo M, Eljaja S, Jensen JT, Siersma VD, Krogsgaard MR.** The role of the anterolateral ligament in ACL insufficient and reconstructed knees on rotatory stability: A biomechanical study on human cadavers. Scand J Med Sci Sports. 2015 Aug 6. doi: 10.1111/sms.12524. [Epub ahead of print]
7. **Kittl C, El-Daou H, Athwal KK, Gupte CM, Weiler A, Williams A, Amis AA.** The Role of the Anterolateral Structures and the ACL in Controlling Laxity of the Intact and ACL-Deficient Knee. Am J Sports Med. 2015 Dec 10. pii: 0363546515614312. [Epub ahead of print]
8. **Sonnery-Cottet B, Thaunat M, Freychet B, Pupim BH, Murphy CG, Claes S.** Outcome of a Combined Anterior Cruciate Ligament and Anterolateral Ligament Reconstruction Technique With a Minimum 2-Year Follow-up. Am J Sports Med. 2015 Jul;43(7):1598-605. doi: 10.1177/0363546515571571. Epub 2015 Mar 4.
9. **Song GY, Zhang H, Wang QQ, Zhang J, Li Y, Feng H.** Risk Factors Associated With Grade 3 Pivot Shift After Acute Anterior Cruciate Ligament Injuries. Am J Sports Med. 2015 Nov 30. pii: 0363546515613069. [Epub ahead of print]
10. **Dodds AL, Halewood C, Gupte CM, Williams A, Amis AA.** The anterolateral ligament: Anatomy, length changes and association with the Segond fracture. Bone Joint J. 2014 Mar;96-B(3):325-31. doi: 10.1302/0301-620X.96B3.33033.
11. **Lubowitz JH.** Editorial Commentary: Knee Lateral Extra-articular Tenodesis. Arthroscopy. 2015 Oct;31(10):2035. doi: 10.1016/j.arthro.2015.07.007.
12. **Claes S, Vereecke E, Maes M, Victor J, Verdonk P, Bellemans J.** Anatomy of the anterolateral ligament of the knee. J Anat. 2013 Oct;223(4):321-8. doi: 10.1111/joa.12087. Epub 2013 Aug 1.

13. **Smith JO, Yasen SK, Lord B, Wilson AJ.** Combined anterolateral ligament and anatomic anterior cruciate ligament reconstruction of the knee. Knee Surg Sports Traumatol Arthrosc. 2015 Nov;23(11):3151-6. doi: 10.1007/s00167-015-3783-5. Epub 2015 Sep 19.

14. **Helito CP, Helito PV, Bonadio MB, da Mota E Albuquerque RF, Bordalo-Rodrigues M, Pecora JR, Camanho GL, Demange MK.** Evaluation of the Length and Isometric Pattern of the Anterolateral Ligament With Serial Computer Tomography. Orthop J Sports Med. 2014 Dec 17;2(12):2325967114562205. doi: 10.1177/2325967114562205. eCollection 2014 Dec.

15. **Lubowitz JH.** Editorial Commentary: The Importance of the Simulated Pivot-Shift Test. Arthroscopy. 2015 Dec;31(12):2455. doi: 10.1016/j.arthro.2015.09.008.

16. **Roessler PP, Schüttler KF, Heyse TJ, Wirtz DC, Efe T.** The anterolateral ligament (ALL) and its role in rotational extra-articular stability of the knee joint: a review of anatomy and surgical concepts. Arch Orthop Trauma Surg. 2015 Dec 29. [Epub ahead of print]

17. **Kennedy MI, Claes S, Fuso FA, Williams BT, Goldsmith MT, Turnbull TL, Wijdicks CA, LaPrade RF.** The Anterolateral Ligament: An Anatomic, Radiographic, and Biomechanical Analysis. Am J Sports Med. 2015 Jul;43(7):1606-15. doi: 10.1177/0363546515578253. Epub 2015 Apr 17.

18. **Guenther D, Griffith C, Lesniak B, Lopomo N, Grassi A, Zaffagnini S, Fu FH, Musahl V.** Anterolateral rotatory instability of the knee. Knee Surg Sports Traumatol Arthrosc. 2015 Oct;23(10):2909-17. doi: 10.1007/s00167-015-3616-6. Epub 2015 May 5.

19. **Pomajzl R, Maerz T, Shams C, Guettler J, Bicos J.** A review of the anterolateral ligament of the knee: current knowledge regarding its incidence, anatomy, biomechanics, and surgical dissection. Arthroscopy. 2015 Mar;31(3):583-91. doi: 10.1016/j.arthro.2014.09.010. Epub 2014 Nov 8.

20. **Helito CP, Demange MK, Bonadio MB, Tirico LE, Gobbi RG, Pecora JR, Camanho GL.** Radiographic landmarks for locating the femoral origin and tibial insertion of the knee anterolateral ligament. Am J Sports Med. 2014 Oct;42(10):2356-62. doi: 10.1177/0363546514543770. Epub 2014 Aug 7.

21. **Segond P.** Recherches cliniques et experimentales sur les epanchements sanguins du genou par entorse. Paris: Aux Bureaux du Progres Medical, 1879.

22. **Claes S, Luyckx T, Vereecke E, Bellemans J.** The Segond fracture: a bony injury of the anterolateral ligament of the knee. Arthroscopy. 2014 Nov;30(11):1475-82. doi: 10.1016/j.arthro.2014.05.039. Epub 2014 Aug 8.

23. **Helito CP, Bonadio MB, Gobbi RG, da Mota E Albuquerque RF, Pécora JR, Camanho GL, Demange MK.** Is it safe to reconstruct the knee Anterolateral Ligament with a femoral tunnel? Frequency of Lateral Collateral Ligament and Popliteus Tendon injury. Int Orthop. 2015 Jul 12. [Epub ahead of print]

24. **Caterine S, Litchfield R, Johnson M, Chronik B, Getgood A.** A cadaveric study of the anterolateral ligament: re-introducing the lateral capsular ligament. Knee Surg Sports Traumatol Arthrosc. 2015 Nov;23(11):3186-95. doi: 10.1007/s00167-014-3117-z. Epub 2014 Jun 15.

25. **Daggett M, Ockuly AC, Cullen M, Busch K, Lutz C, Imbert P, Sonnery-Cottet B.** Femoral Origin of the Anterolateral Ligament: An Anatomic Analysis. Arthroscopy. 2015 Dec 22. pii: S0749-8063(15)00833-6. doi: 10.1016/j.arthro.2015.10.006. [Epub ahead of print]

26. **Lutz C, Sonnery-Cottet B, Niglis L, Freychet B, Clavert P, Imbert P.** Behavior of the anterolateral structures of the knee during internal rotation. Orthop Traumatol Surg Res. 2015 Sep;101(5):523-8. doi: 10.1016/j.otsr.2015.04.007. Epub 2015 Jul 13.

27. **Imbert P, Belvedere C, Leardini A.** Knee laxity modifications after ACL rupture and surgical intra- and extra-articular reconstructions: intra-operative measures in reconstructed and healthy knees. Knee Surg Sports Traumatol Arthrosc. 2015 Jun 3. [Epub ahead of print]

28. **Parsons EM, Gee AO, Spiekerman C, Cavanagh PR.** The biomechanical function of the anterolateral ligament of the knee. Am J Sports Med. 2015 Mar;43(3):669-74. doi: 10.1177/0363546514562751. Epub 2015 Jan 2.

29. **Kittl C, Halewood C, Stephen JM, Gupte CM, Weiler A, Williams A, Amis AA.** Length change patterns in the lateral extra-articular structures of the knee and related reconstructions. Am J Sports Med. 2015 Feb;43(2):354-62. doi: 10.1177/0363546514560993. Epub 2014 Dec 24.

30. **Zens M, Niemeyer P, Ruhhammer J, Bernstein A, Woias P, Mayr HO, Südkamp NP2, Feucht MJ4.** Length Changes of the Anterolateral Ligament During Passive Knee Motion: A Human Cadaveric Study. Am J Sports Med. 2015 Oct;43(10):2545-52. doi: 10.1177/0363546515594373. Epub 2015 Aug 11.

31. **Spencer L, Burkhart TA, Tran MN, Rezansoff AJ, Deo S, Caterine S, Getgood AM.** Biomechanical analysis of simulated clinical testing and reconstruction of the anterolateral ligament of the knee. Am J Sports Med. 2015 Sep;43(9):2189-97. doi: 10.1177/0363546515589166. Epub 2015 Jun 19.

32. **Helito CP, Helito PV, Bonadio MB, da Mota E Albuquerque RF, Bordalo-Rodrigues M, Pecora JR, Camanho GL, Demange MK.** Evaluation of the Length and Isometric Pattern of the Anterolateral Ligament With Serial Computer Tomography. Orthop J Sports Med. 2014 Dec 17;2(12):2325967114562205. doi: 10.1177/2325967114562205. eCollection 2014 Dec.

33. **Helito CP, Demange MK, Helito PV, Costa HP, Bonadio MB, Pecora JR, Rodrigues MB, Camanho GL.** Evaluation of the anterolateral ligament of the knee by means of magnetic resonance examination. Rev Bras Ortop. 2015 Apr 7;50(2):214-9. doi: 10.1016/j.rboe.2015.03.009. eCollection 2015 Mar-Apr.

34. **Klontzas ME, Maris TG, Zibis AH, Karantanas AH.** Normal Magnetic Resonance Imaging Anatomy of the Anterolateral Knee Ligament With a T2/T1-Weighted 3-Dimensional Sequence: A Feasibility Study. Can Assoc Radiol J. 2015 Dec 15. pii: S0846-5371(15)00093-5. doi: 10.1016/j.carj.2015.08.004. [Epub ahead of print]

35. **Porrino J Jr, Maloney E, Richardson M, Mulcahy H, Ha A, Chew FS.** The anterolateral ligament of the knee: MRI appearance, association with the Segond fracture, and historical perspective. AJR Am J Roentgenol. 2015 Feb;204(2):367-73. doi: 10.2214/AJR.14.12693.

36. **Rasmussen MT, Nitri M, Williams BT, Moulton SG, Cruz RS, Dornan GJ, Goldsmith MT, LaPradeRF.** An In Vitro Robotic Assessment of the Anterolateral Ligament, Part 1: Secondary Role of theAnterolateral Ligament in the Setting of an Anterior Cruciate Ligament Injury. Am J Sports Med. 2015 Dec 18. pii: 0363546515618387. [Epub ahead of print]

37. **Hughston J, Andrews J, Cross M, Moschi A.** Classification of knee ligament instabilities, part II: the lateral compartment. J Bone Joint Surg Am. 1976;58(2):173-179.

38. **Rezansoff AJ, Caterine S, Spencer L, Tran MN, Litchfield RB, Getgood AM.** Radiographic landmarks for surgical reconstruction of the anterolateral ligament of the knee. Knee Surg Sports Traumatol Arthrosc. 2015 Nov;23(11):3196-201. doi: 10.1007/s00167-014-3126-y. Epub 2014 Jun 17.

Effect of Hamstring Lengthening on Pelvic Tilt and Lumbar Lordosis during Normal Gait

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BACKGROUND: A direct correlation between hamstring tightness and severity of lower back pain (LBP) has been previously reported [1]. Hamstring contraction creates knee flexion, hip extension and posterior rotation of the pelvis (pelvic tilt). Posterior pelvic tilt causes the lumbar spine to flatten (hypolordosis) which places pressure on the anterior structures of the spine, including the intervertebral disc. This increased pressure may predispose individuals to disc degeneration and associated pain [2]. For this reason, hamstring stretching is often prescribed to alleviate LBP, however, the effect of hamstring lengthening on the kinematics of the lumbar spine and pelvis is not well understood. Accurate measurement of lumbar spine move-ment is difficult to obtain in a motion capture laboratory due to subtle differences in marker placement, tissue interface and distribution. Therefore, the purpose of this study was to develop and apply a lumbar curvature correction factor to assess the effect of hamstring lengthening on pelvic tilt (PT) and lumbar lordosis (LL) in healthy subjects during normal gait.

METHODS: Healthy individuals with reported tight hamstrings and no history of LBP or back injuries were recruited for this study. Hamstring length was assessed by a physical therapist with the subject in supine with one limb passively moved to 90º hip flexion. Each knee was independently, passively extended to reported discomfort and the angle between shank and vertical (popliteal angle) was measured. A popliteal angle (PA) greater than 25º was required to participate in the study. Upon confirmation of tight hamstrings, nine (7 M, 2 F) participants were enrolled into the study and signed institutional review board approved informed consent. A physical therapist placed 58 reflective markers by palpation on anatomical landmarks of the torso and lower extremities. Ten optoelectronic cameras (Qualisys, Gothenburg, Sweden) and 3 force plates (AMTI, Watertown, MA) were used to track marker position and define gait events. Subjects walked at a self-selected speed across the force plates until ten clean trials were performed. Subjects were then scanned with the reflective markers on the spine using an EOS (EOS Imaging, France) bi-planar x-ray system. Following testing, participants completed a six week stretching program designed to increase hamstring length. All baseline testing was then repeated. Laboratory based measures of pelvic tilt (PT) and lumbar lordosis lordosis (LL) were calculated for all trials. Laboratory based PT was defined as the angle between horizontal and the line extending from the posterior superior iliac spine marker to anterior superior iliac spine marker. Laboratory based LL was defined as the acute angle between lines connecting the markers on T12 to L2 and S2 to L4. Anatomical based LL was found using the bi-planar x-ray by measuring the acute angle formed by a line drawn along the superior surface of L1 and inferior surface of the

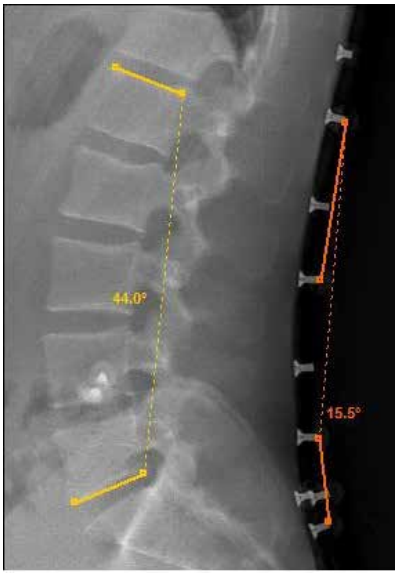

Figure 1: Anatomical based LL (Yellow) and marker based LL (Orange)

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Table 1: Degrees changed in popliteal angle (PA), pelvic tilt (PT), lumbar lordosis (LL), and corrected lumbar lordosis (LL*) at heel strike

Subject	Change PA (Deg)	Change PT (Deg)	Change LL (Deg)	Change LL* (Deg)
145	12.5	1.1	-7.0	-14.5
148	22.5	3.9	1.3	4.8
150	22	3.0	3.7	4.7
151	27.5	4.8	-0.8	-4.6
152	39	-4.0	-3.8	2.1
153	15	3.6	-4.6	-8.9
155	5	2.3	0.4	1.0
MEAN	17.4	3.1	-1.5	-2.2

L5. Marker based LL was also derived on the x-ray by measuring the acute angle between lines connecting T12 to L2 markers and S2 to L4 markers **(Figure 1)**. Both measurements were made three separate times on each scan and averaged to decrease the human error in measurement. The ratio of anatomical and marker based LL measures were then used to calculate a correction factor which was multiplied by all laboratory based LL measures producing a Corrected LL. Both corrected LL and laboratory based PT at heel strike was averaged over ten trials. The correction factor was validated by comparing correction factors of seventeen different subjects each standing in two different positions.

RESULTS: Seven participants completed the stretching program and post intervention testing. PA increased in all subjects (mean ± SD) 20.5° ± 11° ($p<.01$). Six of seven subjects had a decrease in posterior PT resulting in a mean change of 2.1° ± 2.9° ($p<.01$). The average error in anatomical based LL and marker based LL was ±1.7° and ±0.8° respectively. The average difference in the correction factor between standing positions was 8%. Corrected LL increased in four subjects **(Table 1)**.

CONCLUSIONS: Utilization of the correction factor allowed comparison of LL pre and post intervention. Posterior PT decreased, however LL did not increase consistently among participants. The small sample size was a limitation to this study as well as applying a novel method for LL comparison. Continued research, including an expansion of the study to include more subjects and validation of radiograph measurements by a physician, will provide additional information to strengthen the validity and generalizability of this study.

REFERENCES

1. **Radwan, A.** et al (2011) Journal of Back and Musculoskeletal Rehabilitation

2. **Day, J.** et al (1984) Physical Therapy, 64(4): pp. 510-516

Campbell Foundation Achievements

Jack R. Blair
Chairman, Board of Trustees
Campbell Foundation

Reflecting on the past year and my affiliation with the Campbell Foundation, one of the greatest sources of pride has been the progress made to build a robust research infrastructure that would accelerate the discovery of answers to challenging clinical questions.

Approximately three years ago, the Campbell Foundation Board of Trustees validated the mission of the foundation to enhance quality of life through the science of orthopaedic medicine. In addition, the three main "pillars" of the mission: surgeon education, orthopaedic research, and community outreach healthcare were also reinforced. The change, however, was a driving effort to focus our research efforts for greater impact. The Trustees sought the "sweet spot" of orthopaedic research at the intersection of

- areas of clinical expertise at Campbell Clinic where we could provide unique insights,
- issues of clinical significance in our local area, and the orthopaedic community in general, and
- those areas likely to be supported by grants, donors and others interested in innovation.

Our research results have proven the wisdom of the focused approach. At this year's annual meeting of the American Academy of Orthopaedic Surgeons (AAOS), research from our team was recognized as the "best of the best," making the "Top 10" lists within the Foot & Ankle and Shoulder & Elbow sections of the meeting - even winning the Charles S. Neer Clinical Research Award. The abstracts of this work are presented within this journal.

When working to deliver meaningful, impactful results, it is important to have a strategic focus. Our research is designed to address real-world, clinical problems that persist; and it is our intention to quickly share our findings with the world, in order to implement our results for the immediate benefit of patients everywhere. Our efforts to focus our research, as evidenced in this journal, have paid off, resulting in innovative and meaningful research output, that will benefit thousands of patients.

Ongoing donor support is needed to sustain our momentum and expand our impact. I hope you see the potential of the work in these pages and will join us in our efforts to broaden 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 magnify our impact.

Jack R. Blair, Chairman
Campbell Foundation Board of Trustees

CAMPBELL PRESENCE ACROSS THE GLOBE:

International Community Service Elective

"I heard a great presentation by local businessman, Bill Courtney, on the responsibility of a business leader to give back to his community," says Daniel Shumate, CFO of Campbell Clinic. "He (Courtney) is known for leading a previously losing high school football team, in an impoverished area of Memphis, to a winning season. The movie, *Undefeated,* was made about his experience. But more important than winning, the movie told the story of how Courtney molded these young men into fine adults, capable of great things. I had the chance to hear him talk about 'doing what you can,' and it really got me thinking."

Dr. Sean Calloway and the orthopaedic residents of the Kilimanjaro Christian Medical Clinic review patient x-rays at the beginning of the day.

And, in that instant, the idea of a Community Service Scholarship was born. Shumate continues, "I wanted to help patients who needed orthopaedic care, but I'm not a physician. I thought, 'What can I do? What are my talents and how can I use them?' I knew I didn't have the skill set to do medical missions myself, but I had access to people who could." So, with that motivation, and to honor his wife, three years ago, Daniel founded the Molly Shumate Community Service Scholarship to sponsor medical missions nationally and internationally as a way to provide excellent orthopaedic care to patients in need - here and across the globe.

Screws of all types, lengths, and head shapes arranged randomly in a screw caddy.

Thanks to the scholarship, four orthopaedic surgery residents in training at the Campbell Foundation have now gone on medical mission trips. Locations have included Nicaragua, Guatemala and Honduras, and this year, to Moshi, Tanzania. Senior resident Dr. Sean Calloway, traveled with a seasoned team to a Health Volunteers Overseas outpost, the Kilimanjaro Christian Medical Clinic (KCMC). Calloway served for two weeks, participating in clinic, rounds, surgeries, and even presenting four lectures on surgical treatment of complex

Screws organized by type, length, head size.

Dr. Sean Calloway and the team at the Kilimanjaro Christian Medical Clinic operating on a patient.

orthopaedic trauma. Calloway was also able to deliver critical medical supplies, including vital small and large fragment fracture sets, external fixator equipment, and operating room supplies to KCMC.

"I gained great insights into what makes this kind of enterprise successful. It is more than just a 'come in and cut' mentality. Much like orthopaedic training in the United States, resident education is critical. I was able to share with the surgeons and residents in Tanzania some of the techniques and surgical approaches that we learn in our residency training. It's similar to the biblical proverb of 'teaching a man to fish so he will never go hungry.' Also, each day, we spent time organizing the surgical equipment in order to allow for much more efficient and successful surgery."

> "We are so fortunate in the U.S., and this is one small thing we can do to make a difference in the world."
>
> *- Sean P. Calloway, MD, Class of 2016*

So many things that surgical teams in the U.S. take for granted require deliberate measures in developing and underserved countries. Health Volunteers Overseas has a well-organized infrastructure and, for more than thirty years, has been dedicated to improving the availability and quality of health care through the education, training and professional development of the health workforce in resource-scarce countries.

"I am so grateful for this experience," says Dr. Calloway. "I learned so much, and I hope, in a small way, that I was able to share some of my knowledge with the team in Kilimanjaro. I am indebted to the Campbell Foundation, and to Drs. Sue and Glen Crawford from Portsmouth, New Hampshire, who were my mentors and travel guides while we were in Tanzania. A final thank you goes to Health Volunteers Overseas. I know that this is one way that I will work to continue to give back. We are so fortunate in the U.S., and this is one small thing we can do to make a difference in the world."

Dr. Sean Calloway leads an in-service on fracture management.

What started at a business luncheon has grown into a robust medical mission. The Shumates are continuing their support, and there is a desire to expand the program this year.

You can make an impact with your gift to the Campbell Foundation. Go online to www.campbell-foundation.org to donate, or call the Development Office at (901) 759-5490 to support this mission.

2016 Graduating Orthopaedic Residents

KAKU BARKOH, MD
Hometown: Columbia, Missouri

Undergraduate Institution: Texas A&M University

Medical School: University of Texas Southwestern

Dr. Barkoh is the first in his immediate family to pursue a medical career, however his cousin is finishing his pediatric residency in Houston, TX. Dr. Barkoh chose to pursue a career in medicine because it allowed him to combine his passion for biology, anatomy, and physiology with his desire to help and serve others through his profession. Dr. Barkoh chose to specialize in orthopaedics because it allows him to help people get back to doing what they wanted to do physically, and have a more immediate, tangible result.

Plans After Campbell: Dr. Barkoh will complete a Spine Fellowship at the University of Southern California before returning to his home state of Texas to begin his practice.

Dr. Barkoh extends thanks to his co-residents, faculty, and patients for teaching him about orthopaedics and the practice of medicine. *"I hope my career will make you all proud."*

COLLIN C. BILLS, MD
Hometown: Tullahoma, TN

Undergraduate Institution: Harding University

Medical School: East Tennessee State University Quillen College of Medicine

With medicine as a career choice for Dr. Bills, he follows in his father's footsteps, who is an internal medicine physician.

Dr. Bills chose the medical field because he grew up witnessing what a great impact his father had on the lives of his patients. He chose orthopaedics because " I wanted to learn a profession that serves both through knowledge and tactical skill."

Plans After Campbell: Dr. Bills will complete a Sports Medicine Fellowship in Jackson, MS.

"I am grateful for the opportunity I have had to train here at Campbell Clinic. My many thanks to the surgeons who allowed my unskilled hands hold a retractor, cut with a knife, burn with the bovie, stitch with a needle, tie over a vessel, screw through precarious bone, and even watch from a distance in order that I may learn, grow, and participate in this honored profession of orthopaedics. My praise goes to the physicians in my life that represent a true servant-led life. To my fellow residents, thank you for challenging me every day. I will never work amongst a more talented and hard working group of men and women."

2016 Graduating Orthopaedic Residents

TYLER J. BROLIN, MD
Hometown: Fargo, ND

Undergraduate Institution: Concordia College – Moorhead, MN

Medical School: University of North Dakota School of Medicine and Health Sciences

Dr. Brolin is the first in his family to pursue medicine. He chose the field of orthopaedics because of his personal experience with a knee injury during football in his freshman year of high school. The injury, his love for the health sciences, and the ability to work around different personalities each day solidified his career path.

Plans After Campbell: Dr. Brolin will complete a Shoulder and Elbow Surgery Fellowship at Thomas Jefferson University/ Rothman Institute and then return to Memphis to join the Campbell Clinic staff in 2017.

Dr. Brolin would like to thank the Campbell Clinic staff who have been instrumental in his development, not only as an orthopaedic surgeon, but also a person. *"I am truly grateful for the opportunity to train here and join the Campbell Clinic family. I simply could not have asked for a better experience. As for my fellow residents, it has been quite the journey and I am glad to call you all part of my family."*

SEAN P. CALLOWAY, MD
Hometown: Valparaiso, IN

Undergraduate Institution: University of Notre Dame

Medical School: Indiana University School of Medicine

Dr. Calloway is the first in his family to pursue medicine. Medicine was his career choice because of the selflessness of the profession and because it gives him the opportunity to improve the lives of others, which he believes is remarkably powerful and should not be taken for granted.

He was drawn to the field of orthopaedics because of the opportunity to "fix" clinical injuries or conditions. It is rewarding to operate on a patient with a femur fracture, ACL tear, or hip arthritis and give him or her the opportunity to get back to a desired level of activity. Dr. Calloway believes there are very few other specialties in medicine that allow the physician to see the "results" of their work so quickly. These positive results are what drives him to work hard and continue the lifelong learning that is required to be a successful practitioner and orthopaedic surgeon.

Plans After Campbell: Dr. Calloway will complete a Sports Medicine Fellowship at Santa Monica Orthopaedic Group in Santa Monica, CA.

Dr. Calloway would like to thank the Campbell Clinic and Campbell Foundation for the opportunity to train at "the birthplace of orthopaedics". He states, *"I am humbled to walk the halls of the Germantown office and see all of the Campbell Clinic Alumni who have come before me: those who have made the Campbell name synonymous with the very best in orthopaedic education. I look forward to my fellowship; and I will do my very best to represent the Campbell Clinic's legacy of excellence in the future."*

2016 Graduating Orthopaedic Residents

MARCUS C. FORD, MD
Hometown: Louisville, KY

Undergraduate Institution: University of Kansas

Medical School: University of Texas Health Science Center

With Dr. Ford's choice of medicine as a career, he is following in the footsteps of his father, who is an anesthesiologist. He was drawn to medicine because he enjoyed helping people, along with the science that is involved in medicine. Dr. Ford chose the field of orthopaedics because the vast majority of patients get better and are typically happy with their surgical results. His career decision was also influenced by the orthopaedic surgeons teaching at his medical school, along with his genuine interest in studying musculoskeletal anatomy.

Plans After Campbell: Dr. Ford will complete a Joint Reconstruction Fellowship at Washington University in St. Louis, MO, and will join the Campbell Clinic staff in 2017, focusing in total joint arthroplasty.

Dr. Ford would like to thank the faculty for the opportunity to be a part of Campbell Clinic. *"It is a special place with great people."*

JOHN W. HARKESS, MD
Hometown: Memphis, TN

Undergraduate Institution : University of Virginia

Medical School: University of Tennessee Health Science Center

Dr. Harkess follows in the medical footsteps of his father and grandfather, both orthopaedic surgeons. He was drawn to medicine because he was interested in science from a very young age and was attracted to the idea of using that knowledge to help people. He explained, "I grew up seeing how much my dad loved his job and the difference that orthopaedics can make it people's lives. I love the technical challenge and the satisfaction of seeing patients regain function and mobility".

Plans After Campbell: Dr. Harkess will complete a Total Joint Fellowship at Scripps Clinic in La Jolla, CA.

Dr. Harkess added *"The Campbell Clinic is a truly special place, and I am forever grateful for the opportunity to have trained here. The attendings are excellent teachers and role models. My fellow residents and the clinic staff have become my dear friends. I will miss each of them next year, but will always stay connected to "the Clinic"."*

2016 Graduating Orthopaedic Residents

RYAN P. MULLIGAN, MD
Hometown: Plano, TX

Undergraduate Institution: Texas A&M University

Medical School: Texas A&M Health Science Center College of Medicine

Dr. Mulligan is the first in his immediate family to pursue a career in medicine, however, his wife is also a physician.

He chose the medical field because he enjoyed science, working with people, and applying both to solve difficult problems. He was drawn to orthopaedics because he enjoyed seeing the instant impact made on patients and working with a wide spectrum of the population, using his hands and orthopaedic instruments and implants, and the camaraderie among orthopedic surgeons.

Plans After Campbell: Dr. Mulligan will complete a Foot and Ankle Fellowship at Duke University following residency. After fellowship, he plans to move back to his home state of Texas, with practice plans still in development.

"Thank you Rebekah. You have put up with a lot and deserve all the credit. Thank you to the Campbell Clinic physicians and Campbell Foundation staff for your constant support. To my brothers (co-residents), I could not have done it without you. You have a life-long friend in me and I'm there if you need anything."

MATTHEW G. STEWART, MD
Hometown: Columbus, GA

Undergraduate Institution: Auburn University

Medical School: Medical College of Georgia

With Dr. Stewart's choice of medicine as his career, he will be following in the footsteps of his grandfather, an orthopaedic surgeon, and three uncles who are physicians. Dr. Stewart chose orthopaedics because of his grandfather. After writing a biography about him for a school project in 4th grade, he became fascinated by his life. He explained, "My grandfather loved his job and spoke about it with such great passion that I knew that it was something I had to do. He couldn't have been more right."

Plans After Campbell: After graduation from residency, Dr. Stewart will move to Durham, North Carolina to participate in a one-year Foot and Ankle Fellowship at Duke University.

Dr. Stewart added: *"I want to thank the Clinic for the past five years. It has been one of the great honors of my life to train here under such giants of Orthopaedics, but more importantly, with faculty who set such a great example of what it means to be well-rounded clinicians, surgeons, and teachers. I also want to thank my fellow residents. We have stayed such a strong program because we attract the best. Their drive and commitment to this place has only strengthened my own experience, forcing me to stay at the top of my game so I don't fall behind. I'd also like to thank Dr. Jim Beaty. You have been an excellent mentor from the time I was a medical student and I can't thank you enough for the guidance you've given me."*

2016 Orthopaedic Fellows

MARIELLE A. AMOLI, MD

Pediatric Fellow

Hometown: Atlanta, GA

Undergraduate Institution: University of Notre Dame

Medical School: Medical College of Georgia

Orthopaedic Residency: University of Florida

The choice of a career in medicine runs in Dr. Amoli's family, her brother is a critical care attending at Emory university in Atlanta, her sister-in-law is and ID physician at Emory, and her husband is an Oral Maxillofacial and Cosmetic Surgeon in Jacksonville, FL.

She was drawn to medicine from a young age and loves the opportunity it provides to meet and work with people from all aspects of life. Also, she finds the human body and what it can endure, how it can heal and adapt, to be fascinating. Dr. Amoli chose the field of orthopaedics because of the hands-on nature of it, the variety of procedures performed, and the ability to fix something that's broken: or otherwise help alleviate someone's pain and get them back to a normal life.

Plans After Campbell: Dr. Amoli will be joining Pediatric Orthopaedic Group at Nemours Children's Health System in Jacksonville, FL.

Dr. Amoli added, *"A big thank you to everyone I've met and worked with this year. You've made this year a wonderful experience I'll never forget!"*

JACOB GUNZENHAEUSER, MD

Sports Medicine Fellow

Hometown: Roanoke, VA

Undergraduate Institution: Miami University, Oxford, OH

Medical School: University of Cincinnati College of Medicine

Orthopaedic Residency: University of Cincinnati Department of Orthopaedic Surgery

With Dr. Gunzenhaeuser's choice of medicine as a career, he is following in the footsteps of his father, an anesthesiologist.

His father inspired him to chose medicine, and he chose the field of orthopaedics because he enjoys working with motivated individuals and getting them back to the activities they love.

Plans After Campbell: Dr. Gunzenhaeuser will be moving back home to Cincinnati and joining a community hospital as a general orthopaedics / sports medicine physician.

Dr. Gunzenhaeuser adds, *"Thank you Dr. Fred Azar, Dr. Quin Throckmorton, Dr. Robert Miller, Dr. Tony Mascioli, and Dr. Barry Phillips for an amazing and invaluable year in sports medicine."*

SEAN B. KUEHN, MD

Trauma Fellow

Hometown: Great Lakes, IL

Undergraduate Institution: University of Wisconsin-Madison

Medical School: University of Wisconsin-Madison School of Medicine

Orthopaedic Residency: University of New Mexico

With the choice of orthopaedics as a career, Dr. Kuehn follows in his late father's footsteps who was an orthopaedic surgeon. His brother is currently a orthopaedic resident and will start his trauma fellowship next year. Dr. Kuehn's wife is an orthopaedic intern at University of Utah.

Dr. Kuehn chose medicine because of his family's influence and his strong interest in science. He chose the field of orthopaedics because it is a constantly evolving field, always presenting new challenges, with the ability to help patients in a tangible and immediate way.

Plans After Campbell: Orthopaedic trauma in Utah.

Dr. Kuehn would like to thank all the trauma attending at Campbell Clinic for making this a very worthwhile year and incredible learning experience. *"Thank you to the residents, many of whom are now good friends, for making this year truly enjoyable."*

2016 Orthopaedic Fellows

RODRIGO GOES MEDEA DE MENDONCA, MD

Pediatric Spine Research Fellow

Hometown: Sao Paulo, Brazil

Medical School: School of Medicine of the Santa Casa de São Paulo, Brazil

Orthopaedic Residency: Spine Surgery Fellow of the Santa Casa de São Paulo, Brazil

Dr. Medea is not the only person in his family to chose orthopaedic medicine as a career, his younger sister, Priscilla, is a PGY1 resident in orthopaedic surgery in Brazil. Dr. Medea's wife is a pediatrician.

Dr. Medea chose medicine and the field of orthopaedics to help people in the most effective way.

Plans After Campbell:. Dr. Medea will return to Brazil to start his academic career in Orthopaedic Reseach.

"The best staff that I've had the privilege to work with! A special thanks to: Dr. Terry Canale's team, Dr. Jeff Sawyer as a wonderful mentor, Dr. Derek Kelly as an incredible surgeon, Dr. David Spence for his surgical talents, Dr. Bill Warner is a gifted teacher, and Dr Beaty for his vast knowledge."

"I appreciate all the residents that helped me this year: Clayton Bettin, Don Franklin, Nick Jew, Will, Clay Nelson, Chris Carver, Chad Campion, Catherine Olinger, Erin Meehan, Collin Bills… and special thanks to Kaku Barkoh and Daniel Wells."

F. PATTERSON OWINGS, MD

Hand Fellow

Hometown: Atlanta, GA

Undergraduate Institution: Washington and Lee University

Medical School: Medical College of Virginia

Orthopaedic Residency: Emory University

A career in medicine is a Owings family tradition. Dr. Owings' father is a general surgeon, with other family members in orthopaedics, radiology, pathology, dermatology, and family practice medicine.

Plans After Campbell: Dr. Owings will start his own private orthopaedic practice.

"My sincerest thanks to all of the faculty and staff at the Campbell Clinic and in particular the hand surgery faculty: Dr. Calandruccio, Dr. Cannon, Dr. Jobe, and Dr. Mauck."

DAVID J. RUTA, MD

Foot & Ankle Fellow

Hometown: Elmhurst, IL

Undergraduate Institution: University of Illinois

Medical School: Rush University Medical Center

Orthopaedic Residency: University of Michigan

Dr. Ruta is the first in his family to chose a career in medicine. He chose this field because a medical career provides an opportunity to help people, the opportunity and duty of a physician is to aid others with often their most valued possession: their personal health and that of their loved ones. Further, this help is typically needed when people are ill and therefore most vulnerable. That is a distinct privilege.

Dr. Ruta was drawn to the field of orthopaedics because, "I have found the anatomy, pathology, patients, treatments, and colleagues within the field of orthopaedics to be independently enjoyable of their respective categories. I'm exceedingly grateful that these are all found in orthopaedic surgery."

Plans After Campbell: Dr. Ruta will be joining the staff of St. Luke's Orthopedics & Sports Medicine in Duluth, Minnesota.

"Drs. Grear, Ishikawa, Murphy, and Richardson: I cannot thank you enough for the time, instruction, opportunity, and mentorship you've provided me and the hospitality you've shown me. I am indebted to you all. To all faculty, staff, and residents: I'm very proud to have trained at this outstanding institution and to be a part of the Campbell family."

Current Orthopaedic Residents

INTERNS

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

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

Matthew 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 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 2

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

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

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

Clay G. Nelson, MD
Undergraduate: University of North Carolina
Medical School: Eastern Virginia Medical School

Mims G. Oschsner, MD
Undergraduate: University of Georgia
Medical School: Mercer University
School of Medicine

Colin W. Swigler, MD
Undergraduate: Florida State University
Medical School: Florida State
College of Medicine

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

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

Current Orthopaedic Residents

CLINICAL YEAR 3

Thomas R. Acott, MD
Undergraduate: University of Illinois at Urbana-Champaign
Medical School: St. Louis University School of Medicine

D. Christopher Carver, MD
Undergraduate: East Tennessee State University
Medical School: East Tennessee State University James H. Quillen College of Medicine

Justin D. Hallock, MD
Undergraduate: Birmingham Southern College
Medical School: University of Tennessee Health Science Center College of Medicine

Travis W. Littleton, MD
Undergraduate: Lipscomb University
Medical School: University of Tennessee Health Science Center College of Medicine

Timothy M. Lonergan, MD
Undergraduate: Saint Louis University
Medical School: Saint Louis University School of Medicine

Erin M. Meehan, MD
Undergraduate: Clemson University
Medical School: Mercer University School of Medicine

A. Ryves Moore, MD
Undergraduate: University of Mississippi
Medical School: University of Mississippi School of Medicine

Daniel B. Wells, MD
Undergraduate: University of Georgia
Medical School: Mercer University School of Medicine

CLINICAL YEAR 4

Eric N. Bowman, MD
Undergraduate: University of Tennessee
Medical School: University of Tennessee Health Science Center College of Medicine

John J. Feldman, MD
Undergraduate: Denison University
Medical School: West Virginia University School of Medicine

Christopher M. Hopkins, MD
Undergraduate: University of Texas
Medical School: University of Texas Medical Branch at Galveston

Nicholas B. Jew, MD
Undergraduate: University of Mississippi
Medical School: University of Mississippi School of Medicine

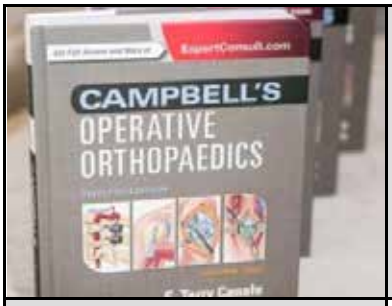
Megan N. Mayer, MD
Undergraduate: Webster University
Medical School: University of Missouri- Kansas City School of Medicine

Arturo D. Villarreal, MD
Undergraduate: Texas State University- San Marcos
Medical School: University of Texas Medical Branch at Galveston

William J. Weller, MD
Undergraduate: Illinois College
Medical School: Rush Medical College

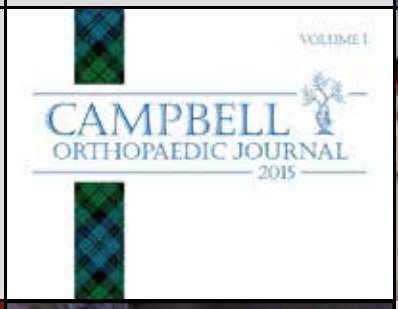
Andrew J. Wodowski, MD
Undergraduate: University of Tennessee
Medical School: University of Tennessee Health Science Center College of Medicine

Thank you, Campbell Alumni



Community Health Care Outreach

Award Winning Research



40 Residents Trained

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