THE TOWER AT RUSH UNIVERSITY MEDICAL CENTER, which opened its doors in January 2012, is one of the nation’s most advanced—and visually striking—hospitals.

A TRADITION OF EXCELLENCE

“OUR THRIVING CLINICAL PRACTICE is enhanced by collaborations with specialists at Rush from rheumatology, physical medicine and rehabilitation, physical therapy, and other areas.”

Midwest Orthopaedics at Rush (MOR) is a private practice medical group whose 38 fellowship-trained physicians are on the faculty of Rush University Medical Center in Chicago. With MOR based primarily at Rush, our renowned surgeons and physicians have access to all the resources of a world-class academic medical center, including the state-of-the-art operating rooms in Rush’s new hospital.

Our thriving clinical practice is enhanced by collaborations with specialists at Rush from rheumatology, physical medicine and rehabilitation, physical therapy, and other areas. As part of our commitment to continually advance orthopedic care, our physicians participate in cutting-edge multidisciplinary research, which is translating into new treatments that benefit patients at Rush—and around the globe.

Physicians from Midwest Orthopaedics at Rush also hold key leadership positions in national societies and organizations, and serve as the team physicians for a variety of professional, collegiate, and high school teams and clubs, including the Chicago Bulls, Chicago White Sox, and DePaul University. These impressive clinical, research, and administrative activities distinguish orthopedics at Rush as among America’s best.

U.S. News & World Report has ranked the orthopedics program at Rush in the top 12 each of the past 10 years—including 7 times in the top 10.
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Midwest Orthopaedics at Rush
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To view the 2012 Rush Orthopedics Journal online, please visit the Rush website at www.rush.edu/orthopedicsjournal.
I began my letter in last year’s Rush Orthopedics Journal with a preview of Rush’s new hospital, known as the Tower, which was scheduled to open within the next several months. At that time, although I knew the Tower would be an outstanding clinical resource, I could not have foreseen how much of an impact it would have on our orthopedic practice. Like the Orthopedic Building before it, the new hospital is transforming the way we care for our patients.

After 7 years of planning and construction, the doors to the Tower opened on January 9, 2012—it’s worth noting that the first patient to cross the threshold into the new facility was a woman who had undergone knee replacement surgery a few days earlier—and already our surgeons are realizing the benefits. In particular, they appreciate the design of the new operating rooms, which was based on input from surgeons across numerous specialties, including orthopedics. Every feature in these new ORs—including state-of-the-art imaging equipment, real-time video conferencing capabilities, and a ventilation system that produces higher-than-OR-quality air to minimize the risk of infections—is helping to improve surgical efficiency and patient outcomes.

The opening of the Tower isn’t the only noteworthy highlight from the past year. Two esteemed faculty members from the Department of Orthopedic Surgery—one former, one present—were recognized for their remarkable career achievements. The Scoliosis Research Society presented its Lifetime Achievement Award to Ronald L. DeWald, MD, professor emeritus. And Gunnar B. J. Andersson, MD, PhD, was given two prestigious awards: the Henry Farfan Award for outstanding contributions in spine—furthering knowledge in the field of musculoskeletal disease; and the Harry Hutfelin Award for outstanding contributions in spine-related basic science research from the North American Spine Society at its 2011 annual meeting.

At that same meeting, two papers co-authored by Frank M. Phillips, MD, were awarded “Best Overall Papers”: “Preclinical Study of Human Allogeneic Amniontic Membrane as a Barrier to Epidural Fibrosis in the Early Wound of a Post Laminectomy Rat Model,” and “Why Don’t Annular Defects Heal? Does Interposed Nucleus Pulposus Prevent Healing? An In Vivo Study.” Among the many other awards and honors bestowed on physicians and researchers from our department, Craig J. Della Valle, MD, was co-recipient of the Hip Society’s 2012 John Charnley Award for the paper “Clinical Multi-Center Studies of the Wear Performance of Highly Cross-Linked Remelted Polyethylene in THR.” Charles A. Bush-Joseph, MD, who is head team physician for the Chicago White Sox, was appointed president of the Major League Baseball Team Physician Association. And I officially stepped into the role of first vice president of the American Academy of Orthopaedic Surgeons (see opposite page).

Our nationally renowned residency and fellowship programs also enjoyed a stellar year, with a dedicated, talented, and diverse group completing their training at Rush. An important component of our department’s mission is to train specialists who will make significant contributions to their field in the years to come, and our faculty members are committed to providing a strong foundation on which our residents and fellows can build their careers.

Finally, when we talk about advancing orthopedic care, we tend to focus on the front lines—the clinicians and researchers who are directly involved. But so much of the work we do, at the bench and at the bedside, would not be possible without substantial backing from our many donors. The philanthropic support our department received this past year included gifts from the Grainger Foundation, Goldman Sachs Gives, Mrs. William A. Hark, Paul and Joan Rubschlager, the Segal Family, and too many others to list in this space. From creating endowed chairs to providing funding for basic science research to purchasing needed equipment for our labs and clinics, these generous individuals, families, corporations, and organizations enable us to better the lives of our patients while we continue striving to improve the tools of our trade.

I’m pleased to present the 2012 Rush Orthopedics Journal, which represents the breadth and quality of research undertaken by our faculty—and the discoveries that are helping to advance the understanding and treatment of orthopedic conditions.

Joshua J. Jacobs, MD
The William A. Hark, MD/Susanne G. Swift Professor of Orthopedic Surgery
Chairman and professor, Department of Orthopedic Surgery
Rush University Medical Center

After serving as second vice president of the American Academy of Orthopaedic Surgeons (AAOS), Joshua J. Jacobs, MD, officially assumed the role of first vice president at the 2012 AAOS annual meeting in February. “I am extremely honored to be part of the presidential line of the premier orthopedic society, and to work with the talented and accomplished individuals who make up the academy’s Board of Directors, volunteers, and staff leadership team,” Jacobs says.
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ADULT RECONSTRUCTIVE SURGERY

Aaron Rosenberg, MD  
Director, Section of Adult Reconstruction  
Professor, Department of Orthopedic Surgery

Richard A. Berger, MD  
Assistant professor, Department of Orthopedic Surgery

Craig J. Della Valle, MD  
Assistant professor, Department of Orthopedic Surgery  
Director, Adult Reconstructive Orthopedic Surgery Fellowship Program

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Residency - Duke University Medical Center

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Medical School - New York University School of Medicine  
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Simon Lee, MD  
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Director, Orthopedic Residency Program
ORTHOPEDEIC FACULTY AND FELLOWS (2011)

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Not pictured:
Joachim Kunze, PhD, visiting instructor, Department of Orthopedic Surgery
Michael Laurent, PhD, scientist, Department of Orthopedic Surgery
Three-Dimensional Anatomy of the Hip, Utilizing Computer Navigation and Plain Radiographs

“These descriptions of normal hip morphology may improve preoperative planning and postoperative outcomes of hip joint preservation surgery.”

RACHEL M. FRANK, MD / JEREMY ALLAND, BS / ROBERT C. GRUMET, MD / MARK A. SLABAUGH, MD / VINCENT M. WANG, PHD / ALEJANDRO A. ESPINOZA ORÍAS, PHD / BERNARD R. BACH JR, MD / SHANE J. NHO, MD, MS

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ARTICLES

Three-Dimensional Anatomy of the Hip, Utilizing Computer Navigation and Plain Radiographs

With femoro-acetabular impingement (FAI) as a known etiology of hip osteoarthritis, medical researchers have recently expressed interest in hip joint preservation surgery. As FAI becomes increasingly recognized as a source of intra-articular hip pathology, particularly in the young, active patient population, doctors are beginning to favor nonarthroplasty treatment options. As with any orthopedic intervention, appropriate patient selection is critical for successful surgical outcomes; however, there remains a lack of consensus among orthopedic surgeons on the diagnosis, assessment, and surgical treatment of hips with FAI.

The surgical treatment options for young patients with FAI remain controversial. As techniques in diagnostic modalities as well as instrumentation and implant design continue to improve, surgical treatment options will also continue to evolve. Current options include nonoperative approaches, hip arthroscopy (Figures 1 and 2),30,13-18 open surgical dislocation (Figure 3),19-23 and periacetabular osteotomy.44 Open surgical hip dislocation has traditionally been considered the gold standard for FAI, with good to excellent technically reproducible results. In 2004, Murphy et al4 described a cohort of patients representing 23 hips at an average of 5 years following open hip dislocation and found that 7 (30%) had converted to total hip arthroplasty. While this open hip dislocation provides excellent visualization and typically allows for muscle preservation, the open nature of the surgery provides a source of morbidity not seen with less-invasive techniques, including arthroscopically assisted and all-arthroscopic procedures.

While the underlying etiology causing FAI varies, the mechanical process that leads to early osteoarthritis occurs when the proximal femur has repeated contact with the native acetabular rim upon normal range of motion. Pincher FAI is caused by excessive acetabular coverage with linear contact between the acetabulum and head-neck junction, which across time and with continued impact can cause degeneration and ossification of the hip joint. End-stage degenerated acetabular anatomy that may lead to pincher FAI includes acetabular retroversion, coxa profunda, coxa protrusio, dysplasia, and trauma. Cam FAI is caused by an abnormal femoral head-neck junction with an increased radius at the waist, causing shearing forces on the acetabular rim, which can lead to cartilage and labral damage. End-stage degenerated femoral head and femoral anatomy that may lead to cam FAI include coxa vara, slipped capital femoral epiphysis (SCFE), femoral head avascular necrosis, retroversion, Legg-Calvé-Perthes disease, and trauma. Many cases of abnormal acetabular and femoral anatomy are idiopathic. FAI may result from cam or pincer impingement; however, components of both mechanisms often contribute. In general, the most common location for FAI is along the anterosuperior acetabular rim, and thus a precise...
Three-Dimensional Anatomy of the Hip, Utilizing Computer Navigation and Plain Radiographs

“These descriptions of normal hip morphology may improve preoperative planning and postoperative outcomes of hip joint preservation surgery.”

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ARTICLES

With femoro-acetabular impingement (FAI) as a known etiology of hip osteoarthritis,1 medical researchers have recently expressed interest in hip joint preservation surgery.2 As FAI becomes increasingly recognized as a source of intra-articular hip pathology, particularly in the young, active patient population, doctors are beginning to favor nonarthroplasty treatment options. In 2004, Murphy et al3 described a cohort of patients representing 23 hips at an average of 5 years following open hip dislocation and found that 7 (30%) had converted to total hip arthroplasty. While this open hip dislocation provides excellent visualization and typically allows for muscle preservation, the open nature of the surgery provides a source of morbidity not seen with less-invasive techniques, including arthroscopically assisted and all-arthroscopic procedures.

While the underlying etiology causing FAI varies, the mechanical process that leads to early osteoarthritis occurs when the proximal femur has repeated contact with the native acetabular rim upon normal range of motion. Pincer FAI is caused by excessive acetabular coverage with linear contact between the acetabular rim and the femoral head-neck junction, which across time and with continued impact can cause degeneration and destruction of the articular labrum. Etiologies underlying abnormal acetabular anatomy that may lead to pincer FAI include acetabular retroversion, coxa profunda, coxa protrusio, dysplasia, and trauma. Cam FAI is caused by an abnormal femoral head-neck junction with an increased radius at the waist, causing shearing forces on the acetabular rim, which can lead to cartilage and labral damage. Etiologies underlying abnormal femoral anatomy that may lead to cam FAI include coxa vara, slipped capital femoral epiphysis (SCFE), femoral head avascular necrosis, retroversion, Legg-Calvé-Perthes disease, and trauma. Many cases of abnormal acetabular and femoral anatomy are idiopathic. FAI may result from cam or pincer impingement; however, components of both mechanisms often contribute. In general, the most common location for FAI is along the anterosuperior acetabular rim, and thus, a precise
configurations,25-27 the posterior acetabular rim has been described as irregular, including curved, angular, irregular, and straight. Understanding the normal acetabular anatomy is of critical importance. For example, the anatomy of the anterior acetabular ridge has been consistently described as irregular, including curved, angular, irregular, and straight configurations.24,25 The posterior acetabular rim has been described as hypoplastic in some studies26 but not in others.27,28 Additionally, the majority of published morphologic studies were designed to help with the design and sizing of acetabular components for total hip arthroplasty surgery. While the anatomical data presented in these studies24-28 are clearly relevant, there still remains a need for improved understanding of normal hip osseous morphology from an anthropometric perspective. Specifically, the goals of arthroscopic treatment for FAI include creating “normal” acetabular and/or femoral neck anatomy or to promote normal articulation of the femoro-acetabular joint during physiologic range of motion. In order to create more “normal” anatomy for a patient with pincer and/or cam FAI, the surgeon must intimately understand the normal osseous morphology of the hip joint.

Thus, when considering surgical treatment of FAI, one of the major challenges for the orthopedic surgeon is the difficulty in determining the precise anatomic location and severity of the impingement. A reproducible, noninvasive method utilizing computer navigation for both diagnostic assessment and proper treatment planning may present a possible future solution.29 Nevertheless, equally as important as a noninvasive model for assessing FAI is a functional and comprehensive understanding of the normal hip osseous morphology, which is currently not available in the literature. An improved understanding of 3-dimensional (3D) acetabular anatomy will allow the orthopedic surgeon to plan appropriate hip joint preservation surgery. Our study creates a novel method that would allow for comprehensive and reproducible mapping of the osseous morphology of the acetabulum using 3D analysis.

BRIEF DESCRIPTION OF LABORATORY WORK

We performed this study in our biomechanics laboratory33 with the participation of orthopedic surgeons specializing in hip arthroscopy and research faculty within the Department of Biomechanics at Rush University. Following institutional review board approval, 16 human cadaveric pelvis specimens underwent plain radiographic evaluation and were then dissected to the level of the hip joint capsule, without removal of cartilage from the acetabulum. The geometry of each hip was then acquired via hundreds of data points using the Brainlab Hip Navigation Application (Brainlab, Inc., Feldkirchen, Germany). The Brainlab Hip Navigation Application was originally created for total hip arthroplasty computer navigation and utilizes a camera to detect the location of optical pointers via optical sensors (Figure 4). The point-cloud data collected from the navigation application was then translated into a graphical computer-aided design environment (SolidWorks 2007; Dassault Systèmes SolidWorks Corp., Waltham, Massachusetts), which allowed for the creation of orthogonal data planes (equivalent to transverse, sagittal, and coronal) as a local coordinate system centered through the acetabulum. These data, from this application, we correlated with the acetabular fossa progressively decrease both in the anterior (3 o'clock) and the posterior (9 o'clock) directions. The anterior acetabular wall appears to decrease more dramatically at the 4 o'clock position; and 4) The acetabular arc length (or sourcil) may correspond to between the 10 o'clock to the 2 o'clock positions but most frequently corresponds to the 2 o'clock position.

Surgical intervention may be able to prevent the development of hip osteoarthritis. For example, arthroscopic trimming of the acetabular rim is one possible method for addressing pincer FAI. When deciding whether or not a patient is a candidate for an acetabular rim trimming, the orthopedic surgeon must have knowledge of normal hip morphology in order to compare it to that patient’s unique bony morphology. The results from this 3D analysis of the acetabulum provide more insight into the normal anatomy of the hip joint. Specifically, the acetabular surface does not have a constant depth around its circumference, and therefore, the rim extends with a variety of different arc lengths. For example, the length to the anterior rim is smaller than the length to the posterior rim. Additionally, the longest length is at the superior aspect of the acetabulum. These results set the standard for the normal morphology of the acetabulum, which is imperative for the diagnosis, and ultimately the treatment of anatomical abnormalities, resulting from either acute injury or insidious onset.

A comprehensive definition of the normal morphology of the hip joint can also be applied to preoperative planning for the orthopedic surgeon. A radiographic view of the hip provides a clear, 2-dimensional (2D) delineation of arc lengths from the center of the joint to the acetabular rim. By utilizing this radiographic methodology, the length of the superior arc can be analyzed with 3D data to determine which clockface value correlates best to the 2D arcs. Our results suggest that the superior radiographic arc is represented at the 2 o'clock position in 37% of cases and...
configurations, the posterior acetabular rim has been described of the anterior acetabular ridge has been consistently described normal hip osseous morphology. For example, while the anatomy critical importance. as hypoplastic in some studies but not in others. Additionally, these studies are clearly relevant, there still remains a need for help with the design and sizing of acetabular components for total hip arthroplasty surgery. While the anatomical data presented in these studies are clearly relevant, there still remains a need for improved understanding of normal hip osseous morphology from an arthroscopic perspective. Specifically, the goals of arthroscopic treatment for FAI include creating “normal” acetabular and/or femoral neck anatomy in order to promote normal articulation of the femoro-acetabular joint during physiologic range of motion. In order to create more “normal” anatomy for a patient with pincer and/or cam FAI, the surgeon must intimately understand the normal osseous morphology of the hip joint.

Thus, when considering surgical treatment of FAI, one of the major challenges for the orthopedic surgeon is the difficulty in determining the precise anatomic location and severity of the impingement. A reproducible, noninvasive method utilizing computer navigation for both diagnostic assessment and proper treatment planning may present a possible future solution. Nevertheless, equally as important as a noninvasive model for assessing FAI is a functional and comprehensive understanding of normal hip osseous morphology, which is currently not available in the literature. An improved understanding of 3-dimensional (3D) acetabular anatomy will allow the orthopedic surgeon to plan appropriate hip joint preservation surgery. Our study creates a novel method that would allow for comprehensive and reproducible mapping of the osseous morphology of the acetabulum using 3D analysis.

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BRIEF DESCRIPTION OF PRELIMINARY RESULTS

Statistical analysis showed that the mean age of 73 ± 12 years. The surface area of the acetabular fossa and articular surface were computed using the acetabular mesh created from the custom-written programming environment and measured at 474.1 ± 72.1 mm$^2$ and 504.5 ± 53.6 mm$^2$, respectively. The largest arc lengths were in the 12 o’clock direction, and arc lengths decreased both clockwise and counterclockwise from 12 o’clock. For each arc length measurement, high inter- and intra-observer reliability was evident. The intraclass correlation coefficient (a descriptive statistical calculation that describes how strongly data within the same group correlate with one another) was 0.995 ($P < .001$), both among each observer and between the observers. Furthermore, the results from both the navigation application arc length measurements and the radiographic arc length measurements showed a high correlation ($r = 0.276$) between the radiographic measurement and the navigation application’s measurement at the 2 o’clock position.

DISCUSSION

Normal hip anatomy has been difficult to characterize given its complex 3D morphology. The purpose of the present research was to map the normal osseous morphology of the acetabulum using 3D analysis, in an effort to allow the orthopedic surgeon to plan appropriate hip joint preservation surgery for patients with FAI and other hip joint pathology. Based upon the clockface data, the principal findings of this preliminary study are as follows: 1) The largest distance from the acetabular fossa to outer edge of the acetabulum is at 12 o’clock; 2) Distances from the acetabular fossa progressively decrease both in the anterior (3 o’clock) and the posterior (9 o’clock) directions; 3) The anterior acetabular wall appears to decrease more dramatically at the 4 o’clock position; and 4) The acetabular arc length (or sphericity) may correspond to between the 10 o’clock to the 2 o’clock positions but most frequently corresponds to the 2 o’clock position.

Surgical intervention may be able to prevent the development of hip osteoarthritis. For example, arthroscopic trimming of the acetabular rim is one possible method for addressing pincer FAI. When deciding whether or not a patient is a candidate for an acetabular rim trimming, the orthopedic surgeon must have knowledge of normal hip morphology in order to compare it to that patient’s unique bony morphology. The results from this 3D analysis of the acetabulum provide more insight into the normal anatomy of the hip joint. Specifically, the acetabular surface does not have a constant depth around its circumference, and therefore, the rim extends with a variety of different arc lengths. For example, the length to the anterior rim is smaller than the length to the posterior rim. Additionally, the longest length is at the superior aspect of the acetabulum. These results set the standard for the normal morphology of the acetabulum, which is imperative for the diagnosis, and ultimately the treatment of anatomical abnormalities, resulting from either acute injury or insidious onset.

A comprehensive definition of the normal morphology of the hip joint can also be applied to preoperative planning for the orthopedic surgeon. A radiographic view of the hip provides a clear, 2-dimensional (2D) delineation of arc lengths from the center of the joint to the acetabular rim. By utilizing this research methodology, the length of the superior arc can be analyzed with 3D data to determine which clockwise value correlates best to the 2D arcs. Our results suggest that the superior radiographic arc is represented at the 2 o’clock position in 37% of cases and...
CONCLUSIONS

The normal morphologic characteristics of the acetabular joint are poorly understood, and few studies adequately describe normal acetabular osseous anatomy. As FAI becomes increasingly recognized as a precursor to early hip osteoarthritis, less-invasive treatment options may become more favorable. Arthroscopy has proven to be a successful short- and medium-term surgical solution for appropriately indicated patients; however, a comprehensive understanding of “normal” hip ossaeus morphology is absolutely critical prior to any attempt at surgical correction. Our preliminary research provided a comprehensive description of “normal” acetabular osseous morphology by using 3D computer navigation and correlating the resulting data with plain radiographs. These descriptions of normal hip morphology may improve preoperative planning and postoperative outcomes of hip joint preservation surgery. Future areas of research will be conducted to further analyze the correlation between 3D measurements and radiographic images, as well as to map the osseous morphology of the femoral head-neck junction.

REFERENCES

at the 1 o'clock position in nearly 20% of cases, while the 12 o'clock position was found in nearly 20% of cases, and the 9 o'clock position was found in nearly 20% of cases. Further, the researchers in this study obtained specimens having a nonuniform morphology with peaks and depressions along the rim. These descriptions of normal hip morphology may improve preoperative planning and postoperative outcomes of hip joint preservation surgery. Future areas of research will be conducted to further analyze the correlation between 3D measurements and radiographic measurements, as well as to map the osseous anatomy of the acetabulum within the hip joint itself.

CONCLUSIONS

The normal morphologic characteristics of the acetabular joint are poorly understood, and very few studies adequately describe normal acetabular osseous anatomy. As FAI becomes increasingly recognized as a precursor to early hip osteoarthritis, less-invasive treatment options may become more favorable. Arthroscopy has proven to be a successful short- and medium-term surgical solution for appropriately indicated patients; however, a comprehensive understanding of “normal” hip osseous morphology is absolutely critical prior to any attempt at surgical correction. Our preliminary research provided a comprehensive description of “normal” acetabular osseous morphology by using 3D computer navigation and correlating the resulting data with plain radiographs.

REFERENCES

Metal Ion Levels After Second Joint Arthroplasty

“Determining serum metal ion concentrations after total joint arthroplasty may be useful in the work-up of patients with local pain or unexplained systemic symptoms...”

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RESULTS
Minimum 5-year data were available for all patients after their second joint arthroplasty, with an average follow-up of 36.4 months (range, 56-368 months). Of the concentrations of serum cobalt, chromium, or titanium was below the standard detection limits described above. Normal serum levels of the metal ions analyzed for the current study have been previously reported as being less than 4.1 ng/ml for cobalt.11

Patients undergoing a secondary TKA after a primary THA had no significant trends or differences in cobalt, chromium, or titanium ion levels from baseline up to 72 months after their operation. In addition, there were no significant differences in cobalt, chromium, or titanium ion levels at baseline between unilateral THA and secondary TKA groups. Patients with a secondary THA had significantly elevated cobalt ion levels at 36 months follow-up, reaching a peak at 48 months (Figure 1A). Chromium levels in patients with a secondary TKA were significantly elevated at 12 months follow-up with sustained increased concentration at 24 months (Figure 1B). Patients with a secondary TKA also had significantly elevated titanium ion levels at 48 and 72 months follow-up (Figure 1C).

DISCUSSION
Elevation of serum metal ion levels after primary THA is a well-described phenomenon,12 however, the impact of a second joint arthroplasty on these levels has not been well investigated. It is commonly found that patients who develop degenerative joint disease requiring hip arthroplasty often go on to develop joint arthroplasty in an adjacent or contralateral joint necessitating future joint arthroplasty. In the present study, cobalt ion concentrations after secondary THA were significantly increased at 36 months follow-up, reaching a peak at 48 months, while chromium levels were increased at 12 and 48 months. Titanium levels were...
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Elevated serum metal ion levels have been found after primary total hip arthroplasty (THA) regardless of the type of articulation couple used.1–3 With the recent focus on reported adverse responses to metal-on-metal THA, there is mounting concern regarding local soft tissue reactions, systemic immune modulation, and end-organ deposition and damage associated with elevated serum metal ion concentrations. The metal components of joint replacements can undergo electrochemical corrosion resulting in the formation of chemically active metal ion degradation products.1 Tower reported 2 patients with metal-on-metal THA who developed systemic neurological and cardiac complications associated with an elevation in serum cobalt levels.2 Tower suggested a cause-effect relationship due to the fact that systemic symptoms improved following revision surgery, presumably lowering serum cobalt concentrations although no serum measurements were reported following revision and there was limited information regarding case details. Adverse systemic responses to metal debris from joint replacement are extremely rare. It is also important to note that increased serum metal ion levels are not unique to metal-on-metal bearings, because other metal devices with accelerated damage due to wear or corrosion can lead to elevated levels of metal in local and remote tissues.

Currently, there is no generally accepted threshold above which serum concentrations of metal ions such as cobalt, chromium, and titanium are known to be toxic in patients with a joint replacement. However, cobalt and chromium are both toxic in high concentrations in vivo, and titanium has been shown to be potentially carcinogenic at high levels in animal models. Previous work has also shown that wear particle from total hip and knee replacements can disseminate to the liver, spleen, and abdominal lymph nodes, causing as-yet-unknown long-term effects.4 Degenerative arthritis disease of the hip will often impact the contralateral hip and knee, thus requiring a future second total joint replacement.5 However, we know little about the effect of this second arthroplasty on metal ion levels in the body. The purpose of the present study was to determine the effect of a second joint replacement on serum concentrations of cobalt, chromium, and titanium after a primary metal-on-polyethylene THA as well as the time course of concentration changes.

METHODS
We prospectively enrolled in this study after obtaining research approval from the Rush University Institutional Review Board. We obtained informed consent from all patients prior to study inclusion. The average age of patients was 63.4 years (range, 55-76 years). We included 4 males and 8 females who were all undergoing an initial primary metal-on-polyethylene THA for the treatment of osteoarthritis. All patients had a well-functioning prosthesis determined by Harris hip score, and none had radiographic evidence of loosening or osteolysis at interval follow-up or just prior to their second operation. We included 8 patients who had received cementless proximally porous-coated titanium-alloy femoral stems and titanium acetabular components. The femoral stem was made of Ti-6Al-4V with a titanium fiber-metal porous-coated femoral surface diffusion bonded onto the proximal aspect of the stem. We used 6 Anatomic and 2 Harris-Galante Multilink femoral components (Zimmer, Warsaw, Indiana). The acetabular component, which we inserted without cement, consisted of a titanium shell with a diffusion-bonded, titanium fiber-metal porous-coated surface (Zimmer). We used 2 titanium alloy self-tapping screws for fixation. The bearing surface consisted of a modular cobalt-alloy femoral head and ultrahigh molecular weight polyethylene liner.

Two patients received cementless, extensively porous-coated, cobalt alloy femoral stems with modular titanium-alloy acetabular components. We inserted anatomical mediullary locking (AML) femoral components (DePuy, Warsaw, Indiana) based on preoperative templating and intraoperative bone quality. We used Duraloc acetabular sockets, consisting of titanium alloy shells with a beaded titanium porous coating (DePuy). Using 3 porous-coated titanium-alloy spines, we secured the acetabular shells to the pelvis. We used modular cobalt-alloy femoral head and ultrahigh molecular weight polyethylene liner for the articulation surface.

The second joint replacement consisted of 8 subsequent THAs at follow-up intervals and annually thereafter. We verified all vessels and inserted component failure requiring component revision, and then performed metal-ion analysis on the contents of the serum samples.

We collected blood samples for serum metal ion level analysis with an average follow-up of 36.4 months (range, 45-58 months) for one of the concentrations of serum cobalt, chromium, or titanium was below the standard detection limits described above. Normal serum levels of the metal ions analyzed for the current study have been previously reported as 0.15 ng/ml (parts per billion) for chromium and 0.1 to 0.2 mg/ml for titanium.6 The normal level of titanium has been reported as being less than 4.1 ng/ml (2 pg/ml).

Patients undergoing a secondary TKA after a primary THA had no significant trends or differences in cobalt, chromium, or titanium ion levels from baseline up to 12 months after their operation. In addition, there were no significant differences in cobalt, chromium, or titanium ion levels at baseline between unilateral THA and secondary TKA groups. Patients with a secondary THA had significantly elevated cobalt ion levels at 36 months follow-up, reaching a peak at 48 months (Figure 1A). Chromium levels in patients with a secondary THA were significantly elevated at 12 months follow-up with sustained increased concentration at 24 months (Figure 1B). Patients with a secondary THA also had significantly elevated titanium ion levels at 48 and 72 months follow-up (Figure 1C).

Elevation of serum metal ion levels after primary THA is a well-described phenomenon7–11; however, the impact of a second joint arthroplasty on these levels has not been well investigated. It is commonly found that patients who develop degenerative joint disease requiring hip arthroplasty often go on to develop joint disease in an adjacent or contralateral joint necessitating future joint arthroplasty.7 In the present study, cobalt ion concentrations after secondary THA were significantly increased at 36 months follow-up, reaching a peak at 48 months, while chromium levels were increased at 12 and 48 months. Titanium levels were...
Figure 1. Metal ion levels after unilateral total hip arthroplasty (THA) and secondary THA from baseline (0 months) to 72 months follow-up. Values shown are means with standard deviation bars. (* = significant difference < .05).

Figure 2. Intraoperative photo from a case outside of the present study showing fretting corrosion at the modular femoral head-neck junction resulting in metallosis and metal ion release.
in the literature regarding metal ion concentrations is the wide variability in how measurements are gathered, analyzed, and reported, thus making comparisons between studies difficult. In addition, detection of differences between groups has been notably difficult in previous studies due to variations among individuals and among samples from the same individual with regard to the concentrations of serum metal ions. Advantages of the present study were the long-term follow-up, for a duration of 72 months, and the fact that each patient served as his or her own control for measurement comparisons.

There are several existing modes of metal ion release, including passive dissolution, wear (mechanical), corrosion (electrochemical), and combined mechanical and electrochemical processes (e.g., fretting corrosion). Our previous prospective work has described and quantified the rise in metal ion levels of cobalt, chromium, and titanium at all follow-up intervals. However, these results are difficult to interpret because only certain time periods were statistically significant. We also found that a secondary metal-polyethylene TKA after primary THA had no significant trends or effects on serum metal ion levels at any time period.

The small number of patients in this study and absence of power analysis represent major limitations and may have prevented us from detecting further trends and levels of significance. It is possible that increased serum metal ion concentrations derived from total joint arthroplasty may have yet-unknown long-term deleterious biological effects, requiring future investigation. Accurate and longitudinal monitoring of serum metal concentrations is especially critical now, given the dramatic increase over the past decade in the use of metal-on-metal bearings and in the modularity of femoral prostheses. It is important to note that even in the absence of increases in the concentrations of metal in the serum during work-up, previous research has shown that deposition and accumulation of metal ions can occur locally and in remote organ stores in association with a well-functioning device. In addition, the kinetics of metal ion production, transport, and excretion are complex, making it difficult to interpret the significance of elevated metal ions. The present study contributes to the growing body of literature investigating the bioactivity and biocompatibility of metal ion degradation products generated by the presence of joint replacements.

Routine periodic surveillance is necessary for any patient who has undergone a total joint replacement in order to expedite care in the event of complications. Determining serum metal ion concentrations may be useful in the work-up of patients with local pain or otherwise unexplained systemic symptoms that may indicate an adverse reaction to metal ions. Surgeons need to be aware of the rare systemic complications of metal devices undergoing accelerated wear and corrosion so that a timely revision operation can be considered. Studies involving larger numbers of patients and longer-term follow-up are necessary to determine the biomechanical and biochemical extent and impact of elevated metal ion levels.

REFERENCES


Figure 1. Metal ion levels after unilateral total hip arthroplasty (THA) and secondary THA from baseline (0 months) to 72 months follow-up. Values shown are means with standard deviation bars. (⁎ = significant difference P < .05). A, Cobalt ion levels in serum. B, Chromium ion levels in serum. C, Titanium ion levels in serum.
Medical devices and drugs discussed in the preceding article are approved by the FDA for use in the manner described. This work was supported in part by NIH/NIAMS Grant AR39310. Authors Hsu, Skipor, and Hallab receive no funds from commercial sources. Dr Levine is a paid consultant to Zimmer and to Janssen Pharmaceutical; and receives funds to support research from Zimmer and Biomet. Dr Paprosky is a paid consultant to Stryker and for Pivot Medical, and receives funding for research from Stryker, Arthrex, and Allosource.

“Three-Dimensional Anatomy of the Hip, Utilizing Computer Navigation and Plain Radiographs,” beginning on p. 13, does not discuss consultant to Zimmer and its Janssen Pharmaceutical; and receives funds to support research from Zimmer and Biomet. Dr Paprosky is a paid consultant to Stryker and for Pivot Medical, and receives funding for research from Stryker, Arthrex, and Allosource.
Specialized anesthesia and rapid rehabilitation protocols play equally important roles in enabling a minimally invasive outpatient approach to total hip replacement.12,13 The use of regional anesthesia allows for less narcotic administration, which leads to decreased postoperative nausea and hypotension.9 Initiation of preemptive oral analgesia and antinociceptives early in the recovery phase also aids in pain management and reduces cost.13,14 Physical therapy, preoperative education, and discharge planning are also critical in managing patient expectations and ensuring adequate care at home.8

Currently the only reported experience with outpatient THA has been with the 2-incision7,14 and miniposterior15 techniques. In both of these studies, the authors demonstrated that outpatient hip replacement is both possible and safe in appropriately selected patients. In the current study, we describe outpatient THA utilizing a minimally invasive, abductor sparing, anterolateral approach, coupled with a rapid rehabilitation and recovery protocol. The purpose of our study is to evaluate the effectiveness of such a pathway for outpatient hip replacement and to assess its feasibility and safety.

MateriaLs and Methods

We retrospectively reviewed 199 consecutive patients who underwent primary THA between January 2011 and August 2011. Of the 87 patients enrolled in this study, 53 (60.9%) were males and 34 (39.1%) were females. The average age of surgery was 56 years (range, 38–73 years). Of the 87, 15 patients (17.2%) were younger than 50 years, 65 patients (74.7%) were between the ages of 50 and 65 years, and 7 patients (8.1%) were older than 65 years.
The average overall weight of the patients was 85.7 kg (range, 47.2-145.2 kg). The average weight of the male patients was 94.2 kg (range, 63.5-145.2 kg) and 73.0 kg (range, 47.2-113.4 kg) for the female patients. The average body mass index (BMI) overall was 27.9 (range, 18.5-43.3). The average BMI for the male patients was 29 (range, 22.5-48.3), and the average BMI for the female patients was 28.8 (range, 18.5-40.2).

PERIOPERATIVE CARE

We enrolled all patients in a comprehensive clinical pathway including preoperative, intraoperative, and postoperative care. The pathway specifically addresses pain management, postoperative nausea and hypotension, and home aftercare.

Preoperatively, all patients attended a class taught by a clinical nurse and a physical therapist. On the morning of surgery, prior to coming to the hospital, patients took 10 mg of oxycodone hydrochloride controlled release (CR). All patients received an epidural catheter, Foley catheter, and intravenous (IV) antibiotics prior to incision. We gave patients propofol for sedation at the discretion of the anesthesiologist. We achieved nausea prophylaxis with IV ondansetron and metoclopramide. All patients received 1 unit of autologous blood, and IV and epidural narcotics were avoided during surgery.

Postoperatively, patients were given additional ondansetron for pre-emptive nausea control. Within 4 hours after surgery, we discontinued the Foley catheter and epidural. We achieved pain control with scheduled oral oxycodone and as-needed oral hydrocodone or IV morphine. The patients started physical therapy 6 hours later and were allowed to bear weight as tolerated, using crutches, a cane, or independently.

A clinical nurse was available to address any postoperative issues. We discharged patients once they met standard physical therapy discharge criteria and had stable vital signs and adequate pain control. Upon discharge, we instructed patients to take 325 mg of aspirin as prophylaxis against venous thromboembolism twice a day for 3 weeks. In addition to oxycodone CR and hydrocodone for pain relief, patients also took diclofenac as an anti-inflammatory medication.

OPERATIVE TECHNIQUE

POSITIONING

We positioned the patient in the lateral decubitus position, utilizing an operating table that allowed us to move the leg sections independently. This allowed us to place the operative leg in a position that extended, adducted, and externally rotated. Retractors were placed around the proximal femur, presenting it anteriorly. It is necessary to release the posterior superior capsule from the saddle point and the inner aspect of the greater trochanter (Figure 7) in order to further expose the femur for instrumentation (Figure 8). We used a curved awl to enter the femoral canal and then reamed out the femoral neck, opening the femoral head (Figure 10). We performed trial reduction with varying neck lengths until adequate hip stability, soft tissue tension, and leg lengths were achieved. Finally we removed the trial head and impacted the final head into place. We then reduced the hip for a final time.

RESULTS

Of the 87 patients who were scheduled for outpatient THA and whose surgery was completed by 12 pm, 86 (98.9%) were discharged home the same day. Of the 87 patients, 1 (1.1%) did not pass physical therapy and was discharged the following day. Mean surgical time was 59 minutes (range, 38-91 minutes). Mean estimated blood loss was 251.1 cc (range, 50-1500 cc). All 87 patients (100%) received epidural anesthesia, and all 87 (100%) patients were discharged home with home physical therapy services.

All patients received uncemented acetabular and femoral THA components. Of the 87 patients, 34 patients (39.1%) had a DePuy Pinnacle Porocoat acetabular shell (DePuy, Warsaw, Indiana), and 53 patients (60.9%) had a Zimmer Trilogy fiber metal mesh acetabular shell (Zimmer, Warsaw, Indiana). Of the 87 patients, 27 patients (31.0%) had a Zimmer VerSys beaded fulcrum stem, 26 patients (29.9%) had a Zimmer MCI Taper Kinetic modular tapered stem, 33 patients (37.9%) had a DePuy Tri-Lock tapered stem, and 1 patient (1.1%) had a Zimmer VerSys fiber metal tapered stem.

Of the 87 patients, 0 patients had any significant medical complications in the acute (<2 weeks) postoperative period. There were no DVTs/PEs, cardiopulmonary events, deaths, or other serious medical complications. There were no readmissions for postoperative complications during this period. One patient had a deep hip infection at 3 weeks postoperatively that was treated with a 1-stage exchange revision hip arthroplasty and IV antibiotics. To date, this patient has not had a recurrence of infection.
The average overall weight of the patients was 85.2 kg (range, 47.2-145.2 kg). The average weight of the male patients was 94.2 kg (range, 63.5-145.2 kg) and 73.0 kg (range, 47.2-113.4 kg) for the female patients. The average body mass index (BMI) overall was 27.9 (range, 18.5-43.3). The average BMI for the male patients was 29 (range, 22.5-43.3), and the average BMI for the female patients was 26.8 (range, 18.5-40.2).

PERIOPERATIVE CARE
We enrolled all patients in a comprehensive clinical pathway including preoperative, intraoperative, and postoperative care. The pathway specifically addresses pain management, postoperative nausea and hypotension, and home aftercare.

Preoperatively, all patients attended a class taught by a clinical nurse and a physical therapist. On the morning of surgery, prior to coming to the hospital, patients took 10 mg of oxycodone hydrochloride controlled release (CR). All patients received an epidural catheter, Foley catheter, and intravenous (IV) antibiotics prior to incision. We gave patients prepped for adhesions at the discretion of the anesthesiologist. We achieved nausea prophylaxis with IV ondansetron and metoclopramide. All patients received 1 unit of autologous blood, and IV and epidural narcotics were avoided during surgery.

Postoperatively, patients were given additional ondansetron for pre-emptive nausea control. Within 4 hours after surgery, we discontinued the Foley catheter and epidural. We achieved pain control with scheduled oral oxycodone and as-needed oral hydrocodone or IV morphine. The patients started physical therapy 6 hours later and were allowed to bear weight as tolerated, using crutches, a cane, or independently.

A clinical nurse was available to address any postoperative issues. We discharged patients once they met standard physical therapy discharge criteria and had stable vital signs and adequate pain control. Upon discharge, we instructed patients to take 325 mg of aspirin as prophylaxis against venous thromboembolism twice a day for 3 weeks. In addition to oxycodone CR and hydrocortisone for pain relief, patients also took diclofenac as an anti-inflammatory medication.

OPERATIVE TECHNIQUE
POSITIONING
We positioned the patient in the lateral decubitus position, utilizing an operating table that allowed us to move the leg sections independently. This allowed us to place the operative leg in a position that allowed us to move the leg sections over the superior and inferior aspects of the femoral neck (Figure 1). We identified the anterior capsule and performed an anterior capsulectomy. We then identified the middle point between the inner aspect of the greater trochanter and the base of the superior femoral neck and cleared off the capsular remnants, marking the superolateral border of the femoral neck osteotomy (Figure 2). We then repositioned the retractors intracapsularly over the acetabular rim.

ACETABULAR PREPARATION
We moved the leg from the pouch and placed it onto the leg holder. Next we placed acetalular retractors, retracting the femur posteriorly. Once we achieved 360º visualization of the acetabulum, we excised the pulvinar and labrum (Figure 5). Next, we performed acetabular reaming until we achieved a good press fit. We then impacted the acetabular component in the appropriate abduction and antversion, with or without adjacent screw fixation, and then placed the acetabular liner (Figure 6).

FEMORAL PREPARATION
We placed the leg into a sterile kangaroo pouch attached to an assistant’s gown, allowing the hip to be extended, abducted, and externally rotated. Retractors were placed around the proximal femur, presenting it anteriorly. It is often necessary to reposition the posterior superior capsule from the saddle point and the inner aspect of the greater trochanter (Figure 7) in order to further expose the femur for instrumentation (Figure 8). We used a curved awl to enter the femoral canal and then reamed out the inner aspect of the greater trochanter with a large motorized burr, preventing varus positioning of the femoral stem. We performed broaching with offset handles until adequate fit, depth, and version were achieved (Figure 9). After inserting the final stem (Figure 10), we performed trial reduction with varying neck lengths until adequate hip stability, soft tissue tension, and leg lengths were achieved. Finally we removed the trial head and impacted the final head into place. We then reduced the hip for a final trial.

RESULTS
Of the 87 patients who were scheduled for outpatient THA and whose surgery was completed by 12 pm, 86 (98.9%) were discharged home the same day. Of the 87 patients, 1 (1.1%) did not pass physical therapy and was discharged the following day. Mean surgical time was 59 minutes (range, 38-91 minutes). Mean estimated blood loss was 251.1 cc (range, 50-1500 cc). All 87 patients (100%) received epidural anesthesia, and all 87 (100%) patients were discharged home with home physical therapy services.

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Of the 87 patients, 0 patients had any significant medical complications in the acute (<2 weeks) postoperative period. There were no DVTs/PEs, cardiopulmonary events, deaths, or other serious medical complications. There were no readmissions for postoperative complications during this period. One patient had a deep hip infection at 4 weeks postoperatively that was treated with a 1-stage exchange revision hip arthroplasty and IV antibiotics. To date, this patient has not had a recurrence of infection.
The purpose of this study is twofold: (1) to describe the technique of minimally invasive THA through a modified anterolateral approach coupled with a comprehensive clinical pathway and (2) to demonstrate the efficacy and safety of such an outpatient surgery protocol. Prior studies have demonstrated that outpatient hip replacement is both feasible and safe with the minimiposterior and 2-incision techniques,7,15 and this study confirms similar results with a modified anterolateral approach.

Of the 87 patients in this study, 86 (98.9%) were successfully discharged on the day of surgery. This represents a higher success rate than previously reported studies on outpatient total joint arthroplasty. Prior studies have demonstrated that outpatient THA has become a reality that is safe, effective, and reproducible.

BMII of patients in this study are lower than the averages of most arthroplasty practices. Length of stay after THA has dramatically decreased in the past 20 years. The average stay has dropped from over 1 week to 3 to 4 days, and is now approaching an overnight stay or same-day surgery. In summary, outpatient THA can successfully and safely be performed in select patient populations. While minimally invasive surgery plays a critical role in outpatient THA, equally important are the contributions from multimodal anesthesia techniques as well as rapid rehabilitation and preoperative patient education.

When combined into the comprehensive clinical pathway outlined in this study, outpatient THA has become a reality that is safe, effective, and reproducible.

REFERENCES

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REFERENCES

The preceding article does not discuss use of medical devices or drugs that are not approved by the FDA. No funds were received in support of the work described. Dr Chen receives no funding from any commercial sources. Dr Berger receives medical device royalties from Zimmer.
Anterior Cruciate Ligament Reconstruction Failure: Analysis of a Single, High-Volume Orthopedic Institution

“With strict attention to good principles of anterior cruciate ligament reconstruction, a lower failure rate can be expected with the majority of the failures resulting from traumatic reinjuries.”

RACHEL M. FRANK, MD / MARK A. SLABAUGH, MD / KEVIN C. MCGILL, MD, MPH / CHARLES A. BUSH-JOSEPH, MD / BRIAN J. COLE, MD, MBA / BERNARD R. BACH JR, MD / NIKHIL N. VERMA, MD

AUTHOR AFFILIATIONS
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Bernard R. Bach Jr, MD; Rush University Medical Center and Midwest Orthopaedics at Rush, 1611 W Harrison St, Suite 300, Chicago, IL 60612 (bbach@rushortho.com).

Failure of primary intra-articular anterior cruciate ligament reconstruction (ACL) can be defined as a knee with persistent pathological laxity, persistent pain, and/or without luxury but with a limited range of motion. Potential etiologies of ligament failure include new trauma, technical errors during the index operation, biological failure of graft incorporation, failure to address concomitant instability pathologies, and poor postoperative patient compliance with rehabilitation protocol. Typically, if a primary ACLR fails within 6 months and trauma has been ruled out, the likely explanation is a technical issue. Specific technical errors include incorrect bone tunnel placement, inappropriate graft tensioning, and inadequate graft fixation. Among the potential factors causing ACLR failure, surgical technique and/or surgeon error remain the most commonly reported causes in the literature. While several studies report the various causes of failed ACLR leading to a revision procedure, there are no reports describing both the primary and revision procedures when both operations are performed by the same surgeon.1,3,5,9,10 The purpose of this study was to determine the causes of failed primary ACLR reconstructions performed by experienced, fellowship-trained, sports medicine surgeons at a single, high-volume institution. Our hypothesis was that the most common cause of failed ACLR would be traumatic reinjury rather than technical error. In addition, we aimed to analyze postrevision ACLR outcomes as determined by assessment with the KT-1000 Arthrometer (MEDMetric, Inc., San Diego, California) and physical examination, as well as knee-specific outcomes surveys. For this aspect of the study, we hypothesized that patients undergoing revision ACLR would demonstrate good to excellent clinical outcomes.

Methods
An independent research fellow conducted a retrospective blinded review of the surgical logs of 4 senior fellowship-trained sports medicine surgeons to find all patients who had undergone ACLR from 2002 through 2009.17 This list of 1944 patients was further narrowed to include only those on whom the same surgeon had performed a subsequent revision ACLR on the ipsilateral knee within the 8-year time period. Patients who had undergone their index procedure with another surgeon were excluded from the study. Patients who had undergone more than one revision (7 patients within the 8-year time period) were included in the statistical analysis of overall failure; however, these patients were not included in the clinical follow-up portion of the study. Out of 1944 ACLR reconstructions, 28 patients (56 reconstructions) were included in the study.
Anterior Cruciate Ligament Reconstruction Failure: Analysis of a Single, High-Volume Orthopedic Institution

“With strict attention to good principles of anterior cruciate ligament reconstruction, a lower failure rate can be expected with the majority of the failures resulting from traumatic reinjuries.”

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2012 / RUSH ORTHOPEDICS JOURNAL

INDEX ACLR

14% BPTB Auto
46% BPTB Allo
11% HS Auto
29% HS Allo

REVISION ACLR

4% BPTB Auto
14% BPTB Allo
82% HS Auto

Figure 3. Pie charts portraying graft selection in both index (A) and revision (B) ACL reconstruction. Bone-patellar tendon-bone (BPTB) autografts were most commonly used in the index procedures, while BPTB allografts were more commonly used in the revision.

CHART REVIEW

For each patient, the research fellow conducted a thorough review of the medical chart to collect preoperative, postoperative, and intraoperative information pertinent to both the index and revision ACLR. Demographic information, graft selection, clinic notes, physical exam measures including KT1000 scores, operative data including concomitant pathologies, procedures performed, and appearance of the ACL graft (at time of revision) were analyzed to determine any potential mechanism of failure. Operative notes (index and revision) were analyzed for evidence of possible technical errors, including tunnel malposition and inadequate fixation. Particular attention was paid to the time between the index ACL and failure.

RADIOGRAPHIC ANALYSIS

Radiographic measurements were obtained on both anteroposterior (AP) and lateral views on radiographs obtained between the primary and secondary reconstruction (Figures 1 and 2). In addition, the position of the center of the tibial tunnel on the lateral radiograph was measured as a percentage in relation to the length of Blumensaat’s line. The femoral tunnel was considered too vertical if this measurement was greater than 10 degrees.20 The femoral tunnel was measured in relationship to the anatomic axis of the femur on the AP radiograph. The femoral tunnel was considered too inappropriately positioned, or if at the time of revision ACLR, radiographs indicated that the femoral and/or tibial tunnels were inappropriately positioned, or if at the time of revision ACLR, plastic meniscectomy and medial meniscus repair 6 (21)

We classified failures as biologic based upon definitive findings of incorporation failure, allograft rejection, or notch impingement from regrowth at the time of revision ACLR, or if failure occurred within the first 6 months following index ACLR in patients with a properly placed and well-fixed graft (if there was no report of a recurrent traumatic event).

We considered a failure to be traumatic only if the patient had a distinct traumatic injury after returning to full activity in his or her sport and if other causes of failure could be ruled out. Further, in order to be considered a traumatic failure, intraoperative findings at the time of revision ACLR had to have shown a midsubstance tear or tear off the femur/tibia with good tissue remaining opposite the tear. Only those patients who met these 3 criteria (clinical history, exclusion of other causes, and intraoperative findings) were included as traumatic failures.

STATISTICAL ANALYSIS

Statistical analyses, including descriptive data analysis, correlation analysis, and inferential analysis, were performed using SPSS (SPSS Inc., Chicago, Illinois) statistical software. We considered results to be statistically significant for all analyses when P < .05.

RESULTS

CHART REVIEW AND RADIOGRAPHIC ANALYSIS RESULTS

From January 2002 through December 2009, all 4 senior knee surgeons at our institution were performing arthroscopic-assisted ACLR with a transtibial technique. After incorporation of the study’s inclusion and exclusion criteria, 28 patients (56 reconstructions) were included in the study. During this same time period, a total of 1944 primary ACL reconstructions were performed, with 35 revision cases (1.8%) (includes only patients, who, to the best of our knowledge, needed a revision.

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Radiographic measurements were obtained on both anteroposterior (AP) and lateral views on radiographs obtained between the index ACLR and failure. Particular attention was paid to the time between the index and revision (A) ACL reconstruction. Bone–patellar tendon–bone (BPTB) autografts were most commonly used in the index procedures, while BTPB allografts were more commonly used in the revision.

**Chart Review**

For each patient, the research fellow conducted a thorough review of the medical chart to collect preoperative, postoperative, and intraoperative information pertinent to both the index and revision ACLR. Demographic information, graft selection, clinic notes, physical exam measures including KT1000 scores, operative data including concomitant pathologies, procedures performed, and appearance of the ACL graft (at time of revision) were analyzed to determine any potential mechanism of failure. Operative notes (index and revision) were analyzed for evidence of possible technical errors, including tunnel malposition and inadequate fixation. Particular attention was paid to the time between the index ACLR and failure.

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Radiographic measurements were obtained on both anteroposterior (AP) and lateral views on radiographs obtained between the primary and secondary reconstruction (Figures 1 and 2). In addition, the position of the center of the tibial tunnel on the lateral radiograph was measured as a percentage in relation to the length of Blumensaat’s line. The femoral tunnel was considered too far anterior if it was greater than 15%.

**Clinical Follow-Up**

Following the chart review, each patient was invited by telephone to return to the clinic for a blinded follow-up examination with the lone independent research fellow. During the clinic visit, the research fellow conducted a thorough physical examination of both knees, including provocative and stability testing, as well as arthrometric evaluation with the KT1000 Arthrometer. Each patient was also asked to complete a follow-up survey containing demographic data and outcomes assessments, including the SF-12 Health Survey, Knee Injury and Osteoarthritis Outcome Score (KOOS), the International Knee Documentation Committee Subjective Form (IKDC), Western Ontario and McMaster Universities Osteoarthritis (WOMAC) index, modified Cincinnati Knee-Rating Scale (10-point), and Lysholm score.

**Definition of ACL Reconstruction Failure**

For the purpose of this study, the cause of ACLR failure was categorized into 3 groups: iatrogenic, biologic, and traumatic. We classified failure as iatrogenic (surgery or technical) if radiographs indicated that the femoral and/or tibial tunnels were inappropriately positioned, or if at the time of revision ACLR, intra- or postoperative findings indicated tunnel malposition or inadequate fixation.

Figure 3. Pie charts portraying graft selection in both index (A) and revision (B) ACL reconstruction. Bone–patellar tendon–bone (BPTB) autografts were most commonly used in the index procedures, while BTPB allografts were more commonly used in the revision.

**Characteristics**

<table>
<thead>
<tr>
<th>NO. (%) OF PATIENTS</th>
<th>Table 1. Summary of Demographic Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total patients</strong></td>
<td>28 (100)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
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<tr>
<td>Male</td>
<td>15 (54)</td>
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<tr>
<td>Female</td>
<td>13 (46)</td>
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<tr>
<td><strong>Operative knee</strong></td>
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<tr>
<td>Left</td>
<td>17 (61)</td>
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<tr>
<td>Right</td>
<td>11 (39)</td>
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<tr>
<td><strong>Time between index and revision ACLR, months</strong></td>
<td>21.7 ± 16.6</td>
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<tr>
<td><strong>Surgery</strong></td>
<td></td>
</tr>
<tr>
<td>Index ACLR</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>22 ± 11 (range, 12-50)</td>
</tr>
<tr>
<td>Revision ACLR</td>
<td></td>
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<tr>
<td>Age, y</td>
<td>24 ± 11 (range, 14-57)</td>
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<tr>
<td><strong>Concomitant procedures</strong></td>
<td>NO. (%) OF PATIENTS</td>
</tr>
<tr>
<td>At index ACLR</td>
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<td>Partial medial meniscectomy</td>
<td>5 (18)</td>
</tr>
<tr>
<td>Medial meniscal repair</td>
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<tr>
<td>Open MCL repair</td>
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<td>Partial lateral meniscectomy and medial meniscus repair</td>
<td>1 (4)</td>
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<tr>
<td>At revision ACLR</td>
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<tr>
<td>Partial medial meniscectomy</td>
<td>6 (21)</td>
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<tr>
<td>Medial meniscal repair</td>
<td>4 (16)</td>
</tr>
<tr>
<td>Partial lateral meniscectomy and medial meniscus repair</td>
<td>4 (16)</td>
</tr>
</tbody>
</table>

| Abbreviations: ACLR, anterior cruciate ligament reconstruction; MCL, medial collateral ligament |

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We considered a failure to be traumatic only if the patient had a distinct traumatic injury after returning to full activity in his or her sport and if other causes of failure could be ruled out. Further, in order to consider a traumatic failure, intraoperative findings at the time of revision ACLR had to have shown a subluxation tear or tear of the femoralis with good tissue remaining opposite the tear. Only those patients who met these 3 criteria (clinical history, exclusion of other causes, and intraoperative findings) were included as traumatic failures.

**Statistical Analysis**

Statistical analyses, including descriptive data analysis, correlation analysis, and inferential analysis, were performed using SPSS (SPSS Inc., Chicago, Illinois) statistical software. We considered results to be statistically significant for all analyses when P < .05.

**Results**

**Chart Review and Radiographic Analysis Results**

From January 2002 through December 2009, all 4 senior knee surgeons at our institution were performing arthroscopic-assisted ACLR with a transtibial technique. After incorporation of the study’s inclusion and exclusion criteria, 28 patients (56 reconstructions) were included in the study. During this same time period, a total of 1944 primary ACL reconstructions were performed, with 35 revision cases (1.8%) (includes only patients, who, to the best of our knowledge, needed a revision...
reconstruction, and incorporates all excluded patients). Demographic data for the study cohort are provided in Table 1. Of note, in 9 of the 28 patients (32%), the revision procedure was performed within 12 months of the index procedure.

Graft selection for both the index and revision ACLR procedures is outlined in Figure 3. Grafts involved were bone-patellar tendon-bone (BPTB) and hamstring (HS). Overall, autograft was used in 16 of the 28 index cases (57%), while allograft was used in 12 cases (43%). For revision procedures, autograft was used in 4 cases (14%), while allograft was used in 24 cases (86%). In 16 cases (57%), autografts were converted to allografts, while in 4 cases (14%) allografts were converted to autografts. In the remaining 8 cases (29%), allografts were converted to new allografts. All graft choices were determined based on surgeron preference, patient preference, and graft availability (ie, if BPTB autograft was used for the index procedure, this would be unavailable for the revision procedure).

Radiographs of the operative knee between the primary and revision ACLR were available for 22 of the 28 patients (79%) and the results are summarized in Table 2. Based upon the radiographic guidelines, 7 of the 28 patients (25%) showed radiographic evidence of an iatrogenic cause (tunnel location) of failure from their primary reconstruction. Of those patients who had iatrogenic failures, 2 patients had BPTB autograft, 3 had BPTB allograft, 1 had HS autograft, and 1 had HS allograft.

Of the 28 patients in our series, only 1 (4%) had definite failure secondary to biologic reasons. This patient had a HS allograft for her index ACLR and was noted to have regrowth of the notch resulting in attenuation of the graft at this site. Finally, traumatic failure was confirmed in 20 of the 28 patients (71%). Of the 20 traumatic failures, the failures occurred at an average of 24.8 months (range, 5.5-82.5 months) after the initial procedure, 1 of which failed within 6 months postoperatively. Of those patients who had traumatic failures, 11 had BPTB autograft, 5 had BPTB allograft, 2 had HS autograft, and 2 had HS allograft. The overall failure results are summarized in Table 3.

**CLINICAL FOLLOW-UP RESULTS**

Of the 28 patients, 20 (71%) were available for follow-up examination at an average of 30.2 ± 17.7 months following revision ACLR. The average Lysholm score for their patient population was 85 points, similar to the average of 94 points reported in our study. The authors additionally reported on the method of failure of the primary ACLR and while not giving completely specific definitions to determine their causes of failure, they reported etiologies of failure (65% recurrent trauma, 35% technical). In direct contrast to our study where we found that 63% of primary ACLR failures were due to traumatic recurrent ACL tears after a successful reconstruction.

A study from a paper presented at a national arthroscopy meeting in 1995 has also been cited frequently to support the assumption that technical causes for failure after ACLR are the most common cause of failure.21 It is difficult, however, to draw conclusions as to definitive etiologies of failure based upon these 4 studies because specific numbers on causes of failure other than iatrogenic are not always provided. The study by Johnson et al22 is the only study of this group in which concrete data were given regarding their cohort of patients undergoing ACLR. In this group of 25 patients, 13 (52%) failed ACLR due to technical errors, while biologic failure was cited as the cause in 5 cases (20%) and trauma in 7 cases (28%).

There were several limitations to the current study. We acknowledge that all ACLR failures might not have presented to our institution after a failure, falsely lowering our rate of revisions. Further, some patients who may be classified as a clinical failure may not have elected to undergo revision surgery and therefore would not have been identified during our case log review. However, the 28 patients do provide insight into several key aspects of revision ACLR, such as probable cause of failure.

Another limitation was all patients did not have radiographs to determine the accuracy of tunnel placement. This could lead to a falsely lowered number of patients who failed the initial
reconstruction, and incorporates all excluded patients). Demographic data for the study cohort are provided in Table 1. Of note, in 9 of the 28 patients (32%), the revision procedure was performed within 12 months of the index procedure.

Graft selection for both the index and revision ACLR procedures is outlined in Figure 3. Grafts involved were bone-patellar tendon-bone (BPTB) and hamstring (HS). Overall, autograft was used in 16 of the 28 index cases (57%), while allograft was used in 12 cases (43%). For revision procedures, autograft was used in 4 cases (14%), while allograft was used in 24 cases (86%). In 16 cases (57%), autografts were converted to allografts, while in 4 cases (14%) allografts were converted to autografts. In the remaining 8 cases (29%), autografts were converted to new allografts. All graft choices were determined based on surgeon preference, patient preference, and graft availability (ie, if BPTB autograft was used for the index procedure, this would be unavailable for the revision procedure).

Radiographs of the operative knee between the primary and revision ACLR procedures were taken at the time of follow-up examination, again an average of 30.2 ± 17.7 months following revision ACLR. The results of the follow-up examination and outcome surveys are summarized in Tables 4 and 5. Prerevision KT1000 scores were taken at the time of the most recent clinic visit prior to the revision ACLR procedure. These were performed at an average of 17.4 ± 18.4 months (range, 1.6-80.7 months) after the index procedure, which was an average of 4.9 ± 5.9 months (range, 0.5-22.5 months) prior to the revision procedure. Postrevision KT1000 procedure. Postrevision KT1000 data were taken at the time of follow-up examination, again an average of 30.2 ± 17.7 months following revision ACLR. With regard to the clinical outcomes assessment, 18 of the 28 patients (65%) had good to excellent Lysholm scores. Higher IKDC scores were correlated with younger patients at both primary and revision surgery (P < .001). Greater differences in postrevision KT1000 scores between the operative and nonoperative knees were associated with elevated KOOS pain and symptomatic values (P < .001). Furthermore, a shorter time period between index and revision ACLR was associated with better KOOS pain scores. Those patients who had surgery within 18 months of their primary reconstruction had KOOS pain scores of 96.0 ± 8.4 in patients who had their reconstruction later than 18 months (P = .001).

DISCUSSION

The principal findings of this study indicate that traumatic rupture is the most common cause of graft failure following index ACLR. Historically, the most common reason cited for revision reconstruction has been technical and/or surgeon errors, and biologic failure was cited as the cause in 5 cases (20%) of these 4 studies because specific numbers on causes of failure other than traumatic are not always provided. The study by Johnson et al23 is the only study of this group in which concrete data were given regarding their cohort of patients undergoing ACLR. In this group of 25 patients, 13 (52%) failed ACLR due to technical errors, while biologic failure was cited in the cause in 5 cases (20%) and trauma in 7 cases (28%).

A study from a paper presented at a national arthroscopy meeting in 1995 also has been cited frequently to support the assumption that trauma is a major cause of failure after ACLR.4 In this study, 77% of patients undergoing revision ACLR had procedures that were considered failures due to technical errors such as tunnel malposition, inadequate fixation or inadequate/insufficient graft. Despite this high percentage of technical errors, there was no definition of what constituted tunnel malposition, inadequate fixation, or inadequate/insufficient graft. Their data are in direct contrast to our study where we found that 63% of primary ACLR failures were due to traumatic recurrent ACL tears after a successful reconstruction.

When comparing our follow-up results of revision ACLR to other studies previously published, our results compare similarly. Denti et al29 reported on their experience with revision ACLR in 66 patients. In their series of 66 patients, 46 (70%) had good/excellent Lysholm scores, which compares favorably to 18 of our 28 patients (65%) who had good/excellent Lysholm scores. Similarly, Salmons et al30 reported on their experience with revision ACLR in 50 consecutive patients at an average of 9 years following revision ACLR. The average Lysholm score for their patient population was 85 points, similar to the average of 94 points reported in our study. The authors additionally reported on the method of failure of the primary ACLR and while not giving completely specific definitions to determine their causes of failure, they reported etiologies of failure (65% recurrent trauma, 35% biologic or technical) similar to those in our cohort (71% trauma, 29% biologic or technical errors).

There were several limitations to the current study. We acknowledge that all ACLR failures might not have presented to our institution after a failure, falsely lowering our rate of revisions. Further, some patients who may be classified as a clinical failure may not have been referred to undergo revision surgery and therefore would not have been identified during our case log review. However, the 28 patients do provide insight into several key aspects of revision ACLR, such as probable cause of failure.

Another limitation was all patients did not have radiographs to determine the accuracy of tunnel placement. This could lead to a falsely lowered number of patients who failed the initial

Table 2. Summary of Radiographic Measurement Results (n = 22 patients)

<table>
<thead>
<tr>
<th>MEASUREMENT</th>
<th>MEAN VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACL position, mm</td>
<td>21.9 ± 5.4</td>
</tr>
<tr>
<td>Tibia width, mm</td>
<td>53.1 ± 7.9</td>
</tr>
<tr>
<td>Position of posterior ACL on tibial width, %</td>
<td>38.2 ± 6.1</td>
</tr>
<tr>
<td>Tibial tunnel diameter, lateral, mm</td>
<td>11.4 ± 1.6</td>
</tr>
<tr>
<td>Tibial tunnel diameter: AP, mm</td>
<td>10.8 ± 1.7</td>
</tr>
<tr>
<td>Femoral tunnel diameter: AP, mm</td>
<td>10.1 ± 1.0</td>
</tr>
<tr>
<td>Femoral angle: AP, degrees</td>
<td>161.7 ± 6.4</td>
</tr>
<tr>
<td>Posterior femoral distance, mm</td>
<td>5.0 ± 1.5</td>
</tr>
<tr>
<td>Length of Blumenessaat’s line, mm</td>
<td>33.9 ± 3.3</td>
</tr>
</tbody>
</table>

Table 3. Summary of Failure Results

<table>
<thead>
<tr>
<th>TYPE OF FAILURE</th>
<th>NO. (%) OF PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>28 (100)</td>
</tr>
<tr>
<td>Iatrogenic</td>
<td>7 (25)</td>
</tr>
<tr>
<td>Biologic</td>
<td>1 (4)</td>
</tr>
<tr>
<td>Traumatic</td>
<td>20 (71)</td>
</tr>
</tbody>
</table>

Table 4. Summary of KT1000 Results (measured in millimeters, mm)

<table>
<thead>
<tr>
<th>MEASUREMENT</th>
<th>MEAN VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operative knee KT1000 (MMT)</td>
<td>12.1 ± 1.4</td>
</tr>
<tr>
<td>Nonoperative knee KT1000 (MMT)</td>
<td>6.7 ± 1.3</td>
</tr>
<tr>
<td>Difference between operative and nonoperative knee</td>
<td>5.4 ± 1.1</td>
</tr>
</tbody>
</table>

Abbreviations: ACL, anterior cruciate ligament; AP, anterior/posterior

Abbreviations: MMT, manual maximum test

PREREVISION (n = 22) | POSTREVISION (n = 20) | SIGNIFICANCE
-----------------------|-----------------------|---------------------
12.1 ± 1.4             | 6.8 ± 2.8             | P < .001            |
6.7 ± 1.3              | 5.9 ± 2.8             | P > .05             |
ACLR, a lower failure rate can be expected with the majority of anatomic placement of both femoral and tibial tunnels with known transtibial ACLR with a variety of grafts, paying attention to

or iatrogenic. During the study period we performed arthroscopic retrospective review of patients who presented with a failed primary had their primary ACLR at the same institution. This allows a look at our failures and outcomes.

to limit our inclusion criteria to only those patients who had the outcome could not be averaged out among many results. We chose outcome-based surveys in a negative direction since a single bad reconstructive attempt secondary to technical error. Furthermore,

Abbreviations: SF-12, SF-12 Health Survey; IKDC, International Knee Documentation Committee Subjective Form; KOOS, Knee Injury and Osteoarthritis Outcome Score; WOMAC, Western Ontario and McMaster University Osteoarthritis Index.

reconstructive attempt secondary to technical error. Furthermore, the limited number of patients in our study could possibly bias the outcome-based surveys in a negative direction since a single bad outcome could not be averaged out among many results. We chose to limit our inclusion criteria to only those patients who had the primary and revision reconstruction at our institution to critically look at our failures and outcomes.

There were several advantages to the current study. This study is unique in that specific radiographic, clinical, and intraoperative criteria were used to define the cause of failure in a group of patients undergoing revision ACLR in patients who had their primary ACLR at the same institution. This allows a retrospective review of patients who presented with a failed primary reconstruction to categorize their failure as biologic, traumatic, or iatrogenic. During the study period we performed arthroscopic traumatic ACLR with a variety of grafts, paying attention to anatomic placement of both femoral and tibial tunnels with known fixation techniques. With strict attention to good principles of ACLR, a lower failure rate can be expected with the majority of the failures resulting from traumatic reinjuries.

Table 5. Summary of Clinical Outcomes at Time of Follow-Up (n = 20 patients)

<table>
<thead>
<tr>
<th>MEASUREMENT</th>
<th>MEAN VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF-12</td>
<td></td>
</tr>
<tr>
<td>Physical</td>
<td>45.1 ± 5.6</td>
</tr>
<tr>
<td>Mental</td>
<td>56.2 ± 5.6</td>
</tr>
<tr>
<td>Lysholm</td>
<td>84.0 ± 15.5</td>
</tr>
<tr>
<td>IKDC</td>
<td>77.4 ± 14.2</td>
</tr>
<tr>
<td>KOOS</td>
<td></td>
</tr>
<tr>
<td>Symptoms</td>
<td>82.9 ± 15.3</td>
</tr>
<tr>
<td>Pain</td>
<td>88.0 ± 11.4</td>
</tr>
<tr>
<td>Activities of daily living</td>
<td>95.9 ± 7.3</td>
</tr>
<tr>
<td>Sport</td>
<td>41.1 ± 12.5</td>
</tr>
<tr>
<td>Quality of life</td>
<td>89.5 ± 10.4</td>
</tr>
<tr>
<td>Cincinnati Satisfaction Rating</td>
<td>8.4 ± 1.6</td>
</tr>
<tr>
<td>WOMAC</td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>1.3 ± 2.1</td>
</tr>
<tr>
<td>Stiffness</td>
<td>1.5 ± 1.5</td>
</tr>
<tr>
<td>Function</td>
<td>2.3 ± 4.3</td>
</tr>
<tr>
<td>Total</td>
<td>5.1 ± 7.4</td>
</tr>
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</table>

The authors wish to acknowledge that the data presented in this article were published in the Journal of Knee Surgery.

The preceding article does not discuss the use of medical devices or drugs that are regulated by the FDA. No funds were received in support of the work described in this article. All authors are associated with the Division of Sports Medicine at Rush University and Midwest Orthopaedics at Rush, which receives financial support for research and education from: Arthrex, Conmed, LimaUSA, Smith & Nephew Endoscopy, Mitek, Ortho, Aesculapius, Physical Therapy, and Schick and Soto Bruza and Orthotics. Authors Frank, Salazar, McGill, and Boush-Joseph have no financial interests to disclose. Dr. Cole receives medical device royalties from Arthrex and DSIOrtho; is a paid consultant to Zimmer, Arthrex, and Depuy; and receives research support from Johnson and Johnson. Dr. Engh receives medical device royalties from Orthopedics, and Arthritis Surface. Dr. Bach receives book royalties from Slack Publishers. Dr. Verma is a paid consultant to Arthrex and Smith & Nephew; holds stock in Omera; and receives medical device royalties from Smith & Nephew.

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Overall, this study provides a solid foundation for continued basic science research.”

Glenohumeral cartilage defects in the young patient are challenging clinical problems given the longer life expectancy after surgery of these patients and the greater demands their more vigorous lifestyles place on their shoulders. Numerous etiologies can lead to glenohumeral cartilage disease: trauma, instability, inflammatory arthritis, postinfectious degeneration, foreign body reaction, and glenohumeral chondrolysis.

The initial treatment of glenohumeral cartilage disease is always nonsurgical, but when measures are needed beyond conservative management, there are a variety of treatment options available, including palliative, reparative, restorative, and reconstructive techniques for cartilage defects in the shoulder.

This study is one of a series from this institution that analyzes the natural history of glenohumeral surgical analysis. At 8 weeks post-op, we dissected and analyzed the glenohumeral joints of the rabbits. On inspection of the rabbits’ glenohumeral joints, we found that they anatomically resembled the human shoulder joint with similar osseous and soft-tissue anatomy. Using a new micro-computed tomography (micro-CT) protocol, we also evaluated fill of the glenohumeral defect for each rabbit and every shoulder.

Based on the assumption that the glenoid cartilage would be approximately 100-500 μm in thickness, we set the micro-CT scanner to 20 μm resolution in all three spatial planes. These scans were carried out at 45 kV, 177 μA, and 520 ms integration time. The average scan consisted of approximately 412 slices. We used analysis of variance (ANOVA) results and Tukey post-hoc testing to determine significant differences between the normalized values.

RESULTS

The results for total cartilage volume and average cartilage thickness in both native and operative shoulders are displayed in Figures 3 and 4. There were no significant differences in the statistical results between all groups; however, there was a trend toward increased defect fill and thickness in the microfracture and AMIC groups (Groups 2 and 3, respectively). The topographical surface maps for the surgical control and AMIC procedures are shown in Figure 5 as an illustrative example of the subjective improvement in the AMIC fill patterns. There were also no significant trends in the attenuation values of the defect fill.

Post-hoc power analysis showed each group would need to have 10 specimens in order to find statistical differences.
Treatment of Cartilage Defects in Young Shoulders: From the Lab to the Clinic

“Overall, this study provides a solid foundation for continued basic science research.”

GEOFFREY S. VAN THIEL, MD, MBA / ANDREW RIFF, MD / WENDELL HEARD, MD / VASILI KARAS, BS / VINCENT M. WANG, MD / JAS CHAHAL, MD / ANTHONY A. ROMEO, MD / NIKHIL N. VERMA, MD / BRIAN J. COLE, MD, MBA

AUTHOR AFFILIATIONS
Department of Orthopedic Surgery (Drs Van Thiel, Riff, Heard, Wang, Romeo, Verma, and Cole), Division of Sports Medicine, Department of Orthopedic Surgery (Drs Heard and Chahal), Rush University Medical Center; Midwest Orthopaedics at Rush (Drs Romeo, Verma, and Cole); and Rush University (Mr Karas), Chicago, Illinois.

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Brian J. Cole, MD, MBA; Rush University Medical Center and Midwest Orthopaedics at Rush, 1611 W Harrison St, Suite 300, Chicago, IL 60612 (bcole@rushortho.com).

Glenohumeral cartilage defects in the young patient are challenging clinical problems given the longer life expectancy after surgery of these patients, and the greater demands their more vigorous lifestyles place on their shoulders. Numerous etiologies can lead to glenohumeral cartilage disease: trauma, instability, inflammatory arthropathies, postinfectious degeneration, foreign body reaction, and glenohumeral chondrolysis.

The initial treatment of glenohumeral cartilage disease is always nonsurgical, but when measures are needed beyond conservative management, there are a variety of treatment options available, including palliative, reparative, restorative, and reconstructive techniques for cartilage defects in the shoulder.

This study is one of a series from this institution that analyzes new bioconstructs and collagen matrices to augment cartilage in shoulder surgery. In this study, we evaluate whether autologous matrix-induced chondrogenesis (AMIC), which involves using a collagen I/III matrix with microfracture, can promote the formation of tissue with similar architecture to native cartilage by organizing adhesion, migration, and differentiation of mesenchymal stem cells to chondrocytes. In order to understand the potential applications of this basic science research, we have employed a framework of clinical needs, which includes palliative, reparative, restorative, and reconstructive treatments, to guide a clinical management algorithm. Thus, we report on a novel treatment method and discuss the background framework into which it and other pieces of basic science research fit.

METHODS
We hypothesized that a collagen I/III matrix superimposed on a chondral defect that has been concomitantly treated with microfracture will provide a superior medium on which functional cartilage will form and heal. To test this hypothesis, we divided 12 rabbits into 3 groups. Each group underwent the same surgical approach to the rabbit glenohumeral joint, including incision and repair of the superior rotator cuff. Group 1, the surgical control, consisted of rabbits that underwent removal of the cartilage layer on the glenohumeral joint only. Group 2 rabbits underwent microfracture to the glenohumeral defect only. Group 3 underwent the autologous matrix-induced chondrogenesis (AMIC) procedure: microfracture of the glenohumeral defect followed by the application of a collagen I/III matrix (Figure 1). Each rabbit had 1 operative shoulder and 1 control nonoperative shoulder. All operations were completed with the same exposure and closure.

The rabbits were then allowed to ambulate as tolerated. All operations were carried out from 45 kV, 177 μA, and 300 ms integration time. Post-hoc power analysis showed each group would need to have 10 specimens in order to find statistical differences.

RESULTS
The results for total cartilage volume and average cartilage thickness in both native and operative shoulders are displayed in Figures 3 and 4. There were no significant differences in the statistical results between all groups; however, there was a trend toward increased defect fill and thickness in the microfracture and AMIC groups (Groups 2 and 3, respectively). The topographical surface maps for the surgical control and AMIC procedures are shown in Figure 5 as an illustrative example of the subjective improvement in the AMIC fill patterns. There were also no significant trends in the attenuation values of the defect fill.

FIGURE 3: Total cartilage volume of the glenohumeral defect in the rabbit joint.

FIGURE 4: Average cartilage thickness in the glenohumeral defect of the rabbit joint.

Abbreviations: Native, no surgery; Surg Cont, surgical control; MicroFx, microfracture; AMIC, autologous matrix-induced chondrogenesis

operations were tolerable from a physiologic standpoint and reconfirming the fact that a rabbit shoulder is a good model for glenohumeral surgical analysis. At 8 weeks post-op, we dissected and analyzed the glenohumeral joints of the rabbits. On inspection of the rabbits’ glenohumeral joints, we found that they anatomically resembled the human shoulder joint with similar osseous and soft-tissue anatomy. Using a new micro-computed tomography (micro-CT) protocol, we also evaluated fill of the glenohumeral defect for each rabbit and every shoulder.

Based on the assumption that the glenoid cartilage would be approximately 100-500 μm in thickness, we set the micro-CT scanner to 20 μm resolution in all three spatial planes. These scans were carried out at 45 kV, 177 μA, and 300 ms integration time. The average scan consisted of approximately 412 slices. We used analysis of variance (ANOVA) results and Tukey post-hoc testing to determine significant differences between the normalized values.
management algorithm. In the shoulder joint to provide a framework to guide a clinical corollaries. In order to understand the potential applications of this model to study glenohumeral cartilage defects (Figure 6). Overall, this study provides a solid foundation for continued basic science research.

However, basic science research in isolation cannot address the issue of glenohumeral cartilage defects without clinical corollaries. In order to understand the potential applications of this basic science research, we reviewed the aforementioned areas of palliative, reparative, restorative, and reconstructive techniques in the shoulder joint to provide a framework to guide a clinical management algorithm.

DISCUSSION

The current study evaluates whether a collagen III matrix with microstructure can promote the formation of tissue with similar architecture to native cartilage by organizing adhesion, migration, and differentiation of mesenchymal stem cells to chondrocytes. The data suggest that both microstructure and autologous matrix-induced chondrogenesis (AMIC) have the ability to fill a glenohumeral cartilage defect in a rabbit model significantly more than the surgical control, based on micro-CF data. Although the current study does not reveal significant differences, there are some very important conclusions that can be drawn. One, further research is needed to characterize the trends seen in this study. We currently have a much larger trial underway that will use histology and MRI to corroborate the results reported here. Two, the rabbit glenohumeral model is a very good in vivo model to study glenohumeral cartilage defects (Figure 6). Overall, this study provides a solid foundation for continued basic science research.

Palliative techniques for the management of glenohumeral cartilage defects without clinical corollaries. In order to understand the potential applications of this basic science research, we reviewed the aforementioned areas of palliative, reparative, restorative, and reconstructive techniques in the shoulder joint to provide a framework to guide a clinical management algorithm.

PALLIATIVE TREATMENTS

Palliative techniques include tissue replacement procedures. Arthroscopic debridement has been shown to have an improvement in functionality in approximately 80% of cases. However, it is important to note that arthroscopic debridement is not a cure for chondral defects and may not be the optimal treatment for all patients. Arthroscopic debridement is best reserved for patients with small to moderate-sized lesions.

REPARATIVE TREATMENTS

Reparative treatments include microfracture, which involves the creation of small perforations in the articular cartilage to stimulate the formation of hyaline cartilage. Other reparative techniques include osteochondral autograft and autologous chondrocyte implantation (ACI). These procedures are generally reserved for patients with large to massive cartilage defects.

RESTORATIVE TREATMENTS

Restorative treatments include osteochondral autograft transfer (OAT) and osteochondral allograft transplantation (OAT). OAT involves the transfer of a segment of articular cartilage and subchondral bone from a donor site to a recipient site. OAT is generally reserved for patients with large to massive cartilage defects and is associated with a higher complication rate compared to microfracture.

The role of autologous chondrocyte implantation (ACI) in the treatment of glenohumeral cartilage defects is evolving. ACI involves the isolation of chondrocytes from the patient’s synovial fluid or biopsy, expansion of the chondrocytes in vitro, and reimplantation into the defect site. Early results have shown promising outcomes, but larger studies are needed to determine the long-term effectiveness of ACI.

Several studies have evaluated the use of osteochondral allografts in the shoulder joint. Allografts are typically used in patients who have failed conservative, palliative, and reparative treatment options. The use of osteochondral allografts requires a multi-center approach, which can increase the cost and time required for treatment. Additionally, there is a risk of disease transmission with the use of allografts.

In conclusion, the management of glenohumeral cartilage defects is a complex process that requires a comprehensive understanding of the disease process and a multidisciplinary approach to treatment. Further research is needed to improve our understanding of the biological mechanisms involved in cartilage repair and to develop more effective treatment options for patients with these injuries.
DISCUSSION

The current study evaluates whether a collagen I/III matrix with microfracture can promote the formation of tissue with similar architecture to native cartilage by organizing adhesion, migration, and differentiation of mesenchymal stem cells to chondrocytes. The data suggest that both microfracture and autologous matrix-induced chondrogenesis (AMIC) have the ability to fill a glenohumeral cartilage defect in a rabbit model significantly more than the surgical control, based on micro-CT data. Although the current study does not reveal significant differences, there are some very important conclusions that can be drawn. One, further research is needed to characterize the trends seen in this study. We currently have a much larger trial underway that will use histology and MRI to corroborate the results reported here. Two, the rabbit glenohumeral model is a very good in vivo model to study glenohumeral cartilage defects (Figure 6). Overall, this study provides a solid foundation for continued basic science research.

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PALLIATIVE TREATMENTS

Palliative techniques for the management of glenohumeral cartilage disease are designed to alleviate symptoms without replacing or restoring the injured articular cartilage. These techniques consist primarily of arthroscopic debridement, capsular release, ligamentous and loose body removal. Arthroscopic debridement is appealing because it is technically straightforward, has low surgical morbidity, and does not preclude other, more advanced, restorative and reconstructive interventions in the future. In a few published series, arthroscopic debridement has led to good or excellent results in roughly 80% of patients at short follow-up intervals.6,7 Cameron et al6 reported on a series of patients with grade IV osteochondral defects and found that 88% experienced significant improvement in pain and function for an average duration of 28 months. Weinstein et al also reported 80% good or excellent results at a mean follow-up of 34 months. The largest series in the literature was reported by Van Thiel, Romeo, Verma, Cole et al. The authors retrospectively reviewed 81 patients who underwent arthroscopic debridement for glenohumeral osteoarthritis. Of the 81 patients, 71 were available for follow-up at an average of 27 months, and 58 of the 81 (72%) were satisfied with the results of the surgery and would have it again. They also experienced a statistically significant improvement in postoperative functional outcome scores and a decreased level of pain. Of the 71 patients, 16 (23%) experienced surgical failures and required arthroplasty at a mean of 10.1 months after debridement. Grade IV bipolar disease, joint space less than 2 mm, and the presence of large osteophytes constituted the most significant risk factors for failure. Overall, arthroscopic debridement is a very reasonable and predictable first-line surgical option that offers relief of pain and improvement in functionality in approximately 80% of cases.

REPARATIVE TREATMENTS

Reparative treatment includes narrow stimulation techniques like chondroplasty, subchondral drilling, and microfracture to replace the damaged cartilage with fibrocartilage (Figure 7). However, despite its reported effectiveness in the knee joint, we are aware of only three series that report clinical outcomes following microfracture in the shoulder joint.8-10 Suhfeld et al8 and Miller et al8 reported on small series of patients that underwent microfracture for full-thickness chondral defects. At final follow-up there was a significant improvement in functional scores with an approximately 20% rate of revision procedures.

Our experience has been similar. Frank, Van Thiel, and Cole et al10 reported minimum 12 months (mean, 28 months) follow-up on 16 patients (17 shoulders) who underwent arthroscopic microfracture of the humeral head or glenoid surface. The 14 patients that were available for follow-up had statistically significant improvements in pain and function. Of the 16 patients, 3 (20%) had subsequent shoulder surgery and therefore, their initial surgeries were considered to be failures. Additional research is needed before definitive statements can be made, but microfracture does appear to be a viable treatment option for select patient populations.

RESTORATIVE TREATMENTS

Restorative treatments aim to reestablish hyaline or hyaline-like cartilage by transferring hyaline cartilage via osteochondral grafting (autograft or allograft) or by growing hyaline-like cartilage using autologous chondrocyte implantation (ACI). At present, osteochondral autograft and ACI require a shoulder arthroscopy and a second surgical procedure at the knee for graft harvest. Consequently, both procedures are more invasive and more technically demanding, and they expose the patient to significantly greater surgical morbidity than arthroscopic palliative or reparative techniques. Therefore, restorative modalities are best reserved for the young, active individual with a distinct chondral lesion of the humera or glenoid who has already failed conservative, palliative, and reparative treatment. Habermeyer et al11 have published good results for 7 patients who received osteochondral autograft transfer from the knee to the shoulder with almost 9-year follow-up. The authors based their results on both functional as well as MRI criteria. Osteochondral allograft transfer employs a similar technique, matching a donor plug to a recipient site, but without the concern for donor-site morbidity. Therefore, allograft transfer can be used to treat more stable lesions than can be treated effectively by autograft transfer.
Given this versatility of osteochondral allografts, a number of case reports describe the use of side- and size-matched osteochondral allografts for large Hill-Sachs lesions at the site of recurrent instability.15,16 Cole and McCarty7 took the allograft transfer one step further and completed an osteochondral humeral head resurfacing in combination with a lateral meniscal allograft resurfacing (Figure 8). In this case report, a 16-year-old girl with symptomatic bipolar glenohumeral chondrolysis after arthroscopic thermal capsulorrhaphy was treated with the meniscal and osteochondral allografts. At 2-year follow-up, the patient reported complete resolution of her shoulder pain, and radiographs showed maintained glenohumeral joint space.

Romeo et al17 published a 2-case report on the use of ACL in a 16-year-old baseball player with a humeral head lesion (Figure 9). Restoration was performed with a 2-stage harvest (knee) and implantation (shoulder) technique with a peristaltic graft from the tibia. At 1 year, the patient had full range of motion without any pain. These case reports offer hope to young patients with end-stage disease of the glenohumeral joint, but further research is needed to determine the long-term outcome in a larger patient population.

**CONCLUSION**

No consensus exists in the literature regarding the most appropriate treatment for glenohumeral chondral lesions in the young patient. The purpose of this manuscript was to report the initial results of a novel technique to manage cartilage deficits in the rabbit glenohumeral joint and (2) to synthesize clinical data regarding the management of glenohumeral lesions in young patients. We hypothesize, and our data suggest but have not yet proven, that a collagen IV matrix superimposed on a chondral defect that has been concomitantly treated with microstructure will provide a superior medium on which functional cartilage will form and heal. Future research will continue to yield new treatment modalities with the goals of increasing function and improving outcomes.

**REFERENCES**


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CONCLUSION

No consensus exists in the literature regarding the most appropriate treatment for glenohumeral chondral lesions in the young patient. The purpose of this study was to report the initial results of a novel technique to manage cartilage defects in the rabbit glenohumeral joint (2) and to synthesize clinical data regarding the management of glenohumeral lesions in young patients. We hypothesized, and our data suggest but have not yet proven, that a collagen I/III matrix superimposed on a chondral defect that has been concomitantly treated with microfracture will provide a superior medium on which functional cartilage will form and heal. Future research will continue to yield new treatment modalities with the goals of increasing function and improving outcomes.

REFERENCES

12. Cameron BD, Galatz LM, Ramsey ML, Williams GR, Iannotti JP. Non-prosthetic management of end stage disease of the glenohumeral joint, but further research is needed to determine the long term outcome in a larger patient population.

RECONSTRUCTIVE TREATMENTS

Reconstructive techniques can use a combination of prosthetic and biologic components to repair the humeral head and glenoid and include soft-tissue interposition with autograft, allograft, Achilles tendon, alloplastic or synthetic material (GraftJet), Wright Medical Technology, Inc., Arlington, Tennessee), and lateral meniscal allografts. Experience with these techniques is generally limited to a few institutions and literature reporting long-term outcomes is sparse.

Burkhead and Hutton proposed biological resurfacing of the glenoid as a means of improving the outcome of hemiarthroplasty in young patients.11 Their good results were supported by Huisinga et al,12 who used a similar technique involving the GraftJet. Yomoguchi et al13 also proposed a lateral meniscal allograft (LMA) as the interposition material (Figure 10). The lateral meniscus is an attractive option given its favorable shape, load-bearing characteristics, and a low morbidity compared with other interposition materials.

Our research on LMA published in 201213 has questioned these good results. In this study, 45 consecutive patients were treated with hemiarthroplasty in conjunction with meniscal resurfacing with either LMA or GraftJet. Short-term follow-up data (minimum 18 months) of 30 patients who underwent LMA resurfacing demonstrated promising; of those 30 patients, 28 (93%) were satisfied with their clinical outcome. However, at mean follow-up of 2.8 years, 21 of 41 patients (31 LMA, 10 GraftJet) had experienced a clinical failure. Clinical failure was defined as conversion to total shoulder arthroplasty (TSA) (9 cases), recommended conversion (5 cases), the American Shoulder and Elbow Surgeons (ASES) score of ≤5 (5 cases), disabling pain of function (2 cases), or graft removal (1 case). These results illustrate the need for both appropriate patient selection and continued research.

Outcomes in the Treatment of Benign Bone Lesions with Bioceramic

“Functional results were excellent, complications were infrequent, and composite bioceramic seems to be a reasonable alternative to autogenous bone graft [for treatment of benign bone lesions].”

YALE A. FILLINGHAM, MD / BRETT A. LENART, MD / STEVEN GITELIS, MD

AUTHOR AFFILIATIONS

Department of Orthopedic Surgery, Rush University Medical Center, Chicago, Illinois (Dr Lenart and Gitelis); Midwest Orthopaedics at Rush, Chicago, Illinois (Dr Gitelis); and Rush University Medical Center, Chicago, Illinois (Dr Fillingham).

CORRESPONDING AUTHOR

Steven Gitelis, MD, Rush University Medical Center and Midwest Orthopaedics at Rush, 1611 W Harrison St, Suite 300, Chicago, IL 60612 (stein@rush.edu).

embone tumor and cysts are relatively common entities encountered in a general orthopedic and orthopaedic oncology practice. This broad category encompasses lesions with widely varying clinical behaviors and natural histories. Treatment, therefore, must be individualized based on factors such as the specific tissue diagnosis, size of the lesion, location, associated symptoms, risk of pathologic fracture, and individual patient characteristics.

MATERIALS

Traditionally, autogenous bone graft has been the “gold standard” for all grafting procedures.14 Limited supply and significant donor site morbidity, however, make this option much less desirable.15 Bone graft substitutes composed of calcium hydroxyapatite (CaHAp) or calcium phosphate (CaP, CaHAP) are attractive alternatives because they are both bioabsorbable and osteoconductive. Furthermore, they do not contain potent cytokines, which may be contraindicated in the oncology setting. Unfortunately, few data exist in the literature regarding the use of bone graft substitutes in orthopedic oncology.16 Most of the reported series using surgical grade CaHAp, CaP, or CaHAP17,18 graft materials to treat patients with benign bone tumors feature relatively small numbers of patients and short-duration follow-up, ranging from 6 to 72 months. Results have been generally acceptable in terms of function and recurrence rates. However, relatively common complications still exist: the most common problem reported is serious drainage.15,16 Radiological appearance and demonstration of union with bone are inconsistent at best. In 2008 Wright Medical Technology ( Arlington, Texas) released Pro-Dense, an injectable CaHAp (CaHAp) composite, or bioceramic, material with high compressive strength and an intermediate degradation profile. A preclinical canine study showed this material to be superior to CaHAp with regard to the quantity and quality of bone formed in a contained humeral defect.19

The bioceramic is a composite graft that incorporates a matrix of CaHAp and dicalcium phosphate dihydrate (DCPD) into which β-tricalcium phosphate (β-TCP) or (CaHAp) granules are distributed.20 The graft is prepared intraoperatively by mixing the powdered graft materials with an aqueous diluent (Figure 1A). The resulting composite is injectable for approximately 5 minutes (Figure 1B) and sets up over a period of 20-30 minutes. The resorption profile is triphasic. The CaHAp resists first through simple dissolution, leaving behind an open-pore structure that allows for vascular infiltration and new bone deposition on the remaining CaHAp scaffold. DCPD has an intermediate profile,20 resorbing by both osteoclastic resorption and simple dissolution. Finally, β-TCP offers osteoclastic resorption and thus exhibits the longest profile. While a preclinical study was extremely promising in the ability to promote bone regeneration,

Disclosures for the preceding article are listed on p. 46.
PATIENTS AND METHODS

Prior to beginning the study, we secured approval by the institutional review board. We performed a retrospective review of 56 consecutive patients with benign bone tumors and cysts who underwent open curettage and debridement during the process of bone grafting. Between 2006 and 2008, one surgeon (S.S.G.), working at a single institution, used a bone-graft substitute, ProPore, in 30 patients with benign bone tumors. There were 29 male patients and 27 female patients. The average age was 17.6 years (range, 4-63 years). The various benign bone tumor diagnoses represented in the study are listed in Table 1. The most common tumor or cyst locations are cited in Table 2.

The surgeon treated all lesions with either a percutaneous technique or open curettage. He used a percutaneous 2-needle technique for diagnosis and treatment of unicameral bone cysts, biopsied the lesion, and diagnosed by frozen section. The surgeon debrided the unicameral bone cysts through 2 4-mm cannulas and then copiously lavaged the area, after which he injected the bioceramic via 1 cannula, while using the other as a vent. Next he used intraoperative fluoroscopy to confirm that the entire cavity was filled via antero-posterior (AP) and lateral imaging. For open curettage, the surgeon made a longitudinal incision and used a power burr to create a cortical window. Once again, a biopsy was taken and sent for pathologic analysis via frozen sectioning. Using curettes and curved Adson elevators, he removed lesional tissue and used a power burr again to enlarge the tumor cavity. He irrigated the tumor cavity with saline, dried it, and filled with the bioceramic.

Of the 56 patients in the initial review, we could not reach 10 of them, leaving 46 patients. The average follow-up was 41.9 months (range, 26-57 months).

The average MSTS functional evaluation score was 28.6 (range, 20-30). The average score for patients with lower-limb lesions was 29.1. The average for patients with upper-limb lesions was slightly lower, at 27.8. The lowest score was 20, in a 32-year-old male with fibrous dysplasia of the humerus at 31 months follow-up. Of the 46 patients, 23 patients reported a perfect score of 30; 8 of these patients were male (see Figure 1). Full resorption of the ceramic material with complete bone repair is demonstrated.

Figure 1. A, The graft is prepared intraoperatively by mixing the powdered graft materials with an aqueous diluent. B, The graft is injectable for approximately 5 minutes and sets up over a period of 20–30 minutes.

Table 1. Benign Bone Tumor Diagnoses

<table>
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<tr>
<th>DIAGNOSIS</th>
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<tr>
<td>Aneurysmal Bone Cyst</td>
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<tr>
<td>Nonossifying Fibroma</td>
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<tr>
<td>Fibrous Dysplasia</td>
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<tr>
<td>Enchondroma</td>
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<tr>
<td>Chondroblastoma</td>
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</tr>
<tr>
<td>Other</td>
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</tr>
<tr>
<td>TOTAL</td>
<td>56</td>
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</table>

Table 2. Tumor or Cyst Locations

<table>
<thead>
<tr>
<th>LOCATION</th>
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<tbody>
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<td>Humerus</td>
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<tr>
<td>Femur</td>
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</tr>
<tr>
<td>Tibia</td>
<td>10</td>
</tr>
<tr>
<td>Fibula</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>17</td>
</tr>
<tr>
<td>TOTAL</td>
<td>56</td>
</tr>
</tbody>
</table>

Table 2. Tumor or Cyst Locations

There were 29 male patients and 27 female patients. The average age was 17.6 years (range, 4-63 years). The various benign bone tumor diagnoses represented in the study are listed in Table 1. The most common tumor or cyst locations are cited in Table 2.

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Figure 2. A, Histology of the bone repair using the composite (bioceramic) graft at 13 weeks in the animal model. B, Histology of the bone repair using the autogenous bone graft at 13 weeks in the animal model. C, Normal cancellous bone histology in this animal model.

Figure 3. Computed tomogram 19 months after percutaneous injection of the bioceramic graft material in the proximal humerus unicameral bone cyst of a 12-year-old male (see Figure 1). Full resorption of the ceramic material with complete bone repair is demonstrated.

After discharge from the hospital, the patient was followed up in the clinic at intervals of 1 week and 1, 6, 12, and 18 months. The surgeon altered the follow-up intervals as needed due to variable healing rates and encountered complications. Each routine follow-up visit in the clinic included assessment of strength, range of motion, functional status, and radiographic investigation to evaluate for potential fractures and the rate of absorption of the bone-graft substitute (Figures 4 and 5).

The MSTS functional evaluation system was employed to measure the clinical outcomes. This survey consists of a list of qualitative responses for multiple categories associated with a graded, numerical score for both upper and lower limbs. For lower limbs, the survey questions evaluate emotional acceptance, supports (e.g., brace, prosthesis, cane or crutches), walking ability, and gait. For upper limbs, the survey questions evaluate function, emotional acceptance, hand positioning, dexterity, and lifting ability. Patients rated each category from 0 to 5. A score of 5 for each section represented the best possible outcome, with a total maximum score of 30.

RESULTS

Of the 56 patients in the initial review, we could not reach 10 of them, leaving 46 patients. The average follow-up was 41.9 months (range, 26-57 months).

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Of the 46 patients, 3 (6.5%) suffered local recurrences. A 14-year-old boy with a chondroblastoma of the proximal femur...
of the graft (Figures 2 and 3), the current study is the first to evaluate this novel biomaterial in a clinical setting and specifically should determine (1) the Musculoskeletal Tumor Society (MSTS) functional scores and (2) the rates of complications and (3) the rates of recurrences.

**PATIENTS AND METHODS**

Prior to beginning the study, we secured approval by the institutional review board. We performed a retrospective review of 56 consecutive patients with benign bone tumors and cysts who underwent open curettage and debridement during the process of bone grafting. Between 2006 and 2008, one surgeon (S.S.G.), working at a single institution, used a bone-graft substitute, ProPorous B, the graft is injectable for approximately 5 minutes and sets up over a period of 20-30 minutes.

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Figure 4. A, Radiograph of a unicameral bone cyst in a 12-year-old male. B, 3-month postoperative radiograph after percutaneous injection of the bioceramic graft material. C, 2-month postoperative radiograph demonstrating resorption of the bioceramic and formation of bone.

Figure 5. A, Postoperative radiograph after open curettage and grafting of a distal tibial aneurysmal bone cyst in a 13-year-old female. B, 1-year postoperative radiograph demonstrating resorption of the bioceramic and formation of bone.

Developed a local recurrence 1 year postoperatively. He was treated with repeat curettage and grafting and was doing well at his most recent postoperative visit. A 43-year-old female with a giant cell tumor of the proximal humerus had a local recurrence of tumor at 6 months after the initial procedure. She later underwent repeat open curettage with bone autograft. The patient was also doing well at her last postoperative visit. The last recurrence was a 9-year-old boy with a proximal humerus unicameral bone cyst who developed a recurrence that was found 1.5 years after his initial procedure. He later underwent repeat percutaneous treatment. He returned to full activity and now participates in hockey.

Of the 46 patients, 2 (4.3%) had postoperative fractures. A 17-year-old boy who underwent curettage of a distal femur osteoid osteoma. He later developed a superficial wound infection that was successfully treated with a 1-week course of oral antibiotics. Resolution was seen 1 month postoperatively. The other was a 32-year-old male with fibrous dysplasia of the proximal humerus. He developed a wound infection 1 month postoperatively, requiring an incision and drainage. He was also treated with a 1-week course of intravenous and oral antibiotics. He went on to a full recovery without complication.

Although the study was not intended to investigate the rate of recurrence of unicameral bone cysts when treated with bioceramic as compared to alternative modes of treatment, a lower recurrence rate following percutaneous treatment with the novel bioceramic was observed as compared to that in the literature. In our case report, only 1 of the 13 (7.7%) unicameral bone cysts treated percutaneously required a second injection of the bioceramic.15,20

DISCUSSION

We performed this retrospective case series to evaluate the initial clinical results using a novel bioceramic injectable graft in 56 consecutive patients with diagnoses of benign bone tumors and cysts who treated at a single orthopedic oncology center. Functional results were excellent, as evidenced by an average MSTS functional evaluation score of 28.6. Complications were infrequent and in most cases were likely not attributable to the graft material itself. Three patients experienced local recurrence. Two patients sustained postoperative fractures, all of which healed with nonoperative treatment. Two patients experienced wound complications, none of which required removal of the graft material. There were no other complications.

Functional results in this series were excellent. This study is comparable to other reported series of CaSO4 and Ca3(PO4)2 bone-graft substitutes reported in the literature.12,13,14,16-19 We hypothesize that the rapid dissolution profile of pure CaSO4 contributes to these complications. Thus, as expected, a composite graft with an intermediate profile appears to lessen the severities of tissue reaction and wound drainage. Furthermore, although it was not specifically quantified in this study, the composite graft material appears to exhibit the expected intermediate resorption profile and is gradually replaced by host bone (Figures 2 and 3). This is in contrast to patients treated with pure Ca3(PO4)2, bone-graft substitutes in whom residual graft material can be seen for years postoperatively and possibly permanently.1,20

The success of the novel bioceramic for the percutaneous treatment of unicameral bone cysts was a surprising finding. Whereas recurrence rates for other benign bone lesions are most likely related solely to the thoroughness of the initial curettage, recurrence rates after percutaneous treatment of unicameral bone cysts is possibly attributable to the injected material itself. With...
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Although the study was not intended to investigate the rate of recurrence of unicameral bone cysts when treated with bioceramic as compared to alternative modes of treatment, a lower recurrence rate was observed as compared to that in the literature. In our case report, only 1 of the 13 (7.7%) unicameral bone cysts treated percutaneously required a second injection of the bioceramic.\(^\text{20,26}\)

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Functional results in this series were excellent. This study is comparable to other reported series of CaSO\(_4\) and Ca\(_3\)(PO\(_4\))\(_2\) bone-graft substitutes reported in the literature.\(^\text{1,12,13,14,15,16,27}\) Complications, specifically tissue reaction and serous wound drainage, appear to be decreased in this series as compared to other series of patients treated with CaSO\(_4\).\(^\text{1,13,14}\) We hypothesize that the rapid dissolution profile of pure CaSO\(_4\) contributes to these complications. Thus, as expected, a composite graft with an intermediate profile appear to lessen the severity of tissue reaction and wound drainage. Furthermore, although it was not specifically quantitated in this study, the composite graft material appears to exhibit the expected intermediate resorption profile and is gradually replaced by host bone (Figures 2 and 3). This is in contrast to patients treated with pure Ca\(_3\)(PO\(_4\))\(_2\), bone-graft substitutes in whom residual graft material can be seen for years postoperatively and possibly permanently.\(^\text{12,13}\)

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regard to recurrence rates, the novel bioceramic appears to perform exceptionally well. Authors have reported multiple pharmacomechanical methods of treating unicameral bone cysts, the most common of which include injections with steroids,19-21,26,28 autogenous bone-graft harvesting from the posterior iliac crest,2,3 radiofrequency ablation,4,10-12 external fixators,13-15 and combinations of these.20,21,23 While most patients can be treated successfully by pharmacomechanical, recurrence rates after the initial injections in these series range from 11% to 17%. In the current series, however, only 1 of the 17 (5.7%) unicameral bone cysts treated prospectively has required a second injection. The remainder appeared to have healed with a single injection.

We acknowledge several limitations to our study. First, this is a relatively small study with short-term follow-up at an average of 3.5 years. Long-term follow-up is required to more adequately evaluate graft incorporation and bone remodeling. Second, this patient population consisted of patients with multiple diagnoses of benign tumors and treated with percutaneous and open techniques. Owing to the small number of subjects in the study, comparison between treatment options and patient outcomes was difficult.

CONCLUSION

We report the results of a consecutive series of 56 patients with diagnoses of benign bone tumors and cysts that were treated with a novel bioceramic CaSO4-Ca3(PO4)2 composite graft material. Functional results were excellent, complications were infrequent, and composite bioceramic seems to be a reasonable alternative to surgery: A prospective analysis of morbidity.

REFERENCES


Radial Head Replacement with a Bipolar Implant

“Patients [given this implant] typically recovered functional range of motion, albeit decreased compared to the unaffected elbow.”

MARK R. ZUNKIEWICZ, MD / JILL S. CLEMENTE, MS / MARK C. MILLER, PHD / MARK E. BARATZ, MD
ROBERT W. WYSOCKI, MD / MARK S. COHEN, MD

ARTICLES


References


To the preceding article, the described use of Pro-Direct has been approved by the FDA. No funds were received in support of this work. Authors/Filipponi and Lemos have no competing financial interests to disclose. Dr Clarke received medical device royalties from Wright Medical.

“Treatment of Cartilage Defects in Young Shoulders: From the Lab to the Clinic,” Appendix on p. 30, does not discuss the use of metal devices or dogs that are replaced by the FDA. The work described in this article was supported, in part, by a grant from the Musculoskeletal Transplant Foundation, Anthony Van Tichelt, MD, and Miami Children’s Hospital. Anthony Van Tichelt, MD, is on the speakers’ bureau for Arthrex, DECO Surgical, and the John Romaine Foundation; and receives medical device royalties from Arthrex. Dr Verma’s and Dr Cole’s financial disclosures are listed on p. 39.
We performed concomitant lateral collateral ligament repair in 15 patients, open reduction and internal fixation of an olecranon fracture in 5 patients, and open reduction of the coronoid in 3 patients. All patients were immobilized initially in a long arm splint. Motion was initiated within 7 to 10 days in all cases.

At a minimum of 2 years following surgery, patients completed a Mayo Elbow Performance Index, a 10-point Visual Analog Scale (VAS) pain score, and a Disabilities of the Arm, Shoulder, and Hand (DASH) survey. An independent examiner completed all clinical evaluations. We obtained bilateral neutral rotation frontal and lateral radiographs of the affected elbow and wrist. Radiographs for ulnar variance of the wrist were taken with the shoulder abducted, the elbow flexed to 90 degrees, and the forearm in neutral rotation. We recorded the lateral and medial ulnohumeral space, degree of proximal radius migration, change in position of the implant stem within the canal, lucency about the prothetic stem, bone spur formation, heterotopic bone formation, and sclerosis/radiolucency at the radiocapitellar and ulnohumeral joints.

Figure 1. Anteroposterior (AP) radiograph of the elbow demonstrating a comminuted radial head fracture that would typically be best treated with radial head arthroplasty.

Figure 2. Kinetimatic measures at final follow-up. The difference in range of motion between affected and unaffected extremities in regards to flexion/extension arc, pronation, and supination was significant (P = .012).

Figure 3. Radiographic measures at final follow-up. The difference between affected and unaffected extremities in regards to distal migration of the radius measured on AP radiographs of the wrist at final follow-up was significant (P = .013).

Figure 4. A, Lateral and B, anteroposterior (AP) radiograph of a right elbow at final follow-up reveals the presence of minimal ulnohumeral bone spurs, no soft tissue calcification (heterotopic ossification), and minimal stem lucency. When we compared immediate postoperative radiographs to radiographs obtained at final follow-up, there was very little (if any) change in the position of the stem within the canal over time.

KINEMATIC MEASURES

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<th>Angle (Degrees)</th>
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<td>80</td>
<td>72</td>
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<tr>
<td>Unaffected</td>
<td>130</td>
<td>90</td>
<td>85</td>
</tr>
</tbody>
</table>

RADIOPHIC MEASURES

<table>
<thead>
<tr>
<th>Angle (mm)</th>
<th>LUHS</th>
<th>MUHS</th>
<th>Distal Migration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affected</td>
<td>2.71</td>
<td>2.21</td>
<td>0.34</td>
</tr>
<tr>
<td>Unaffected</td>
<td>2.72</td>
<td>2.14</td>
<td>0.1</td>
</tr>
</tbody>
</table>

STATISTICAL ANALYSIS

Six distinct quantities allowed direct comparison between affected and unaffected elbows. The kinematic measures of flexion/extension arc, pronation, and supination range of motion and the radiographic measures of medial ulnohumeral space, lateral ulnohumeral space, and proximal migration of the radial shaft as measured at the distal radioulnar joint provided direct means to evaluate outcome. Paired t tests were used to compare the sides in each case, and unpaired t tests were used for comparison of functional scores between those with acute radial head arthroplasty for trauma and those with previous surgery or chronic conditions (ie, arthritis). A significance level of 0.05 was utilized.

RESULTS

Of the 36 implants, 10 (83.3%) were available for review. Follow-up averaged 34 months (range, 24-48 months). The Mayo Elbow Performance Index score averaged 92.1 (range, 65-100), the VAS (from 0 = no pain to 10 = severe pain) averaged 1.4 (range, 0-5), and the DASH score averaged 13.8 (range, 0-52.5) for the entire cohort. When broken down into cases performed for acute injury (n = 23) versus those for chronic conditions (n = 7), the Mayo score in the chronic group demonstrated poorer function (mean, 85.2) compared to the acute group (mean, 94.0) (P = .034). The VAS (means, 1.2 vs. 2.2) and DASH (means, 12.01 vs. 21.8) scores in the acute and chronic groups respectively did not reach significant difference (P = .166 and P = .127).

Clinical evaluation of the affected elbow revealed an average flexion/extension arc of 126 degrees (range, 95-150 degrees). Forearm pronation averaged 69 degrees (range, 45-90 degrees), and supination averaged 74 degrees (range, 60-85 degrees). In comparison, the unaffected elbow measured an average flexion/extension arc of 138 degrees (range, 120-150 degrees), an average 72 degrees of pronation (range, 45-90 degrees), and an average 80 degrees of supination (range, 60-85 degrees). The difference in range of motion between the affected and unaffected arms for flexion/extension arc, pronation, and supination was statistically significant (P = .013). The kinematic measures are shown in Figure 2.

Analysis of orthogonal radiographs of both the affected and unaffected elbows revealed an average lateral ulnohumeral space (LUHS) of 2.71 mm on the operative side (range, 0.3-5.1 mm), as compared to 2.72 mm on the unaffected side (range, 1.0-6.3 mm). This difference was not significant (P = .317). The medial ulnohumeral space (MUHS) on the affected side averaged 2.14 mm (range, 1.0-4.1 mm) and on the unaffected side averaged 2.34 mm (range, 1.0-5.6 mm). This difference was also not significant (P = .120). Wrist radiographs revealed an average proximal migration of the radius of 0.34 mm on the affected side (range, -3.2 to 4.4 mm) as compared to an average ulnar positive variance of 0.26 mm (range, -4.0 to 1.5 mm) on the unaffected side. This difference was statistically significant (P = .012). The radiographic measures are shown in Figure 3. No patient reported wrist pain or exhibited any evidence of distal radioulnar joint instability on clinical stress testing. Further analysis of the radiographs revealed the presence of minimal ulnohumeral bone spurs in 22 patients, small degrees of non-motion-limiting calcification in 13 patients, and stem lucency in 24 patients (Figure 4). Despite this radiolucency, there was very little (if any) change in the position of the stem within the canal over time.

Two patients suffered complications significant enough to require repeat surgery. The first was overstuffing of the radiocapitellar joint. This was a technical error in a patient treated early in the series, for which we returned to the operating room, removed the set screw on the adjustable neck, shortened the neck by 2 mm and reinserted the set screw. The operating room implant tray now includes wands upon which are the 6 combinations of head diameter and neck length that can be used to trial the head diameter and neck length to avoid this complication.

The second patient had a grossly unstable elbow despite repair of the lateral ligament complex, due to incompetent anterior and posterior capsule and medial collateral ligament. This was recognized in his first postoperative visit and was treated with further resection and stabilization of the joint with a hinged external fixator. Neither of these complications was deemed specifically related to the implant.
We performed concomitant lateral collateral ligament repair in 15 patients, open reduction and internal fixation of an olecranon fracture in 5 patients, and open reduction of the coronoid in 3 patients. All patients were immobilized initially in a long arm cast. Motion was initiated within 7 to 10 days in all cases.

At a minimum of 2 years following surgery, patients completed a Mayo Elbow Performance Index, a 10-point Visual Analog Scale (VAS) pain score, and a Disabilities of the Arm, Shoulder, and Hand (DASH) survey. An independent examiner completed all clinical evaluations. We obtained bilateral neutral rotation frontal and lateral radiographs of the affected elbow and wrist. Radiographs for ulnar variance of the wrist were taken with frontal and lateral radiographs of the affected elbow and wrist.

Statistical analysis

Six distinct quantities allowed direct comparison between affected and unaffected elbows. The kinematic measures of flexion/extension arc, pronation, and supination were statistically significant ($p=0.012$). We recorded the lateral and medial ulnohumeral space degree of proximal radius migration, change in position of the implant stem within the canal, lucency about the prosthetic stem, bone spur formation, heterotopic bone formation, and sclerosis/radiolucency at the radiocapitellar and ulnohumeral joints.

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Two patients suffered complications significant enough to require repeat surgery. The first was an 85-year-old patient with a proximal radial head fracture who was treated with a hinged external fixation for non-union. The second patient was a 55-year-old patient with a proximal radial head fracture who was treated with a hinged external fixation for non-union. Neither of these complications was deemed specifically related to the implant.

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A variety of implants has been used to replace the radial head. These include those made of ferrule caps, metal, acrylic, and silicone. While silicone was initially popular, fragmentation and an appreciation of the limited load-bearing capacity of silicone led to the development of metallic implants. Currently, there are a variety of implant designs available. However, few data exist on the superiority of one design over another. Most current implant functions as monoblock or unipolar devices. Midalignment of these implants can lead to decreased radiocapitellar contact area and increased carilage wear from stress concentration. Bipolar radial head implants were developed to maximize radiocapitellar congruence and contact forces. The Katalyst implant is a bipolar implant with a smooth, stainless-steel stem that is inserted without cement. Within the stem is a telescoping shaft with fluted walls and a ball on the proximal end. The flutes provide a surface to engage a set screw to fix the shaft in a distracted position. The ball on the telescoping shaft couples with the polyethylene liner of the head to allow assembly of the head to shaft in situ as a “snap fit.”

The stem was designed to be a smooth, “loose” fit within the canal. This was chosen due to excellent results with a similar stem in a monoblock head (Evolve, Wright Medical, Arlington, Texas). Since this implant’s conception over 10 years ago, the “loose,” smooth stem design has held up well in long-term follow-up. In this series we had similarly good experience with this stem design. The stem has a surrounding lucency by design but did not migrate or tip within the canal during nearly 3-year average follow-up.

The polyethylene-stem coupling mechanism allows in situ assembly. Polyethylene wear is a concern in any implant. To date we have not had the chance to retrieve an implant that has been in place for more than 7 weeks. While wear could become an issue, it has not been apparent clinically or on radiographs. With rotational loads shared between stem and proximal radius, the stem design. The stem has a surrounding lucency by design but did not migrate or tip within the canal during nearly 3-year average follow-up.

The polyethylene-stem connection is also the heart of the bipolar nature of the implant. There are conflicting data regarding the polyethylene-stem connection at the polyethylene-stem interface is implant dissociation at the polyethylene-stem interface is critical for enhancing the biomechanical fixation of tendon-sparing techniques provide a viable alternative to the use of osteotomies or fusions for the correction of the metatarsus primus varus.

REFERENCES

metatarsal osteotomies for hallux valgus, which has advantages of a more minimally invasive approach, less postoperative pain, decreased likelihood of transfer metatarsalgia and recurrence, and avoidance of complications related to osteotomies such as nonunion and malunion.

The indications for this procedure include (1) IMA less than 20 degrees, (2) hallux valgus angle (HVA) less than 30 degrees, (3) absence of instability at the metatarsocuneiform (MC) joint, and (4) distal metatarsal articular angle (DMAA) less than 10 degrees.

Contraindications to the use of this technique include (1) diabetes mellitus; (2) systemic autoimmune diseases such as gout, rheumatoid arthritis, psoriatic arthritis, or lupus; (3) primary arthritis of the first metatarsophalangeal joint; (4) HVA greater than 10 degrees; (5) instability or arthritis of the first MC joint; and (6) irreducibility of the IMA. The presence of an incongruent joint or of an interphalangeus deformity is not a contraindication to this procedure.

Following the soft-tissue releases associated with the McBride procedure, the first intermetatarsal space is manually reduced and held in a reduced position using UHMWPE suture that is routed through drill holes placed across the first and second metatarsals. Buttons plus a buttress plate are placed on the lateral side of the second metatarsal, and buttons are placed on the medial side of the first metatarsal through which the UHMWPE suture is passed to maintain the reduction (Figure 3).

DISCUSSION

The advantages of an osteotomy-sparing technique over an osteotomy include an avoidance of the potential of shortening the first metatarsal in relationship to the second metatarsal. In patients with a Morton’s foot where there is already a relative shortening of the first metatarsal relative to the second metatarsal, further shortening of the first metatarsal can lead to the creation or worsening of transfer metatarsalgia to the second metatarsal.

Osteotomy-sparing techniques avoid the potential complications of malunion. The distal portion of a first metatarsal osteotomy may heal with a dorsiflexed angular deformity, creating a transfer metatarsalgia to the second metatarsal. The complications of avascular necrosis, delayed union and nonunion can also be avoided using an osteotomy-sparing technique.

The available selection of safe, nonsteroidal analgesic medications has been reduced due to the recent withdrawal of Vioxx (rofecoxib) and Celebrex (celecoxib) related products from the market. Other alternatives include oxycodone, morphine and Nucynta (tapentadol). In some cases, these medications may be either stronger than is clinically needed for pain control or may not be well tolerated by patients. However, these concerns can be successfully addressed in patients using the UHMWPE-attached endobutton technique because there is potentially less pain without an osteotomy. In addition, these patients are able to use nonsteroidal anti-inflammatory (NSAID) medications without the risk of delaying bone healing.

CONCLUSIONS

Osteotomy-sparing techniques provide viable alternatives to the use of osteotomies or fusions for the correction of the metatarsus primus varus deformity. The use of osteotomy-sparing techniques can eliminate most of these potential complications and more importantly does not create the obstacles to revision surgery associated with osteotomies and fusions.

REFERENCES

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**DISCUSSION**

The advantages of an osteotomy-sparing technique over an osteotomy include an avoidance of the potential of shortening the first metatarsal in relationship to the second metatarsal. In patients with a Morton’s foot where there is already a relative shortening of the first metatarsal through which the UHMWPE suture is passed to maintain the reduction (Figure 3).

**CONCLUSIONS**

Osteotomy-sparing techniques avoid the potential complications of malunion. The distal portion of a first metatarsal osteotomy may heal with a dorsal angular deformity, creating a transfer metatarsalgia to the second metatarsal. The complications of avascular necrosis, delayed union and nonunion can also be avoided using an osteotomy-sparing technique.

The availability of safe, nonopioid analgesic medications has been reduced due to the recent withdrawal of OxyContin- (propoxyphene/acetaminophen) related products from the market. Other alternatives include cyclooxygenase, morphine and Nocynex (tepoxylate). In some cases, these medications may be successful in addressing patients using the UHMWPE-attached endobutton technique because there is potentially less pain without an osteotomy. In addition, these patients are able to use nonsteroidal anti-inflammatory (NSAID) medications without the risk of delaying bone healing.
Dysphagia Lusoria: An Uncommon Cause of Neck Pain and Hazard to Anterior Cervicothoracic Surgery

“Dysphagia lusoria, a source of incompletely diagnosed neck pain, is caused by an aberrant right subclavian artery, an anomaly that may require special planning for cervicothoracic spine surgery done through an anterior approach.”

DOMINIC SCOLA, BS / SUDEEP BHABAD, MD / DAVID FARDON, MD

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When evaluating neck pain, the presence of degenerative or arthritic changes does not always identify the sole source of symptoms. Lymphadenopathy, thyroid pathology, esophageal and paraesophageal disease, embryologic malformations, and referred pain from lung or heart disease should be considered as primary or concomitant secondary sources of pain. Dysphagia may accompany neck pain because osteophytes efface the esophagus or because another disorder causes both neck pain and dysphagia. Dysphagia lusoria, a condition that may accompany neck pain, is due to an aberrant right subclavian artery (ARSA). Dysphagia lusoria should be in the differential diagnosis of a patient with anterior neck pain and dysphagia. Presence of ARSA and associated anomalies should be considered during preparative evolution or in the event of unusual findings during anterior cervical and upper thoracic surgical procedures.

CASE REPORT
A 72-year-old woman had experienced neck pain for about 1 year. Her primary care doctor evaluated her for cardiorespiratory disease and performed computed tomography (CT) of the soft tissues of her neck, resulting in observations of mural calcification of the aorta and endplate anterior osteophytes at C5-6 and C6-7. The doctor advised the patient that she might have fibromyalgia, treated her with a serotonin uptake inhibitor, and referred her to the Rush orthopedic spine clinic for further evaluation and treatment of the cervical spondylodisc that was thought to be the source of her symptoms.

The patient stated that her throat discomfort and upper anterior chest pain were mostly on the left side. Some pain was present while upright and at rest, but it was exacerbated by movement and by lying down. She recalled that, as a child, she had suffered a severe laceration of the right side of her neck, which resulted in copious bleeding and required surgical repair. She knew nothing else about the nature of the injury or the treatment and had no symptoms after the wound healed. Until she reached her 70s, she had enjoyed good health.

Physical exam showed the patient to be 5 ft 7 in tall, 168 lb; and healthy in appearance. Her blood pressure was 110/70 mm/Hg in the left arm and 130/72 mm/Hg in the right arm. Her radial pulses were normal. There was a long, oblique scar along the right anterolateral surface of her neck with no mass or abnormal pulsation either beneath or in the supravacular fossa. Her neck motions were mildly limited. There were no signs of radiculopathy or myelopathy. On a pain drawing, she marked the left side of her neck, both anteriorly and posteriorly, and the mammary area as sites of aching pain.

Cervical spine radiographs showed hypertrophic spondylodisc along the anterior aspect of the mid-lower cervical spine. Magnetic resonance imaging (MRI) without contrast showed prominent osteophytes at the anterior disc margins and along the ventral canal and uncovertebral joints of C5-C7, creating mild foraminal and central stenosis. The MRI also revealed that the esophagus was displaced anteriorly from the body of the first thoracic vertebra by a mass seen in axial projection to extend across the anterior surface of the vertebral body and in sagittal projection to appear round, compatible with an anomalous vessel (Figure 1). Volumetric computer helical angiography of the chest before and after administration of 75.5 g iopamidol (10 mL of Isovue 370) showed an anomalous branching of the aortic arch, with the right and left carotid arteries arising from a common trunk (truncus bicaroticus), and the right and left subclavian arteries arising from a second common trunk. The right subclavian artery

Figure 1. Magnetic resonance images showing the aberrant right subclavian artery (ARSA). A, Sagittal T2 weighted axial image of the cervical spine shows ARSA (arrow) immediately in front of the C7-T1 disc. There is spondylodisc at C5-6 and C6-7 levels with anterior osteophytes. B, Axial T2-weighted image at the level of thoracic inlet shows ARSA (arrow) traversing left to right immediately in front of thoracic spine and posterior to the trachea (wedge) and esophagus, which is compressed between the trachea and the ARSA.

Figure 2. Thoracic angiogram CT images showing an aberrant right subclavian artery (ARSA). A, Coronal reformatted image of CT thoracic angiogram indicating RSA (arrow). B, Axial image of CT thoracic angiogram showing ARSA (straight arrow) traversing left to right immediately in front of thoracic spine and posterior to the trachea and esophagus (curved arrow), which is compressed between the trachea and the ARSA.
Dysphagia Lusoria: An Uncommon Cause of Neck Pain and Hazard to Anterior Cervicothoracic Surgery

“Dysphagia lusoria, a source of incompletely diagnosed neck pain, is caused by an aberrant right subclavian artery, an anomaly that may require special planning for cervicothoracic spine surgery done through an anterior approach.”

DOMINIC SCOLA, BS / SUDEEP BHABAD, MD / DAVID FARDON, MD

Cervicothoracic Surgery

Uncommon Cause of Neck Dysphagia Lusoria: An Associated Anomalies should be considered during preoperative evaluation or in the event of unusual findings during anterior cervical and upper thoracic surgical procedures.

CASE REPORT

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vascular arch of the proximal right dorsal aorta and persistence of incidence in the range of 0.5% to 2%. Arteria lusoria is the most In 1735, Hunauld described the anatomy of arteria lusoria, an

DISCUSSION

xanthan gums prevented her symptoms. She makes efforts to chew occasional episodes of “phlegm coming up and catching in my

treatments. At the time of last examination, 24 months after the After a consultation with a cardiovascular surgeon and an informed

dimensionally reconstructed, with selected soft tissues removed, way through the right superior mediastinum (Figure 2). Three-

followed an anomalous course passing behind the esophagus on its

image of the CT thoracic angiogram showing ARSA (straight arrow) traversing left to right immediately in front of the thoracic spine.

traversing left to right immediately in front of the thoracic spine.

anomalous course of the aorta (curved arrow).

showing ARSA (straight arrow) of the CT thoracic angiogram, Volume-rendered top view image right subclavian artery (ARSA).

three-dimensional color reconstructions, with deletion of obscuring tissues. Multidisciplinary evaluation may require a spine-care specialist, cardiovascular surgeon, gastroenterologist, laryngologist, radiologist, and primary care physician.

Symptoms and signs of ARSA are usually diverse and complicated by significant risk, is uniquely reserved for younger patients with severe and/or progressive symptoms that are clearly related to the anomaly. For patients with less severe symptoms, the best strategies to treat the dysphagia and the inflammatory and mechanical aspects of the pain include observation, food selection, and chewing precautions, and pharmacologic and physical therapy.

When planning an anterior approach to the cervical and upper thoracic spine, spinal surgeons should be aware that ARSA and related anomalies present special hazards. Thoracic cited a case of death resulting from injury to an ARSA during anterior exposure of T2.32 Awake exposures that challenge the surgeon working anteriorly at C1-T1 in a patient with a short and immobile neck could result in retraction or dissection of such precariously close arteries. The presence of very large anterior osteophytes, as in patients with diffuse idiopathic skeletal hyperostosis, or other extensive anterior pathology may raise the risks imposed by the presence of ARSA. Reported associate anomalies relevant to the surgeon include absence of a recurrent laryngeal nerve; anomalous branches of the vagus nerve, including direct branch to the larynx; right-sided thoracic duct; and anomalies of carotid and vertebral arteries.10,11

CONCLUSION

Dysphagia lusoria, a source of incompletely diagnosed neck pain, is caused by an aberrant right subclavian artery, an anomaly that may require special planning for cervicothoracic spine surgery done through an anterior approach. When considering surgery on patients with an ARSA, the surgeon should consider the challenges imposed by the aberrant artery, the possibility of associated anomalies, and the likelihood of different mobilization of the esophagus. These challenges include deciding whether or not to operate, choosing the approach (posterior, left anterior, or right anterior), and electing special monitoring and technical modifications. Surgeons should be aware of the possibility of the unrecognized presence of an ARSA and associated anomalies while exposing the anterior cervical and upper thoracic spine.

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followed an anomalous course passing behind the esophagus on its way to the right superior mediastinum (Figure 2). Three-dimensional reconstruction, with selected soft tissues removed, further demonstrated the anomaly and the intimate relationship of the aberrant right subclavian artery to the anterior surface of the aortic arch (Figure 3). Our diagnoses were dysphagia lusoria and cervical spondylosis. After a consultation with a cardiovascular surgeon and an informed consent discussion with our patient, we agreed to pursue a course of observation and some supportive measures without invasive treatments. At the time of last examination, 24 months after the onset of symptoms and 8 months after the diagnosis, she continued to experience transient feelings of being "unable to breathe" and pain, except that when her anterior pain increased in severity, she would assume a spine-care specialist, cardiovascular surgeon, gastroenterologist, radiologist, and primary care physician. Surgical treatment of dysphagia lusoria in adults is less common and accompanied by significant risk, is usually reserved for younger patients with severe and/or progressive symptoms that are clearly attributable to the anomaly. For patients with less severe symptoms, the best strategies to treat the dysphagia and the inflammatory and mechanical aspects of the pain include observation, medical intervention, and chronic pharmacologic and physical therapy on an as-needed basis.

When planning an anterior approach to the cervical and upper thoracic spine, spinal surgeons should be aware that ARSAs and related anomalies present special hazards. Thoracic aortic disease can be a cause of death resulting from injury to an ARSA during anterior exposure to the thoracic aorta.7,20


95(5):888-891.

The preceding article does not discuss the use of medical devices or drugs that are regulated by the FDA. No funds were received in support of this work. None of the authors receive financial benefits from commercial sources.

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T

There has been increasing interest in alternatives to autogenous bone graft for patients undergoing instrumented spinal fusion surgery. Reducing the need to harvest the patient’s own bone from iliac crest diminishes problems with pain and potential complications associated with the additional procedure. By introducing proper “ingredients” (osteoinduction/osteodifferentiation/osteoconduction/osteogenic cells), a bone-graft substitute may more predictably lead to fusion.5,6

Single-level instrumented posterolateral spinal fusion for degenerative spondylolisthesis is a common procedure performed by spinal surgeons. What constitutes the optimal mechano-biological environment has been the subject of intense debate. The best bone-graft substitute to supplement rigid instrumentation is still unclear.

Autogenous iliac crest bone graft has been used with great success but carries the risks mentioned previously. Vascular studies have divided the complications of autogenous iliac crest harvest into major and minor complications. Minor complications (approximately 10%) include superficial infections, superficial seromas, and minor hematomas. Major complications (approximately 6%) include hematoma of abdominal contents through massive bone-graft donor sites, vascular injuries, deep infections at the donor site, neurologic injuries (claudication nerve damage), deep hematoma formation requiring surgical intervention, and iliac wing fractures.3,4

Several alternatives to autogenous iliac graft have been introduced with varying degrees of success. Bone-graft extenders, such as corticocancellous allograft, or ceramics, such as hydroxyapatite-tricalcium phosphate, have been used as bulking agents to add to the volume of local bone graft. Bone-graft enhancers, such as demineralized bone matrix (DBM) and DBM-atrial cell composites, are alternatives that have met with recent criticisms.5 More data are needed to draw any firm clinical conclusions about their performance. Finally, bone-graft substitutes such as recombinant bone morphogenetic proteins (rhBMP-2/INFUSE Bone Graft/Medtronic Sofamor Danek Memphis, Tennessee) were introduced a decade ago as effective

ARTICLES

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2012 / RUSH ORTHOPEDICS JOURNAL


...we believe that predictable fusion in instrumented posterolateral arthrodesis for single-level degenerative spondylolisthesis can be achieved by meticulous fusion-bed preparation with local bone graft placed prior to pedicle screw/rod placement at a minimum volume of 15 cc per side."

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alternatives to autogenous bone graft, but current Food and Drug Administration (FDA) on-label use is limited to anterior lumbar interbody fusions with tapered cylindrical cages. Posterolateral spinal fusion data are pending, and recent reports of catastrophic complications have tempered the initial excitement associated with this substitute.6

We did a retrospective radiographic review of single-level instrumented posterolateral fusions performed by the senior author (H.S.A.), with minimum 12 month follow-up. We included all consecutive patients who underwent single-level instrumented posterolateral spinal fusions over a 3-year period for treatment of degenerative spondylolisthesis. Exclusion criteria included patients who received a bone-graft enhancer/substitute or multilevel fusions and revision cases or cases where decompression was not performed. The fusion bed was prepared consistently in the following manner: After appropriate posterolateral exposure and placement of retractors, a thorough decompression was performed. All decompression-related bone (laminctomy bone from Kerrisons/ bone dust collected from suction trap device) was saved, meticulously cleaned of soft tissue with a #15 blade scalpel, and milled with a commercially available bone mill. The final volume of local bone was measured, and we prepared the pedicles for pedicle screw placement. Using a gear shift, the pedicles were probed and tapped, and screw trajectory was confirmed with markers using biplanar fluoroscopy. A matchstick burr was then used to completely decorticate the segmental facet joints and create a bilateral trough from pars to pars that was wide enough for manual insertion of bone graft. The transverse processes were also decorticated and, depending on the volume of local bone graft available, the decorticated trough/paraspinal transverse process beds were packed with the graft. We determined the screw entry point, and placed the pedicle screws. We inserted appropriately sized rods, tightened sets screws, and took final radiographs. Wound closure was performed in the standard fashion.

We divided our series into the following groups:

Group I: Patients with at least 30 cc of local bone graft placed at the fusion bed.

Group II: Patients with less than 30 cc of local bone to which an additional 15-30 cc of corticocancellous allograft chips were added as a bulking agent. Total volume of graft and addrive was no less than 15 cc on each side.

Two sets of blinded reviewers assessed the available radiographs at final follow-up. The reviewers included fellowship-trained spinal surgeons as well as midlevel orthopedic surgery residents. A preliminary set of 12 radiographs was used between blinded reviewers to set an equivalent standard for fusion criteria. The criteria used to determine fusion included intertransverse bridging bone, fusion radiodensity over the facet joints, continued segmental motion at the fusion site and any evidence of instrumentation loosening or failure. Attempted fusions were deemed either fused or unfused. All results were tabulated and analyzed.

RESULTS

A total of 40 consecutive patients met our inclusion criteria and had radiographs that were available for clinical review in this preliminary study (Group I: n = 20, Group II: n = 20). Radiographic review revealed 18 of the 20 Group I patients and 18 of the 20 Group II patients was radiographically fused. See Figures 1 and 2 for examples of radiographic union and nonunion. Final follow-up clinical notes did not indicate any complications including hardware loosening or revisions secondary to nonunions.

DISCUSSION

The bone graft that most predictably leads to fusion for single-level instrumented posterolateral spinal arthrodesis is still debatable. We maintain that both the ingredients of the bone-graft substitute and the preparation of the fusion bed contribute to the predictability of the fusion. Each patient in our series underwent the same preparation of the fusion bed. A key point in our series is that we prepared the fusion bed and packed graft prior to placing the rigid pedicle screw-rod construct. We believe that the predictability of our fusions (as determined by final radiographic evidence of arthrodesis with no clinical evidence of nonunion) is directly related to this method. Once the pedicle screws/rods are placed, the biologic “real estate” for packing bone graft (whether autograft or composite grafts) severely diminishes. Packing 15 cc of bone graft per side within the fresh, bleeding cancellous surface of the trough made within the pars-pars segment leads to a better biologic fusion environment than attempting to place bone graft in the posterolateral gutter after the pedicle screws/rods have been placed.

From a cost perspective, this preliminary study has some important considerations. In Group I, we achieved 80% radiographic fusion without the additional cost of using a bone-graft enhancer such as a DBM or even a ceramic bulking agent. Additionally in Group II, we achieved comparable radiographic fusion with the use of corticocancellous allograft chips, which are vastly cheaper than commercially available DBM products or osteoinductive proteins. Our method of posterolateral fusion also differs in that it is not a true intertransverse process fusion. Our primary focus was to prepare the facet and pars at the motion segment in question and pack as much bone graft as possible within the surgically created trough. The remaining bone graft was then manually packed along the decorticated transverse processes.

This study is not without methodological drawbacks. It was a retrospective review, and we did not have computed tomography to assess the fusions. In addition we did not include disc crest bone-graft group or a rhBMP-2 group as a positive control. As a preliminary study, the numbers were too small to reveal statistical significance of differences between groups in this study and between our data and other published results. However, our intent was to demonstrate equivalency in radiographic fusion rates by using a set amount of local autogenous bone graft alone in single-level lumbar fusion, rather than to show a statistical difference between two groups.

In conclusion, we believe that predictable fusion in instrumented posterolateral arthrodesis for single-level degenerative spondylolisthesis can be achieved by meticulous fusion-bed preparation with local bone graft placed prior to pedicle screw/rod placement at a minimum volume of 15 cc per side.■

REFERENCES


In the preceding article, FDA approval rates of described biomaterials is discussed in the text. No funds were received in support of this work. None of the authors receive financial benefits from commercial sources.
obviating the need to harvest additional bone graft or bed preparation will lead to predictable radiographic fusion, thus spinal fusion data are pending, and recent reports of catastrophic alternatives to autogenous bone graft, but current Food and Drug

radiographic union from Group I. Note exuberant fusion mass in the posterolateral gutter and at the level of the pars/facet junctions. See Figures 1 and 2 for examples of radiographic union and nonunion. 18 of the 20 Group II patients was radiographically fused. See

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DISCUSSION
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Biomechanical Effects on In Situ Distracting Compartment Cage in the Cervical Spine
Development of Rat Discogenic Pain Model and Molecular Therapy
Epidural Stem Cell Transplantation for Intervertebral Disc Degeneration. In Vivo Repair
Intervertebral Disc Degeneration and Pain
Use of Actractin and Actractin Plus for Posterolateral Fusions in the Rabbit Model

BRIAN J. COLE, MD, MBA
Arthrosopic Partial Meniscectomy in Osteoarthritis
Effects of Serial Sectioning and Repair on Lateral Meniscus

CRAG J. DELLA VALLE, MD
Comparative Comprehension of Hip Arthroplasty Options in Young Active Patients
Study of Acetabular System in Patients with Degenerative Hip Disease

TIBOR T. GLANT, MD, PHD
Mapping of Arthritis Susceptibility Genes


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EDWARD J. GOLDBERG, MD
Disc Treatment of Radiologic Symptoms for the Cervical Spine

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Early Histology of CoS2/CoS2–DBM Composite Bone Graft

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Battlefield-Acquired Immunogenicity to Metals Affects Orthopaedic Implant Outcomes

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Biotribological Layers in Metal-on-Metal Hip Replacement

NADIM J. HUNDRED, PHD
Calculation of Total Joint Replacement Contact Forces During Walking

KATALIN MIKECZ, MD, PHD
Myeloid-Derived Suppressor Cells in Autoimmune Arthritis

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SPORER, SCOTT M.


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Biomechanical Effects on In Situ Distracting Cystectomy Cage in the Cervical Spine Development of Rat Discectomy Pain Model and Molecular Therapy Epidural Stem Cell Transplantation for Intervertebral Disc Degeneration In Vivo Repair Intervertebral Disc Degeneration and Pain Use of Activator and Acetate Plus for Posterior Fusional Pain in the Rabbit Model

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Arthroscopic Partial Meniscectomy in Osteoarthritis Effects of Serial Sectioning and Repair on Lateral Meniscus

Craig J. DeLaValle, MD
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Mapping of Arthritis Susceptibility Genes


Zhang, Qiping

Nadin J. Hallab, PhD
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Joshua J. Jacobs, MD
Biomechanical Experiments in Metal-on-Metal Hip Replacement Prospective Randomized Trial of Head-Neck Modularity in Total Hip Arthroplasty

Hannah J. Lundberg, PhD
Calculation of Total Joint Replacement Contract Forces During Walking

Katalin Mikecz, MD, PhD
Myeloid-Derived Suppressor Cells in Autoimmune Arthritis

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Disc Treatment of Radicular Symptoms for the Cervical Spine

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Early Histology of CaSiO3/CaSiO4 Composite Bone Graft

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Myeloid-Derived Suppressor Cells in Autoimmune Arthritis

Edward J. Goldberg, MD
Disc Treatment of Radicular Symptoms for the Cervical Spine
The following research teams from Rush University Medical Center have received Kappa Delta awards:

- The Winston Lanier Award
- The Ann Doner Vaughn Award
- The Young Investigator Award

These awards reflect years of investigation, or a single project of high significance and impact. Currently, 3 annual awards are given: the Elizabeth Winston Lanier Award, the Ann Doner Vaughn Award, and the Young Investigator Award.

KAPPA DELTA ORTHOPEDIC RESEARCH AWARDS

Since 1950, the American Academy of Orthopaedic Surgeons has presented Kappa Delta Orthopedic Research Awards annually to researchers whose key discoveries have led to major advancements in orthopedics. Often referred to as the Nobel Prizes of orthopedic research, Kappa Delta awards are bestowed for outstanding manuscripts that represent either a large body of cohesive scientific work reflecting years of investigation, or a single project of high significance and impact. Currently, 3 annual awards are given: the Elizabeth Winston Lanier Award, the Ann Doner Vaughn Award, and the Young Investigator Award.

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**2011**
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  - Project – Intervertebral Disk Repair or Regeneration by Growth Factor and/or Cytokine Inhibitor Protein Injection

**2002**
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  - Joshua J. Jacobs, MD; Anastasia Skipor, MD; Robert M. Urban; Nadim J. Hallab, PhD; Leslie Pattern, RN; and Jonathan Black, PhD
  - Project – Systemic Implications of Total Joint Replacement

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- Young Investigator Award
  - D. Rick Sumner, PhD; Thomas M. Turner, DVM; Robert M. Urban; and Jorge O. Galante, MD, DMSc

**1983**
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- Ulrich E. Kuettnner, PhD
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**Volume and Quality Data**

About Rush University Medical Center

Rush is a not-for-profit health care, education, and research enterprise located on the West Side of Chicago. Rush encompasses the academic medical center Rush University Medical Center; Rush Oak Park Hospital; Rush University; and Rush Health, a clinically integrated network of providers covering the full spectrum of patient care. In January 2012, Rush opened its new, state-of-the-art hospital, known as the Tower. One of the nation’s most advanced hospitals, the 14-story Tower houses acute and critical care patients, as well as technologically sophisticated surgical, diagnostic, and therapeutic services.

Quality Recognition

- The orthopedics program at Rush has been ranked among the top 12 by U.S. News & World Report each of the last 10 years—including 7 times in the top 10.
- Rush’s nurses have been awarded Magnet status—the highest honor a hospital can receive for outstanding achievement in nursing services—3 times. Rush was the first medical center in Illinois caring for adults and children to receive this prestigious designation, and the first in Illinois to earn a third consecutive 4-year designation.

- Rush has been named among the top hospitals in the country for quality, safety, and efficiency by the Leapfrog Group, a national organization that promotes health care quality, safety, and quality improvement. Rush is one of only 65 hospitals that made the list of top hospitals for 2011 from among nearly 1200 hospitals surveyed.
- University HealthSystem Consortium (UHC) has awarded Rush the highest possible score for “equity of care” in each of the 6 years of its annual quality and accountability study. This ranking measures whether patients receive the same quality of treatment and have the same outcomes regardless of their gender, race, or socioeconomic status. UHC is an alliance of 116 academic medical centers and 261 of their affiliated hospitals, representing approximately 90% of the nation’s nonprofit academic medical centers.
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Total Orthopedic Surgical Cases*

* Source: University HealthSystem Consortium (UHC) orthopedics service line criteria applied to index cases with standard UHC exclusion criteria (FY2011).

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Volumes include surgeries performed at Rush University Medical Center, Rush Oak Park Hospital, and the outpatient Rush SurgiCenter for each fiscal year, covering July 1 to June 30.
SHANE J. NHO, MD, MS  
Biomechanical and Functional Analyses of Hip Labral Repairs

ANTHONY A. ROMEO, MD  
Prospective Study of the Encore Reverse Shoulder Prosthesis

ROBERT M. URBAN  
Evaluation of Bone Regeneration Using Composites in a Metaphyseal Defect  
Implant and Tissue Retrieval Studies

NIKHIL N. VERMA, MD  
Biomechanical Evaluation of Remplissage Procedure for Engaging Hill-Sachs Lesions

VINCENT M. WANG, PhD  
Biologic Repair of Focal Chondral Defects with the Use of Collagen Ullst Matrix in Rabbits  
MR Monitoring of Engineered Tissues

QIPING ZHENG, PhD  
Chondrocyte Maturation and Osteosarcoma

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RUSH ORTHOPEDICS JOURNAL

Volume and Quality Data

TOTAL ORTHOPEDIC SURGICAL CASES*

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LIFE AND LIMBS
An Interview with Pioneering Orthopedic Oncologist and Rush Mainstay Steven Gitelis, MD

BY GUNNAR B. J. ANDERSSON, MD, PHD

When Steven Gitelis, MD, first arrived on the Rush campus in 1972 as a first-year medical student, the medical college occupied just one floor of one building, the Department of Orthopedic Surgery had only a handful of members, and amputation was the predominant treatment for osteosarcoma.

Four decades later, Gitelis is still at Rush—and, as his nurse practitioner and residents will attest, he still has the energy of a 25-year-old. But thanks in part to his dedication and vision, the Medical Center, the department, and the field of orthopedic oncology are all dramatically different. As director of the first limb preservation center in Chicago, Gitelis helped to pioneer surgical techniques, implants, and bone substitutes that have made limb salvage possible for the majority of sarcoma patients. And he has become a respected leader at Rush whose current titles include president-elect of the medical staff, director of the Section of Orthopedic Oncology, and vice chairman of the Department of Orthopedic Surgery, which today has nearly 60 clinical and research faculty. He also holds the prestigious Rush University Chair of Orthopedic Oncology.
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ANDERSSON: You’ve been at Rush for most of your life, as a student, a resident, and an attending. What keeps you here?

GITELIS: Frankly, we've reached the limit of what we can do destructive personally. You must have release valves, because if you don't, it can be very overwhelming, like when I recently had to tell a patient that's going to see nanotechnology in the future. So right now we're at a roadblock, but I think that roadblock will fall apart once these new technologies are refined for clinical application.

GITELIS: One big factor is that treatment of orthopedic cancers is now multidisciplinary. We have a surgeon on staff at Rush that meets regularly to discuss management for these patients. In addition, the medical treatments—chemotherapy and radiation therapy—have improved tremendously, along with diagnostic capabilities. Diagnostics were a bit dicey in the olden days; now there are very precise ways of making a diagnosis pathologically, so we know the optimal treatments for the diseases we face.

And of course, I also believe that the operations I'm doing are better, from a cancer perspective and a reconstructive perspective. I've been privileged to say that in addition to surviving their cancers, today most patients are also able to keep their limbs. I now do about 99 percent limb salvage and only 5 percent amputation. Back when I was a resident, limb salvage was in its infancy, so I've had the opportunity to help develop and refine surgical technologies and techniques—including a self-lengthening prosthesis for pediatric patients, bone substitutes, and the use of allografts and autografts—that are now widely used to reconstruct limbs. It's been exciting to play a role in this amazing progress.

ANDERSSON: You don’t have as many now, but how do you cope with the bad outcomes?

GITELIS: I'm a lot on the treadmill, and I'm being very serious about that. What sticks with you most is not the 75 percent you care, but the 25 percent you lose. Another aspect of my practice is joint replacement, and while there may be complications, they don't threaten a patient's life. The stress of orthopedic oncology can be overwhelming, like when I told a patient whom I operated on 8 years ago that his cancer has relapsed. You must have release valves, because if you don't, it can be very destructive personally.

ANDERSSON: Do you think there will be continued improvement in outcomes?

GITELIS: Frankly, we've reached the limit of what we can do with traditional treatments for sarcomas. We've had these great improvements, but we're still stuck in the post of a more fundamental approach. As is the case with many other cancers, the key is going to be targeted therapies, therapies that attack the cancer cells at a molecular level. There's going to be targeted immunotherapy—we've just started with the use of proteins, a highly targeted form of radiation therapy, for sarcomas, and we're going to see nanotechnology in the future. So right now we're at a crossroad, but I think that roadblock will fall apart once these new technologies are refined for clinical application.

ANDERSSON: In terms of your personal contributions, is there something you feel has had a particular impact on the field?

GITELIS: One of the things I'm most proud of is that I've been medical director of the Bone and Tissue Bank of the Regional Organ Bank of Illinois (ROBI) since its inception. It's an interesting story, actually. When I began practicing in 1981, there was no tissue bank in Illinois. I had a young patient who needed a bone transplant, so I made arrangements to procure a bone from a tissue bank in Miami. I met the plane at O'Hare to pick up the bone—the pilot almost fainted when I told him what he was carrying in that cooler—but then I had to figure out what to do with the bone, because I wasn't transplanting it until the next day. So I brought it home, my wife and I threw out all the food in our freezer, and we washed the bone in the freezer. I still credit my wife with being the first tissue banker in the state.

Shortly thereafter, Jorge O. Galante, MD, DMS, who was department chairman at that time, asked me to start a tissue bank at Rush. He gave me a $20,000 grant from the Rush Woman's Board to buy a Revco freezer, and I handled everything: the procurements, overseeing the operations of the tissue bank, etc. From there, it just grew and grew. However, when the Organ Procurement Organisation (OPO) was developed in the U.S., I realized that a hospital-based tissue bank couldn't exist for very long because there's just too much regulation. That's when I joined forces with one of the OPOs, ROBI. ROBI then joined forces with AlloSource, which is now the fourth largest tissue bank in the U.S. ROBI eventually morphed into the Girl of Hope Organ and Tissue Donation Network (a nonprofit that coordinates organ and tissue procurements, overseen by the organ banks in Illinois and northwest Indiana). So I'm extremely proud of the role I've played in the development of tissue banking and transplantation; many patients benefit from these tissues, which include bone, cartilage, and skin.

ANDERSSON: In addition to your many clinical and research activities, you’re the president-elect of the medical staff, as I once was. It’s an honor, but it’s also a huge responsibility and requires a lot of your time. What compelled you to accept the position?

GITELIS: Sometimes I ask myself that question. It’s particularly challenging for me because I remain a very active surgeon, whereas many presidents are in the waning years of their career, or they’re in a specialty where they have a lot of time. Fortunately, I’m pretty efficient, so I can still maintain a large cancer practice and attend the many meetings that are required as president. Why did I take it? Quite simply, I’ve been at Rush 40 years, and this represents the medical staff’s recognition of the contributions I’ve made.

ANDERSSON: What do you think of Rush’s new facilities, particularly the Orthopedic Building and the new hospital?

GITELIS: Our orthopedic services were much more spread-out before the Orthopedic Building opened. I think this type of consolidated facility greatly enhances patient care because patients can see their doctors, have their imaging, and get their tests done all in the same place. And by housing the clinical programs, plus our residency program and laboratories, the building enables greater collegiality and collaboration. For instance, I frequently walk down to the labs, plus our residency program and laboratories, the building enables greater collegiality and collaboration. For instance, I frequently walk down to the laboratories on a clinic day, talk to my research colleagues, and get updates on what’s happening. I couldn’t do that before because the labs were relatively far from our clinical offices.

As for the new hospital, both my patients and I love it. It’s an outstanding facility. I’ve been impressed with the attention to detail throughout the hospital, from the ORs to the patient floors. In my opinion, it will serve as a model for other institutions around the country to follow.

ANDERSSON: As much time as you spend here, I know family is also very important to you. You have five children, some of whom are following in your footsteps. Did you influence them to become physicians, or did it just happen?

GITELIS: It really did just happen. I try to set an example but not interfere in their lives too much, so my children who opted for careers in medicine did so of their own accord. One of my
One of Gitelis’ mentors at Rush has been Gunnar R. J. Andersson, MD, PhD, chairman emeritus of the department and past medical staff president. The two recently sat down to discuss Gitelis’ prolific career—and why he won’t be retiring anytime soon.

**ANDERSSON:** You’ve been at Rush most of your life, as a student, a resident, and an attending, so what keeps you here?

**GITELIS:** It’s been wonderful to grow up in this institution. I do feel as if I started out here as a child. I still wear my original ID badge from the 1970s because I want to show people what I looked like when I came to Rush 40 years ago. I’ve been mentored by so many great people, first by former Rush President and CEO Leo Henikoff, MD, who chose me to become a student at Rush Medical College, then by former department chairman Jorge O. Galante, MD, DMSc, who recruited me for my residency. I’ve also had the opportunity to work in my lab and co-author numerous articles with you, which I consider a unique combination not offered at many other places. So I haven’t had to leave Rush. I’ve just been around at least another 10 years because my work is still exciting and I still enjoy it.

**ANDERSSON:** And I’ve loved seeing the growth in the surgical treatments you’ve developed. I also love seeing the research you’ve done in your academic career. You’ve been a surgeon at Rush that meets regularly to discuss management for these patients. In addition, the medical treatments—chemotherapy and radiation therapy—have improved tremendously, along with diagnostic capabilities. Diagnoses were a lot dicier in the olden days; now there are very precise ways of making a diagnosis pathologically, so we know the optimal treatments for the diseases we face.

**GITELIS:** Of course, I also believe that the operations I’m doing are better, from a cancer perspective and a reconstructive perspective. You have to be able to treat patients, and you have to love to mentor students, because there are a lot of students from Rush that meet regularly to discuss management for these patients. In addition, the medical treatments—chemotherapy and radiation therapy—have improved tremendously, along with diagnostic capabilities. Diagnoses were a lot dicier in the olden days; now there are very precise ways of making a diagnosis pathologically, so we know the optimal treatments for the diseases we face.

**ANDERSSON:** Do you think there will be continued improvement in outcomes?

**GITELIS:** I’m a bit of a悲观ist, and I’m being very serious about that. What sticks with you most is not the 75 percent you care, but the 25 percent you lose. Another aspect of my practice is joint replacement, and while there may be complications, they don’t threaten a patient’s life. The stress of orthopedic oncology is overwhelming, like where I operate on a patient whom I operated on 8 years ago that his cancer has relapsed. You must have release valves, because if you don’t, it can be very destructive personally.

**ANDERSSON:** So what do you attribute that increase to?

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**ANDERSSON:** Do you think you will be continuing to work in orthopedics?

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**ANDERSSON:** And how does your work fit into the board and executive committee’s efforts?

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**ANDERSSON:** What do you think of Rush’s new facilities, particularly the Orthopedic Building and the new hospital?

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**ANDERSSON:** In terms of your personal contributions, is there something you feel has had a particular impact on the field?

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daughters is a pediatric resident, another is a medical student, and I just found out recently that one of my sons is now considering becoming a physician. So that’s more tuition I’ll have to pay, but I’m proud of the fact that he chose it on his own.

ANDERSSON: You’ve said that retirement is far in the future, but you must at least think about it occasionally.

GITELIS: Not right now. In fact, after my son’s announcement and the new medical school tuition that I face, my retirement plans have been put on indefinite hold. I have more or less committed to be active for another 10 years, assuming I can maintain my surgical skills. Right now I believe I’m the best surgeon I’ve ever been in my career, and as long as I stay sharp, stay healthy, and continue to enjoy the work I’m doing I’ll keep going.

ANDERSSON: What would you like to be remembered for when you do retire?

GITELIS: For my long-term durability and my involvement in many different aspects of the Medical Center: research, education, administration, and surgery. As an academic orthopedic surgeon, you can choose to expand your horizons within your own institution, or externally through involvement in the American Academy of Orthopaedic Surgeons and other societies. I don’t think I could do both very well, so I’ve chosen to focus internally. I did serve as president of both the Musculoskeletal Tumor Society and the Illinois Orthopaedic Society in the late 1990s, but the vast majority of my leadership roles and committee work have been within the department, Rush Medical College, and the Medical Center. I’m a Rush person, and I’d like to be remembered for all that I’ve contributed to Rush’s success.

“OUR THRIVING CLINICAL PRACTICE is enhanced by collaborations with specialists at Rush from rheumatology, physical medicine and rehabilitation, physical therapy, and other areas.”

Midwest Orthopaedics at Rush (MOR) is a private practice medical group whose 38 fellowship-trained physicians are on the faculty of Rush University Medical Center in Chicago. With MOR based primarily at Rush, our renowned surgeons and physicians have access to all the resources of a world-class academic medical center, including the state-of-the-art operating rooms in Rush’s new hospital. Our thriving clinical practice is enhanced by collaborations with specialists at Rush from rheumatology, physical medicine and rehabilitation, physical therapy, and other areas. As part of our commitment to continually advance orthopedic care, our physicians participate in cutting-edge multidisciplinary research, which is translating into new treatments that benefit patients at Rush—and around the globe.

Physicians from Midwest Orthopaedics at Rush also hold key leadership positions in national societies and organizations, and serve as the team physicians for a variety of professional, collegiate, and high school teams and clubs, including the Chicago Bulls, Chicago White Sox, and DePaul University. These impressive clinical, research, and administrative activities distinguish orthopedics at Rush as among America’s best. U.S. News & World Report has ranked the orthopedics program at Rush in the top 12 each of the past 10 years—including 7 times in the top 10.
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