

ORTHOPAEDIC INSIGHTS

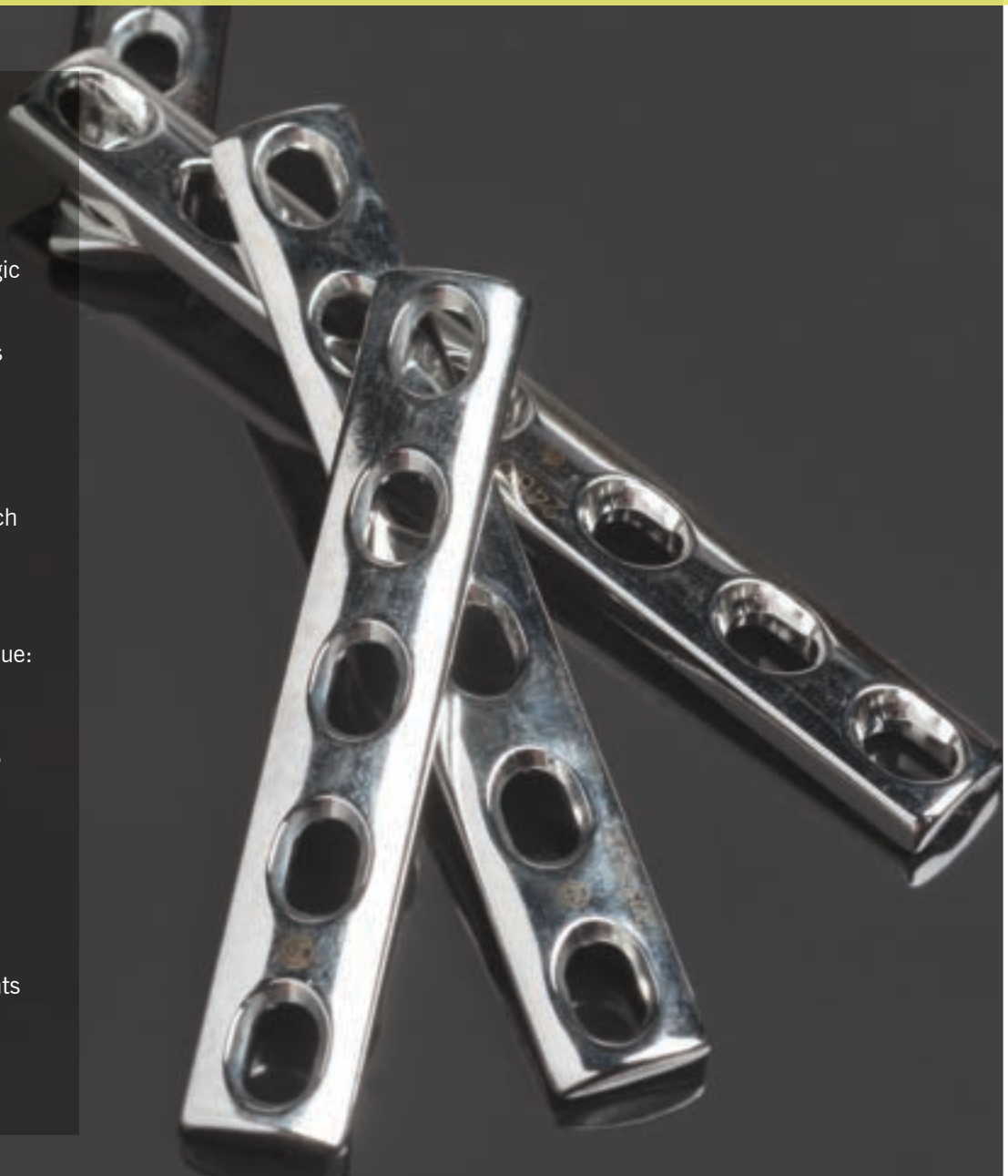
SUMMER 2017



A PHYSICIAN NEWSLETTER FROM
THE DEPARTMENT OF ORTHOPAEDIC SURGERY

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DEAR COLLEAGUES



I'm pleased to report that Cleveland Clinic's Department of Orthopaedic Surgery has made great strides in the past year. With the help of Joseph P. Iannotti, MD, PhD, Chairman, Orthopaedic & Rheumatologic Institute, and the talented members

of my department, we have moved our mission forward remarkably.

Since I became chairman in July 2016, we have delivered on our goal to provide the best possible patient care, and we have expanded the department in many ways. Notably, we have added 20 attending staff members, including a respected orthopaedic group in Lorain, Ohio, as well as new specialists in tumor, trauma, foot and ankle, and joint reconstruction.

In this issue of *Orthopaedic Insights*, a theme quickly emerges: Staying at the forefront of orthopaedic advancements in research, technology and innovation is crucial to improving outcomes for our patients.

Our newly established Musculoskeletal Research Center, a collaborative effort between our institute, Biomedical Engineering and Radiology, is dedicated to innovation

and pushing the envelope. Our recently formed Cleveland Clinic Joint Preservation Center focuses on advancing the tremendous potential of cell-based therapies.

This issue also highlights basic science work on chondrocytes, osteonecrosis of the hip and the use of bone morphogenetic proteins in pediatric patients.

Don't miss articles describing our outcomes tracking program, diagnosis of shoulder infections, innovative biomechanical knee joint simulators and advances in sports medicine, or our Image of the Issue describing an advanced spinal fusion technique.

I am personally quite excited about reporting our knee replacement innovations — robotic therapy, additive manufacturing, cementless prostheses, special braces and new pain treatment methods.

In the educational arena, read about our innovative use of an arthroscopic simulator for teaching fellows, residents and others.

It has been a pleasure working in this department this past year. I am eager to share a sampling of our innovative endeavors in this issue of *Orthopaedics Insights*. Thank you very much for taking the time to review it.

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U.S. News & World Report

Cleveland Clinic's orthopaedics program is ranked No. 3 in the nation in *U.S. News & World Report's* "Best Hospitals" survey — the top-ranked program in Ohio.

ORTHOPAEDIC INSIGHTS | SUMMER 2017

Orthopaedic Insights is published by Cleveland Clinic's Department of Orthopaedic Surgery to inform musculoskeletal specialists about advances in diagnosis, medical and surgical management, and research.

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INNOVATIVE THERAPIES ENHANCE RESULTS OF TOTAL KNEE REPLACEMENT

TECHNOLOGIES OFFER GREAT PROMISE IN ALL PHASES OF CARE

Total knee replacement (TKR) is utilized for end-stage knee osteoarthritis, which often leads to excellent long-term outcomes with greater than 95 percent survival at 20 years. Yet it has been shown that 20 percent or more of these patients can be dissatisfied with the procedure. At Cleveland Clinic, we perform over 3,000 knee replacements annually, and have been making patient-focused efforts to improve short- and long-term outcomes. These clinically based projects cover all phases of care: pre-, intra- and postoperative.

In this article, we review several of these innovative efforts:

- Robotic total knee replacement
- Press-fit implant technology
- Customized 3-D implant printing
- Wound closure technology
- Neuromuscular electrical stimulation
- Innovative pain technologies

Each of these technological advancements individually has the potential to change the field of knee replacement surgery. Together, they can revolutionize TKR procedures to the point that patients will have minimal pain and can almost guarantee optimal short- and long-term results in the future.

Robotic total knee replacement

Robots have been used in various surgical fields, but have only recently been utilized clinically in orthopaedics. They are purported to improve accuracy, precision and outcomes for all types of surgeries. In knee replacements, we have performed studies that show improvements in placement of the implant, which should also translate into better patient outcomes. Michael A. Mont, MD, helped a team complete a cadaver study that assessed knee alignment and component position using robotic and non-robotic methods. Robotic surgery achieved more accurate component position and alignment than the manual (non-robotic) technique. Additionally, Cleveland Clinic is one of four sites involved in a multicenter clinical trial comparing robotic techniques with standard total knee replacements. Investigators are optimistic that this technology will improve outcomes in knee replacement.

Press-fit implant technology

Traditionally during TKR, implants are placed into the knee using cement to allow for initial implant stability and adherence to bone. However, cement may not permit optimal bone-implant integration, which may compromise long-term results. To circumvent this issue, Cleveland Clinic researchers and others have developed “press-fit” implant designs. These implants do not require cement and, therefore, bone grows into the implant surfaces. This theoretically could provide better long-term implant longevity, especially in younger patients in whom these prostheses may need to last for 20 or more years.

Customized 3-D implant printing

Knee implants traditionally have a standard design and come in various sizes to allow the surgeon to choose the best fit for each patient. However, individual patient anatomy can vary markedly. To address the need for individualization, we have worked with a company that develops customized 3-D printed prostheses with additive technology. Theoretically, this will allow for a knee replacement that more closely matches the patient’s native anatomy, thereby potentially improving patient function and satisfaction.

Wound closure technology

Knee replacements require a sizable incision over the knee, which, after completion of the surgery, generally requires a meticulous technique to achieve a durable and aesthetic skin closure. Recently, barbed sutures have gained attention as they offer the surgeon a faster and tighter repair than traditional sutures. These sutures contain very small “barbs” that instantaneously lock wound edges together without requiring the surgeon to tie a knot. The “knotless” technique offers several clinical advantages: shortened operative times and less exposure to anesthesia, use of resorbable sutures that do not require removal at a later visit and more durable wound closure.

We are performing a randomized, controlled trial comparing barbed sutures with traditional ones for patients undergoing total knee replacement.



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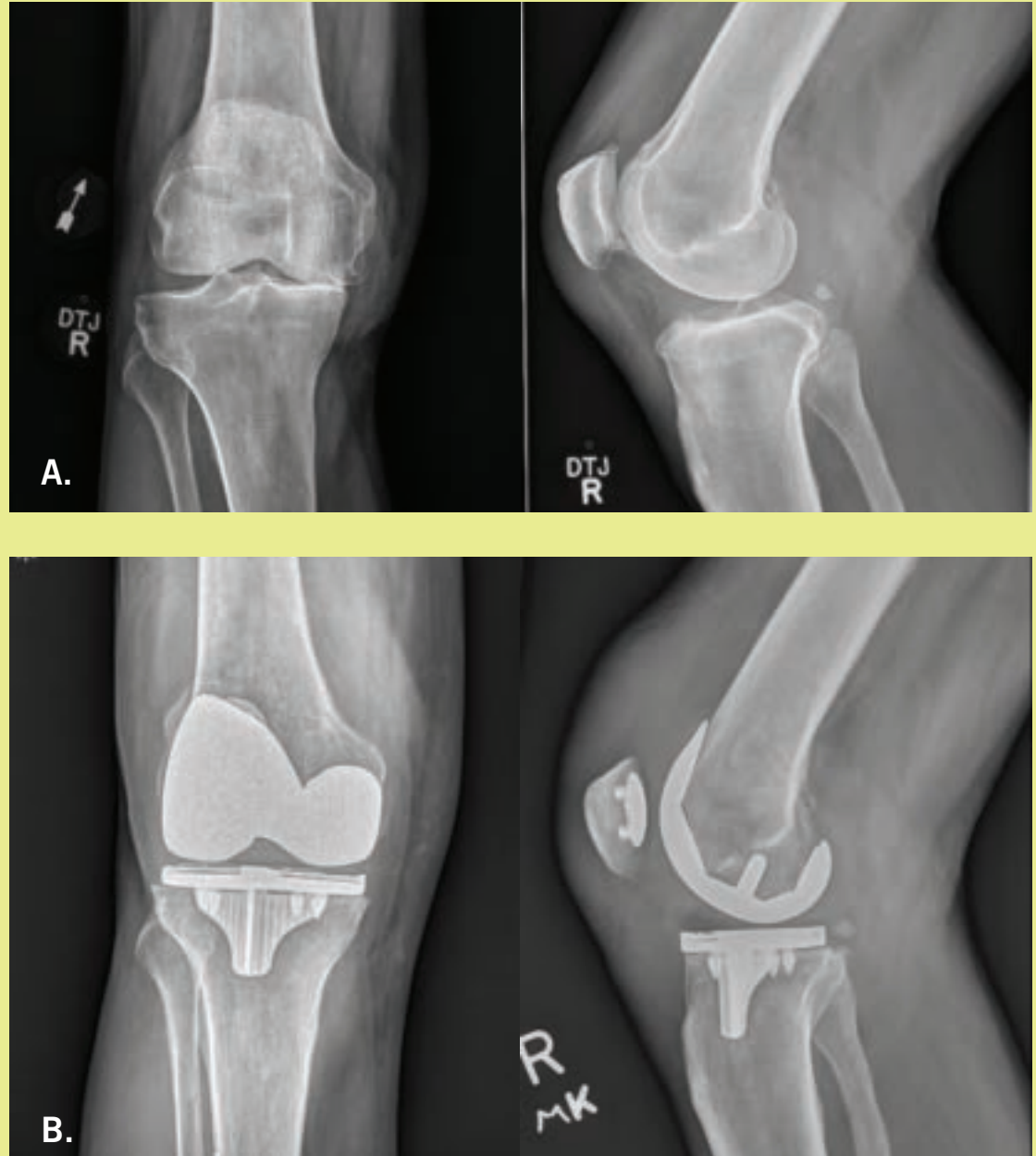


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Figures.

Total knee arthroplasty

- A. Preoperative standing anteroposterior and lateral radiographs of an arthritic knee.
- B. Postoperative standing anteroposterior and lateral radiographs after cementless total knee arthroplasty.



Barbed sutures may become the new standard in joint replacement surgery and may ultimately reduce costs and improve efficiency. These new sutures are antiseptic-impregnated, which is consistent with the World Health Organization guideline that suggests the use of these coatings to reduce surgical site infections.

Neuromuscular electrical stimulation

Adequate muscle strength is an essential component for a successful total knee replacement, and is usually achieved through exercises and physical therapy. A relatively new technique called neuromuscular electrical stimulation (NMES) may make it easier and faster for patients to gain this muscle strength. NMES involves use of a brace that transmits pulses to the muscles around the knee and causes them to contract, thereby strengthening the knee joint.

We are involved in a controlled trial assessing use of this technology both pre- and postsurgery in patients who undergo total knee replacement. The objectives are to strengthen the knee prior to surgery and help with postoperative recovery. Patients should be back in action much faster after using NMES.

Innovative pain technologies

Adequate pain control after total knee replacement can be challenging for both providers and patients. Pain control is often achieved through the use of opioids (narcotic medications), which can have dangerous side effects and are potentially addictive. One opioid-addicted individual dies every 19 minutes in this country, and many have become addicted as a result of surgery-related prescriptions (Centers for Disease Control and Prevention).

We recently participated in a multicenter, randomized controlled trial assessing the use of a novel long-acting local anesthetic. Liposomal bupivacaine is administered to the patient perioperatively, just before closure of the wound. Several studies have demonstrated improved pain control, decreased opioid use and better pain scores in patients who received this agent. The drug has been instituted as a part of our pain management protocol for patients undergoing total knee replacement.

With a recent call to action from the U.S. Surgeon General to end the opioid epidemic, it is essential to investigate and utilize therapies that may potentially help physicians minimize opioid use for pain control, in turn reducing the number of patients who become dependent on or addicted to opioids. Additionally, adequate pain control may result in better patient satisfaction and better Press Ganey scores, which can help optimize hospital reimbursement. Our team has published several reports investigating this, and has found promising results with liposomal bupivacaine.

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Dr. Mont is Chairman of the Department of Orthopaedic Surgery. Dr. Krebs is on staff and Dr. Chughtai is a research fellow in the department.

INTRODUCING CLEVELAND CLINIC'S MUSCULOSKELETAL RESEARCH CENTER

Kathleen Derwin, PhD, named
Executive Director

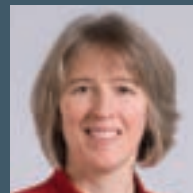
One researcher can't solve arthritis — or any other disease — on his or her own. That's why Cleveland Clinic is uniting musculoskeletal researchers from its Imaging, Lerner Research, and Orthopaedic & Rheumatologic institutes in a new Musculoskeletal Research Center (MSRC).

The goal: to collaborate on efforts that advance the care of people with musculoskeletal disorders. The MSRC will be the administrative hub of basic and translational research, innovation and education.

"Instead of small grants and stand-alone research, the MSRC will seek to build synergies to achieve large-group program project grants to pursue research activities across various orthopaedic and rheumatologic diseases," says Executive Director Kathleen Derwin, PhD.

Research groups are already seeking answers to clinical challenges in joint arthroplasty, psoriatic arthritis, post-traumatic osteoarthritis, periprosthetic joint infection, rotator cuff repair, carpal tunnel syndrome, cell-based therapy and bone fracture repair.

Dr. Derwin has been part of Cleveland Clinic's musculoskeletal research community since 1998 and is on staff in the departments of Biomedical Engineering and Orthopaedic Surgery. In addition to her successful research career, she has invented and licensed multiple technologies for musculoskeletal care. She earned a bachelor's degree in mechanical engineering from the University of Massachusetts Amherst and her master's degree and doctorate in bioengineering from the University of Michigan.



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ORTHOBIOLOGICS AND ORTHOBIOLOGIC RESEARCH: THE CURRENT STATE

UNDERSTANDING APPLICATIONS, TRACKING OUTCOMES AND CREATING STANDARDS FOR USE



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For the uninitiated, the term orthobiologics refers to all treatments that utilize molecules, cells or tissues to aid in the healing and reparative process of a musculoskeletal injury or chronic orthopaedic condition. This includes cell-based therapies and platelet-rich plasma (PRP), about which orthopaedists are hearing increasingly more from colleagues and answering many questions from patients.

Addressing a lack of understanding and standardization

Several studies on the use of cell-based therapies and PRPs have demonstrated marked heterogeneity between preparations, appropriate uses and patient-reported outcomes. This lack of standardization undermines the ability to reliably reproduce studies. Consequently, there is a glaring lack of large-scale, high-quality research.

Recognizing the powerful potential applications of these treatments, Cleveland Clinic has undertaken a proactive approach to developing solid standards that we hope will guide our and other teams' use of these new therapies. This effort is an important component of the newly established Cleveland Clinic Joint Preservation Center. (See related article page 9.)

Tracking protocols, safety, efficacy, outcomes

Our approach to developing these standards started with the creation of a reliable tracking mechanism. We developed a specific orthobiologic module within Cleveland Clinic's OrthoMiDaS Episode of Care system, in collaboration with Kurt Spindler, MD. (See related article page 16.) The module ensures standardization of injection protocols and tracks longitudinal safety, efficacy and outcomes for every orthobiologic treatment performed at our institution (Table 1).

Each of these treatments is just beginning to be understood in detail, and clinical efficacy is still to be proven. Therefore, insurance coverage is minimal and patients must usually pay out of pocket. We offer these treatments as part of a comprehensive, multimodal program combined with physical therapy, bracing and activity modification in a safe, controlled environment.

Building on previous research here

We have also collaborated with George F. Muschler, MD, who has been a referral source in orthopaedic regenerative medicine research. He and his team have optimized surgical techniques for bone marrow aspiration to improve the yield of stem and progenitor cells (connective tissue progenitors or CTPs), designed standards to measure cell-based therapies, and improved understanding of the complexity of multiple orthobiologic treatments. (See related article page 10.)

Problems in tendinopathy classification

The lack of consistency in orthobiologic use, specifically in the treatment of tendinopathies, is fundamentally related to the lack of a reliable tendon damage classification system. Ultrasound findings, such as tendon thickening, hypoechogenic tendinosis, neovascularization denoted by power Doppler-flow-enhanced hyperemia and intrasubstance partial tearing, all may result in different outcomes after the same orthobiologic injection. Yet these are lumped into a single general category of "tendinopathy" in most research articles. Recognizing the lack of a standard classification system, we are also developing our own tendinopathy classification system at Cleveland Clinic (Table 2).

Where to go from here

There has been a paucity of high-quality, reproducible research for orthobiologics. Instead, we have mostly relied on trial-and-error approaches. To rectify this situation, we are laying the foundation to build standards that will help ensure excellent outcomes for patients.

This includes a transparent, controlled, evidence-based effort to understand pathologies underlying the maladies we treat and the mechanisms of action of orthobiologic products and, most importantly, to set reproducible standards in orthobiologic care. Data we collect will help guide our research directives and establish national guidelines for orthobiologic research.

We look forward to sharing our evidence and having ongoing discussions with colleagues about our approach and findings, and we welcome your feedback.



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TABLE 1. In-office Orthobiologic Treatments

ORTHOBIOLOGIC PROCEDURE	PROPOSED MECHANISM OF ACTION	CONDITIONS
Hyaluronic acid viscosupplementation	Cross-linking of CD-44 ligand to decrease synovial inflammatory response, likely a small true effect on overall synovial fluid viscosity due to joint residence time	Intra-articular injection for osteoarthritis (knee, hip, shoulder, elbow, wrist, ankle, first carpometacarpal)
Platelet-rich plasma	Platelets introduced through injection release a multitude of growth factors that signal an inflammatory response and aid in the healing process	Intra-articular injection for osteoarthritis (as above) Various ligament and tendon pathologies, specifically those with ultrasound findings of hyperemia and mild tendinosis
Amniotic fluid-derived allograft	Cryopreserved injectable amniotic fluid-derived allograft that is used to protect and promote development at the injured site	Intra-articular injection for osteoarthritis (as above) Various ligament and tendon pathologies, specifically those with ultrasound findings of partial tears and marked tendinosis
Amniotic membrane-derived allograft	Amniotic membrane-derived tissue matrix of growth factors, collagen and bioactive molecules, used to supplement or replace damaged or inadequate connective tissue	Intra-articular injection for osteoarthritis (as above) Various ligament and tendon pathologies, specifically those with ultrasound findings of partial tears and marked tendinosis

TABLE 2. Research Underpinning Tendinopathy Classification System

Systematic review of quadriceps tendinopathy
Systematic review of fat pad impingement
Systematic review of the lack of tendinopathy classification in orthobiologic research
Intra-/Inter-rater reliability study on the characterization of tendinopathy features utilizing musculoskeletal ultrasound
Retrospective analysis of tendinopathy classification and tendon characterization of patients undergoing platelet-rich plasma injections at Cleveland Clinic
Randomized controlled trial (RCT) of Kager fat pad hydrodissection for recurrent Achilles tendon pain and “tethered tendon syndrome”
RCT of leukocyte-rich, platelet-rich plasma for the treatment of common extensor tendinosis with and without hyperemia
RCT of placental tissue matrix for proximal vs. distal elbow ulnar collateral ligament partial tear in baseball pitchers
RCT of placental tissue matrix after in-office ultrasound-guided percutaneous tenotomy

Drs. King and Genin are associate staff in Sports Medicine and Medical Orthopaedics. Dr. Muschler is a Professor of Orthopaedic Surgery, specializing in all aspects of knee and hip replacements. He is Director of the Regenerative Medicine Laboratory, where he conducts research on bone and cartilage tissue regeneration. Dr. Piuze is a clinical scholar in Orthopaedic Regenerative Medicine and Cellular Therapies.

SURGICAL TRENDS FOR TREATING OSTEONECROSIS OF THE HIP

MOST PATIENTS STILL UNDERGO TOTAL HIP ARTHROPLASTY



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Osteonecrosis is a potentially devastating disorder of various joints, including the hip, knee, shoulder and ankle, that can progress to end-stage arthritis.

Osteonecrosis has many causes, with corticosteroids and alcohol abuse accounting for over two-thirds of cases. The pathophysiology and pathology of osteonecrosis are similar regardless of etiology: bone death leads to joint collapse and eventual arthritis. The treatment of this disease aims to halt the progression or delay the onset of arthritis.

The treatment of osteonecrosis (also known as avascular necrosis or AVN) of the hip has evolved over the past two decades. Multiple treatment options are available for this disorder, which often strikes a younger population. Treatment is based on disease stage and progression, the orthopaedist's experience and patient preference. However, once substantial joint surface collapse has occurred or signs of degenerative arthritis appear, total joint arthroplasty becomes the most appropriate treatment option. Osteonecrosis cases make up an estimated 10 percent of all total hip arthroplasties performed annually in the United States.

Finding answers with NSQIP

The utilization of various treatment options for hip AVN is currently unknown. We conducted an analysis of the American College of Surgeons' National Surgical Quality Improvement Program (ACS NSQIP®) surgical outcome database to determine surgical treatment trends for hip osteonecrosis. Using ICD-9 codes, we identified 3,958 cases of hip osteonecrosis that underwent surgical treatment between 2008 and 2014. We determined annual distribution of surgical treatments for all specific procedures and for joint-sparing versus joint-replacing procedures.

The overall number of surgical procedures performed annually increased from 88 in 2008 to 1,161 in 2014. The rate of total hip arthroplasty performed increased from 81 percent in 2008 to 95 percent in 2014. Although the

number of joint-preserving procedures increased during this period, the percentage of preserving procedures decreased.

The findings of this study validate previous reports that found total hip arthroplasty to be the most common procedure performed for treatment of osteonecrosis of the hip. The results also demonstrate an increasing number of procedures performed for osteonecrosis, suggesting higher awareness of this disease.

Advances on the horizon

Operative interventions for early-stage disease include joint-preserving procedures such as core decompression, with or without the use of bone grafts and biologic agents such as bone morphogenetic proteins (BMPs), or cell-based therapy. These procedures first evacuate the necrotic bone through a window in the femoral head-neck junction and subsequently fill the defect with a combination of the above-mentioned materials.

At Cleveland Clinic, some of these treatments, such as BMPs, percutaneous drilling and the "trapdoor" procedure, which replaces the dead bone with cancellous and cortical autograft, are being studied and have been quite successful. These joint-preserving procedures are usually attempted in precollapse lesions, when the articular cartilage is generally intact with only the underlying subchondral bone affected.

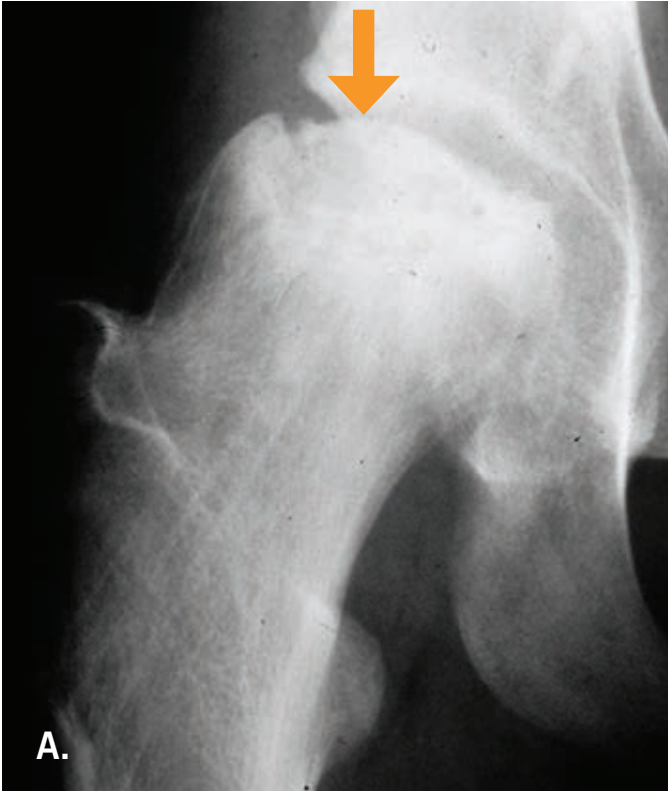
Conversely, after severe subchondral collapse has occurred, procedures that attempt to salvage the joint are rarely successful, and joint arthroplasty is necessary to relieve pain. Fortunately, reports have shown successful results for these procedures utilizing modern prostheses.

Dr. Mont is Chairman of the Department of Orthopaedic Surgery.

Figures.
Osteonecrosis

A. Radiographic image of hip osteonecrosis. Arrow indicates a necrotic zone with collapse of the femoral head.

B. MRI of hip osteonecrosis. Arrow indicates a necrotic zone.



CLEVELAND CLINIC JOINT PRESERVATION CENTER NOW UP AND RUNNING

Organizing and overseeing joint preservation efforts

The recently established Cleveland Clinic Joint Preservation Center (CCJPC) centralizes the Orthopaedic & Rheumatologic Institute's surgical and nonsurgical offerings geared toward saving functional joints.

The center brings the burgeoning field of orthobiologics as well as surgery, rehabilitation and research into one administrative entity to better coordinate the continuum of care for patients, to develop standardized protocols and to organize research efforts.

Mission: Improve people's lives by reducing pain, restoring mobility and preserving function of diseased or injured joints.

Vision: The multidisciplinary team of the center integrates innovations and advances in orthobiologics for the care of patients. In a highly collaborative environment, which is rigorously objective in assessment of outcomes, we are committed to continuous improvement, excellence and advancing the field through the systematic assessment of alternative therapies.

For more information, contact CCJPC Co-chairs:



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CARTILAGE REGENERATIVE THERAPY RESEARCH: HARNESSING HIGH-TECH ANALYTIC TECHNIQUES

OPTIMIZING QUALITY OF CARTILAGE-FORMING CELLS



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How to repair, replace or regenerate cartilage has been the Holy Grail for orthopaedic researchers worldwide for more than five decades. Great strides have been made, and orthopaedic surgeons and researchers have developed numerous strategies to attempt to form new cartilage in the knee, including microfracture, periosteal flaps, cartilage transplantation and autologous chondrocyte implantation.

The most widely used cell therapy procedure, using bone marrow aspirate concentrate (BMAC) for the treatment of knee osteoarthritis, is yet another manifestation of the high value we and our patients place on cartilage health, preservation and restoration.

Each strategy has something in common: the need for a source of cells that can form new cartilage. These chondrogenic connective tissue progenitor cells (CTP-Cs) differ from CTPs that tend to form other tissues (e.g., bone, fat or scar).

What is the best source for chondrogenic cells?

Unfortunately, none of the repair options developed to date has proven 100 percent successful in restoring the native articular cartilage structure with hyaline cartilage. To determine the best strategy and to have a profound effect on the outcome, we are trying to answer a number of specific questions about the nature of the cells and their biological performance: How many chondrogenic cells need to be transplanted? What is the quality of cells being transplanted? How does the number and quality of cells vary from patient to patient and tissue source to tissue source? What is the best source for high-quality CTP-Cs?

Our research team, from the departments of Orthopaedic Surgery and Biomedical Engineering, is diligently working to answer these questions. We collect discarded samples of cartilage, synovium, periosteum and retropatellar fat from knees of patients undergoing elective total knee arthroplasty (those who grant permission). Most patients also graciously agree to allow us to collect bone marrow by aspiration from the iliac crest. These samples provide an exceptional opportunity to directly compare the quality of CTP-C tissue sources. Our goal is to measure both the number of CTPs and their relative ability to form cartilage (i.e., develop an assay of CTP-Cs).

EACH STRATEGY
HAS SOMETHING
IN COMMON:
THE NEED FOR A
SOURCE OF CELLS
THAT CAN FORM
NEW CARTILAGE

In order to perform our analysis of cultured CTP-Cs in a reliable and reproducible manner, we use a customized robot to collect the high-resolution images needed to measure and characterize CTPs. This robot was designed and built in the Muschler laboratory at Cleveland Clinic in collaboration with Parker Hannifin Corp., a Cleveland company that focuses on

motion and control technologies. Automated image analysis software was also developed in the laboratory to extract detailed quantitative information from each CTP-C colony, based on cell surface markers and extracellular matrix molecules (Figures 1 and 2). These methods have become valuable well beyond our laboratory and have been incorporated into the ASTM Standard Methods for Automated Cell and Colony Analysis.¹

Comparing CTPs: Which tissues perform best?

In our current study, tissue sources from 20 patients were compared with respect to cell concentration (cells per gram of tissue), prevalence (CTPs per million cells plated) and CTP concentration (CTPs per gram of tissue). The table (page 12) shows the comparison between four tissue sources. Periosteum and synovium had a high cell concentration, but the prevalence of CTPs was low. Fat, on the other hand, was less cellular, but had a relatively higher prevalence of CTPs. Cartilage performed the best in terms of concentration, prevalence, expression of chondrogenic markers of CTP-Cs and the ability to grow in 3-D gels.

The rational development of cell therapy based on adult progenitor cells will require a qualitative and quantitative assessment to define optimal sources of cells for cartilage tissue repair. This source should have several characteristics: 1) means of harvest with minimal morbidity or cost (availability); 2) efficient methods for isolation in sufficient

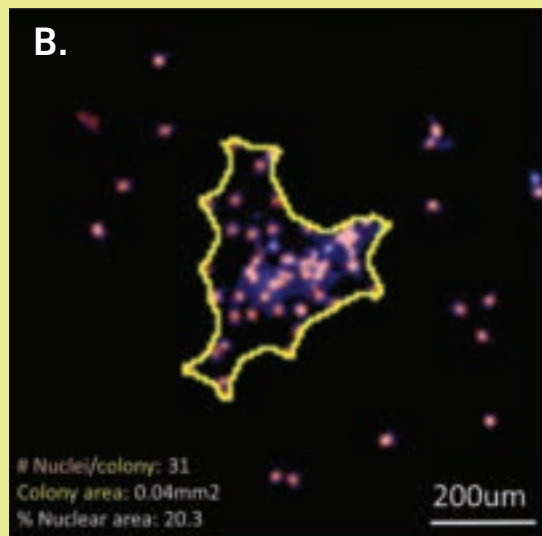
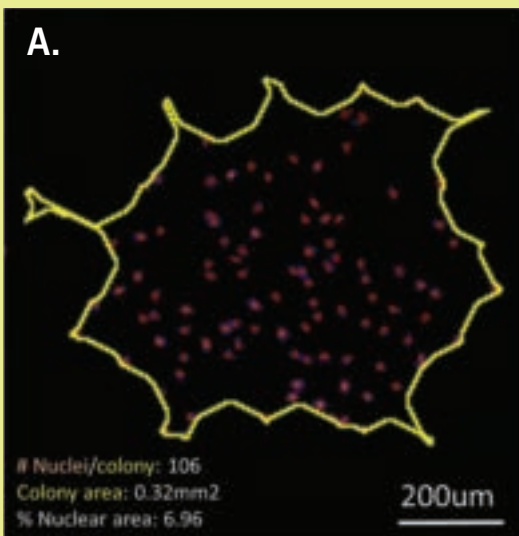


Figure 1.

Analysis of two colonies derived from CTPs resident in A. synovium and B. cartilage. CTPs from synovium proliferate more rapidly and form larger colonies, which are less dense. In contrast, CTPs from cartilage form smaller and more densely packed colonies in both 2-D and 3-D cultures.

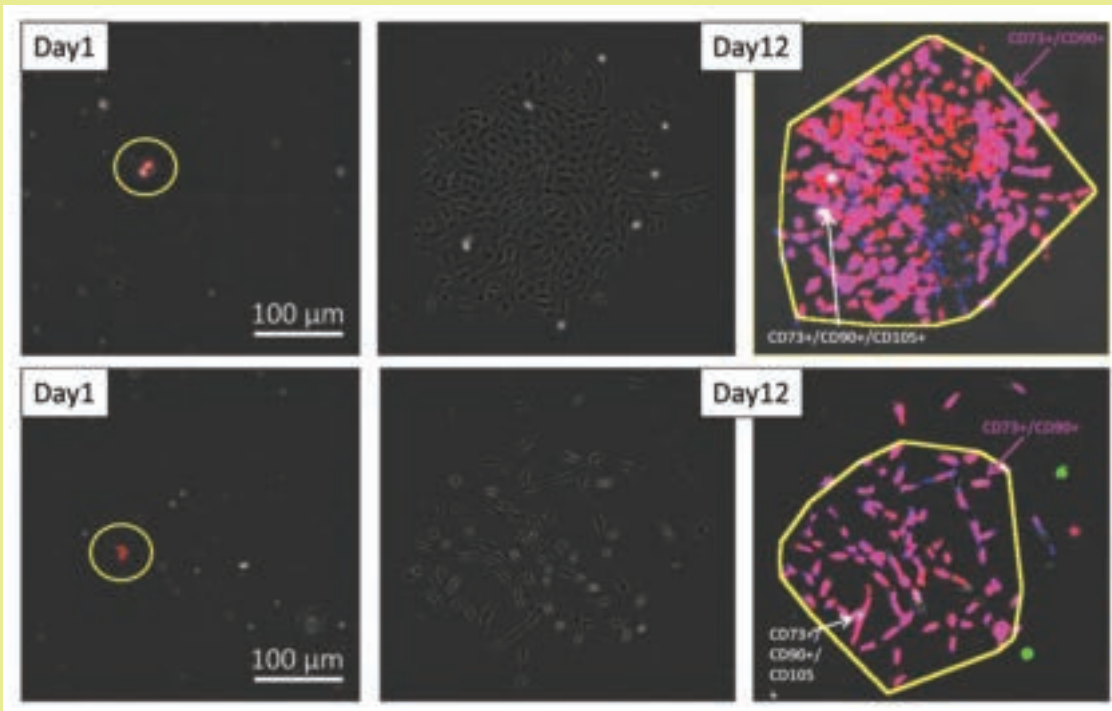


Figure 2.

Time-lapse videomicroscopy allows quantitative analysis of colony formation, starting with the colony founding CTP-C (left panels). The colonies formed by two founding cells are presented using phase-contrast microscopy (middle panels) and quantitative three-color immunofluorescence (right panels). Large variation is seen in colony morphology. The upper colony shows tightly packed cuboidal cells with chondrogenic morphology. The lower colony comprises loosely packed, elongated fibroblastic cells at day 12.

TABLE. Comparative Assessment of Cell and CTP-C Concentrations Present in Various Tissues Around Knee Region

	Fat	Synovium	Periosteum	Cartilage
Cell concentration (cells/mg)	4,842 ± 2,493	7,249 ± 4,552	7,923 ± 5,625	7,101 ± 2,993
Observed prevalence CTP-C (CTP-Cs/million cells plated)	1,148 ± 1,359	924 ± 1,250	287 ± 616	1,652 ± 1,592
CTP-C concentration (CTP-C/mg tissue)	5 ± 6	6 ± 10	2 ± 5	12 ± 12

numbers; and 3) the capacity of progenitors (proliferation and differential potential of CTP-Cs) to repair cartilage.

Further work in identifying optimal sources of CTP-Cs will be essential for the ongoing development of safe, efficient and reliable therapies for the repair and regeneration of cartilage and joint preservation.

This work is supported by a National Institutes of Health R01 grant, AR063733.

Dr. Mantripragada is a postdoctoral fellow in the Biomedical Engineering Department, Lerner Research Institute. Dr. Muschler is a Professor of Orthopaedic Surgery, specializing in all aspects of knee and hip replacements. He is Director of the Regenerative Medicine Laboratory, where he conducts research on bone and cartilage tissue regeneration.

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SAFETY OF BONE MORPHOGENETIC PROTEIN USE IN PEDIATRIC PATIENTS

MULTICENTER STUDY DEMONSTRATES RATES OF COMPLICATIONS

Bone morphogenetic protein (BMP) is used extensively in adult spine and fracture surgery, with well-documented safety and efficacy. Though its use in pediatric patients is increasing, its safety and efficacy in the pediatric population is not well-defined in the literature. Additionally, BMP is considered contraindicated in skeletally immature patients by the FDA; thus, its use in children is off-label. Our recent study sought to establish utilization trends of BMP in pediatric orthopaedic surgery practice, with a focus on studying its complications.

Study design

We retrospectively reviewed all pediatric orthopaedic surgical cases that utilized BMPs at six institutions between 2000 and 2013. We analyzed 312 cases, including

RESULTS SUGGEST THAT BMP USE DOES NOT LEAD TO GREATER COMPLICATION RATES

demographic information, surgical indication, procedure details and surgical complications. Each complication was classified using the Clavien-Dindo scheme, which grades complications from one to five based on the severity of insult to the patient.

BMP utilization and complication rates

BMPs were utilized for spinal fusion or revision in 86 percent of cases, and were utilized for long-bone non-unions in 11 percent of cases. The overall complication rate was 21 percent, including 9 percent minor complica-



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Dr. Goodwin (right) and colleague performing spine fusion surgery for scoliosis.



Figures.

Surgery with adjunct BMP

A. A 15-year-old male with progressive kyphosis secondary to Loeys-Dietz syndrome.

B. Surgical correction in the form of T2-L3 posterior spinal fusion with multiple osteotomies was performed. The procedure was complicated by T6 pseudarthrosis and failure of the proximal construct eight months postoperatively.

C. Revision of instrumentation and fusion was performed, using BMP as an adjunct. The patient went on to heal uneventfully and is asymptomatic today.

tions (wound breakdown, radiculopathy, temporary sensory deficit, etc.) and 12 percent major complications (infection, implant failure requiring revision, unresolved motor or sensory deficit, etc.). Of these complications, seven (three radicular pain, three temporary sensory deficit and one heterotopic ossification) appeared to be directly related to BMP use.

Confounding factors and cautious use

In our study, the overall complication rate was very high at 21 percent. However, given the complexity of the procedures in which BMPs were utilized, this complication rate is consistent with previously published studies. In only 2 percent of cases in which BMP was used could it be directly linked to a complication (7/312), with only one of these cases resulting in a major complication. Thus, the results of our study suggest that BMP use does not lead to greater complication rates than would be expected to accompany these complex procedures at baseline. We recommend, however, that physicians are forthright about the relatively unestablished safety and efficacy of BMP use in children.

Dr. Kolmodin is a pediatric orthopaedic surgery fellow. Dr. Goodwin is Director of the Center for Pediatric Orthopaedics and Spine Deformity.

NEW HEAD OF PEDIATRIC ORTHOPAEDIC RESEARCH

R. Tracy Ballock, MD, named to post

The Department of Orthopaedic Surgery has appointed R. Tracy Ballock, MD, as the Director of Pediatric Orthopaedic Research in the Center for Pediatric Orthopaedic Surgery. The center's efforts are directed toward improving quality, safety and value in the care of children who have musculoskeletal disorders.

Among the center's major clinical research initiatives:

- Developing patient-specific implants for pedicle screw fixation in scoliosis surgery
- Investigating the use of liposomal bupivacaine (a long-acting anesthetic agent) for postoperative incisional pain relief in children
- Using removable cast braces combined with virtual visits for follow-up of children with buckle fractures of the distal radius
- Researching the utility of a standardized clinical care path for treatment of children with adolescent idiopathic scoliosis

A graduate of Harvard College and Harvard Medical School, Dr. Ballock completed his internship and residency training at the University of California, San Diego. Following residency, he completed research training at the National Institutes of Health and at the Johns Hopkins School of Medicine. He joined Cleveland Clinic in 2002, serving as Head of the Section of Pediatric Orthopaedics until 2012. Dr. Ballock directed a basic science research program in growth plate biology that was funded by the NIH for over 20 years, and has recently turned his attention to clinical outcomes research.



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TRANSFORMING HEALTHCARE TO VALUE: THE ORTHOPAEDIC SOLUTION

ORTHOMIDAS EPISODE OF CARE (OME) OFFERS SLEEK WAY OF MEASURING OUTCOMES



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With our nation's aging population, orthopaedics now accounts for 20 to 30 percent of all healthcare dollars spent in the United States. This has clearly accelerated the motivation to move reimbursement away from a volume-based model toward a value-based model. It has also provided the impetus for Cleveland Clinic's Department of Orthopaedic Surgery to develop its own robust system for accurately measuring outcomes.

A history of metrics

Fortunately, the goal (desired outcome) of the vast majority of treatments for musculoskeletal injuries and disease is measurable: to relieve pain or restore function. Measuring pain and function has a scientific history spanning more than three decades. It began with the 36-item Short Form Health Survey and Western Ontario and McMaster Universities Arthritis Index (WOMAC®) in the 1980s. In the late 1990s and early 2000s, joint-specific measurement tools focusing on the knee, hip and shoulder were psychometrically developed and validated. These patient-reported outcome measures (PROMs), self-administered by patients either on paper or electronically, can be easily completed at designated preoperative and postoperative times, when the patient is at home.

ORTHOMIDAS EPISODE OF CARE HAS THE POTENTIAL TO TRANSFORM OUR NATION'S HEALTHCARE SYSTEM

Experience spawns innovative measurement tool

Cleveland Clinic orthopaedists have been national leaders in outcome measurement for over a decade. Joseph P. Iannotti, MD, PhD, Orthopaedic & Rheumatologic Institute Chairman, was instrumental in the design of the widely used Penn Shoulder PROM. I was the principal investigator of the NIH-funded Multicenter Orthopaedic Outcomes Network (MOON) anterior cruciate ligament reconstruction prospective longitudinal cohort that involved following over 3,500 patients at two, six and 10 years. Primary out-

growths of this project were sports-specific knee PROMs. Richard Parker, MD, former Chairman, Department of Orthopaedic Surgery, now Cleveland Clinic Hillcrest Hospital President, was an original member and executive leader in the MOON group.

With this experience behind us, in 2014, our team began designing a new clinical outcome measurement tool to transform orthopaedic surgery into a value-based model of care. We named our resulting tool OrthoMiDaS Episode of Care (OME).

Research-grade evaluation system

The intent of OME is to accurately capture patient-reported outcome measures (relief of pain and restoration of function) in a cost-effective, scientifically valid and scalable manner.

OME is a research-grade clinical outcomes evaluation system that builds on 14 years of experience (NIH-funded MOON and Cleveland Clinic outcomes tracking in orthopaedics), the expertise of over 20 orthopaedic surgeons, the skills of expert statisticians and database/web programmers, and the robustness of a customized REDCap¹ database system.

The program collects three separate data sets to effectively measure, track and, most importantly, scientifically evaluate a patient's pain and/or functional changes after an episode of care. We measure outcomes of orthopaedic surgeries ranging from arthroscopy to every knee, hip and shoulder arthroplasty at several Cleveland Clinic facilities in Northeast Ohio and Florida.

Data sets collected:

- PROMs for pain, function, and quality-of-life status prior to surgery (Figure 1)
- Surgeon capture of procedures performed, including disease severity and proven risk factors, immediately following surgery (Figure 2)
- Same PROMs one year postsurgery (Figure 3)

OME implementation at five Cleveland Clinic hospitals began Jan. 1, 2016. Results thus far (Table 1) have been exceptional, with no additional cost.



Figure 1.
iPad® capture PROM by patient

Validated PROMs tools are administered to patients prior to their orthopaedic surgery to establish baseline health measures specific to the operative joint. Administered electronically, they usually require five to seven minutes to complete.

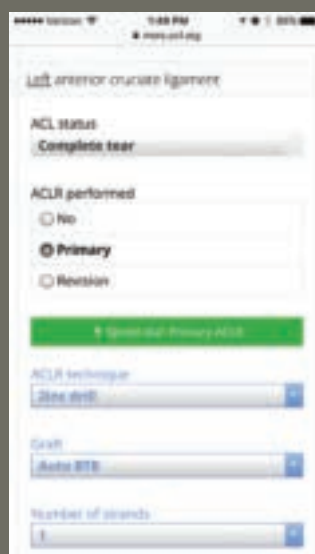


Figure 2.
iPhone® capture by surgeon

Each surgeon receives an email for each patient. This includes forms that document details, including diagnosis, past surgeries, treatment details and implants used, on the surgery just performed. Developed by Cleveland Clinic surgeons, the forms employ complex yet intuitive branching logic to capture information quickly (in two to three minutes) from Cleveland Clinic-issued iPhones.

Cost-effective, scientifically valid and scalable

Cost-effective: The majority of data collection is done electronically using existing technical infrastructure and commodity hardware, and is integrated into the operational workflow so that no additional employees are required and no operating room schedules are delayed.

Scientifically valid: OME has captured baseline data on over 97 percent of 10,095 elective orthopaedic surgeries over the course of 13 months in all knee, hip and shoulder surgeries, from joint replacement to arthroscopic procedures. Thus, initial sampling bias is avoided by having less than 5 percent failure-to-collect outcomes at the outset. Our goal is to collect follow-up data on a minimum of 70 percent of these surgeries, thus reducing follow-up bias.

Scalable: The OME platform currently collects data on orthopaedic surgeries at five high-volume Cleveland Clinic locations, and is slated to expand to other hospitals and ambulatory surgical centers in the future. We also plan to scale to episode-based procedures outside of orthopaedics and use OME as the platform by which large-scale multicenter orthopaedic studies can be performed.

Rich data capture

The rich data capture in OME can accurately adjust a hospital's performance on publicly reported metrics. For example, hospitals are rated for arthroplasty (total hip or total knee) based on lengths of stay, readmissions and infections. The scientific literature has shown that elective revision arthroplasty has longer lengths of stay, higher readmissions and higher infection rates. This should be self-evident given the more complicated and longer surgeries. But Table 2 shows sizable differences in elective revision rates from a few to over 30 percent. Public reporting does not separate primary total knee or hip arthroplasty from revisions, nor does it adjust for revisions. Thus, the publicly reported metric is severely biased against arthroplasty centers of excellence that are referral centers and that perform a high percentage of complicated revision cases.

Prognosis and modifiable predictors

These high-quality data determine both prognostic and modifiable predictors for a patient's clinically relevant outcome of pain and function, the primary reason that they underwent surgery. Using the data we have collected, we are developing risk-adjusted multivariate modeling that will help guide patient and physician decision-making.

We view OME as the "Framingham" cohort of ALL orthopaedic surgeries of the knee, hip and shoulder, and believe it has the potential to transform our nation's healthcare system.

Dr. Spindler is Vice Chairman of Research for the Orthopaedic & Rheumatologic Institute.



Figure 3.
Display of one result for a patient, both before and after

The same PROMs captured at baseline are actively collected at the time of expected peak relief from pain and functional recovery. For the majority of orthopaedic procedures, this occurs at one year. Patients are contacted electronically, or by a research assistant if electronic follow-up is unsuccessful. At one-year follow-up, we also assess return-to-work/sports participation and ask about patients' acceptable symptom state.

TABLE 1. One-Year Data Capture by Procedure

PROCEDURE TYPE	VOLUME
Knee arthroplasty	2,410
Primary	2,100
Total	1,892
Partial	208
Revision	310
Knee arthroscopy	2,368
Primary	2,287
ACLR ²	601
Meniscectomy	1,101
MeTeORB ³	758
PF rep/recc ⁴	97
Arthroscopy	488
Revision	81
Hip arthroplasty	2,347
Primary	2,040
Total	1,673
Resurfacing	367
Revision	307
Hip arthroscopy	444
Primary	424
Revision	20
Shoulder arthroplasty	431
Primary	379
Total	164
Reverse	215
Revision	52
Shoulder arthroscopy	1,515
Primary	1,440
Instability	295
Rotator cuff repair	659
Arthroscopy	486
Revision	75
Other	211
GRAND TOTAL	9,726

TABLE 2. Total Joint Arthroplasty Primary vs. Revision Across Institutions

Site	Primary		Revision		Percent Revision	
	Knee	Hip	Knee	Hip	Knee	Hip
Florida	667	715	105	103	13.6	12.6
Euclid	448	696	25	24	5.3	3.3
Lutheran	619	358	17	11	2.7	3.0
Main Campus	467	395	183	184	28.2	31.8
TOTAL	2,201	2,164	330	322	13.0	13.0

Date range: July 29, 2015 - Dec. 31, 2016

Notes

1. REDCap (Research Electronic Data Capture) is a secure web application for building and managing online surveys and databases. It is available free of charge.
2. Anterior cruciate ligament repair
3. Meniscus Tear in Osteoarthritis Research collaboration
4. Patellofemoral repair reconstruction

EFFICACY OF PREOPERATIVE ASPIRATION IN DIAGNOSIS OF PERIPROSTHETIC JOINT INFECTIONS OF THE SHOULDER

IN SEARCH OF A USEFUL DIAGNOSTIC TOOL

With the number of shoulder arthroplasties expected to quadruple in the coming years, the incidence of periprosthetic joint infections (PJIs) of the shoulder is of great concern to orthopaedic surgeons.

This serious complication of shoulder replacement surgery is associated with poor outcomes, technically difficult revision surgery and increased costs. Accurate diagnosis is crucial to making decisions about treatment, including the decision to proceed with a one- or two-stage revision.



PJI's indolent, nonspecific nature

PJI of the shoulder often presents a diagnostic challenge due to the non-specific clinical presentation and the indolent nature of the common infecting organisms, including *Propionibacterium acnes* (*P. acnes*) and coagulase-negative *Staphylococcus* species. Patients frequently present only with symptoms of pain and stiffness in the shoulder, without other signs of infection.

In addition, standard diagnostic testing, effective in identifying knee and hip PJI, is far less effective in identifying shoulder infections. Serum erythrocyte sedimentation rate and C-reactive protein show sensitivities in the 80 to 90 percent range for PJIs in the hip and knee, compared with less than 50 percent in the shoulder.

What about synovial fluid aspiration?

Preoperative synovial fluid aspiration is an important diagnostic test for shoulder PJIs, as it provides the opportunity to diagnose infection prior to revision surgery. However, obtaining an adequate fluid sample for testing from the shoulder can be more challenging because of the decreased synovial fluid volumes that are present relative to the hip and knee. Due to this increased difficulty in aspirating the shoulder, limited data is available on its efficacy in the diagnosis of shoulder PJI. Our group's recent study sought to determine the rate of successful preoperative synovial fluid aspiration and its effectiveness in the diagnosis of PJI in patients undergoing revision shoulder arthroplasty.

Study design

Our review included 202 cases evaluated for painful shoulder arthroplasties at Cleveland Clinic between January 2009 and February 2015. In 110 cases, a preoperative fluid aspirate was obtained and sent for culture, and 97 of these cases went on to revision arthroplasty surgery. Mean age at the time of surgery was approximately 63 years (range, 29 to 89). We identified all cases of attempted preoperative aspiration to determine the incidence of successful and unsuccessful aspiration. Preoperative synovial fluid culture results were then compared with culture results at the time of revision surgery to determine the efficacy of preoperative synovial fluid aspiration for diagnosis of shoulder PJI.

Culture results: preoperative and intraoperative

Aspiration was attempted preoperatively in 137 of the 202 cases (68 percent), and a fluid sample was obtained and sent for culture in 110 of those cases (80 percent). Of the 137 cases, 27 resulted in a dry tap (20 percent). Samples were culture-positive in 18 percent of cases (20 of 110), with *P. acnes* the most commonly isolated organism (11 of 20, 55 percent). Of the cases in which a preoperative aspirate was obtained, 97 proceeded to revision surgery, including 20 with a positive and 77 with a negative culture of the preoperative aspirate.



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Diagnostic test characteristics for preoperative synovial fluid aspiration as a predictor of shoulder PJI.

This utilizes a definition of PJI based on Musculoskeletal Infection Society criteria, with two or more positive intraoperative cultures of the same organism representing infection.

TABLE. Preoperative Synovial Fluid Aspiration as Predictor of Infection		
STATISTIC	VALUE	95% CI*
Sensitivity	26.3%	15.5% to 39.7%
Specificity	87.5%	73.2% to 95.8%
Positive likelihood ratio	2.11	0.83 to 5.32
Negative likelihood ratio	0.84	0.69 to 1.02
Positive predictive value	75%	50.9% to 91.3%
Negative predictive value	45.5%	34.1% to 57.2%

*Calculated as "exact" Clopper-Pearson confidence intervals

Of those who underwent revision surgery, 59 percent (57 of 97) grew positive intraoperative tissue cultures, with *P. acnes* the most commonly isolated organism (43 of 57, 75 percent). Of the cases with positive preoperative cultures, 16 out of 20 (80 percent) grew positive intraoperative cultures, and the same organism was isolated in 15 of 16 cases. Of the 77 cases with negative preoperative cultures, 41 (53 percent) grew positive intraoperative cultures.

Sensitivity for preoperative aspiration in predicting infection was 26.3 percent and specificity was 87.5 percent, with positive and negative likelihood ratios of 2.11 (95 percent CI 0.83, 5.32) and 0.84 (95 percent CI 0.69, 1.02), respectively. Preoperative aspiration had a 75 percent positive predictive value and a 45.5 percent negative predictive value.

Seventy-five percent (15 of 20) of patients with positive preoperative aspirates had more than 50 percent of their intraoperative cultures turn positive (average percent positive = 70) compared with 34 percent (26 of 77) in those cases with negative preoperative aspirates (average percent positive = 36) ($P = 0.002$). (See Table.)

Preoperative aspiration as a diagnostic tool

In this study, we found that obtaining a preoperative aspiration sample for analysis was possible in the majority of patients (80 percent successful aspiration), and a culture positive sample was highly specific (87.5 percent) for the diagnosis of shoulder PJI. Having a positive preoperative culture was predictive of obtaining a positive intraoperative culture, with the same organism being identified 94 percent of the time, and was significantly associated with having more than 50 percent positive intraoperative cultures.

The timing of diagnosis of PJI can be important in determining management of this complex complication. When PJI is identified prior to or at the time of revision surgery, it can significantly impact treatment decision-making.

Dr. Iannotti is Chairman of the Orthopaedic & Rheumatologic Institute. Dr. Ricchetti is staff in the Department of Orthopaedic Surgery.

IMAGE OF THE ISSUE



Figures.

A 78-year-old male with debilitating left leg pain was treated with lateral lumbar interbody fusion and percutaneous instrumentation.

Top images: Preoperative anterior-posterior and lateral X-rays showing rotatory subluxation of lumbar 2-3.

Bottom images: Three-month postoperative images showing restored alignment. The patient reported complete resolution of pain.



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Lateral Lumbar Interbody Fusion: A New and Useful Tool for the Spine Surgeon

With minimal-access lateral lumbar interbody fusion (LLIF), spine surgeons perform anterior interbody fusions through 2- to 4-cm incisions using a tubular retractor. The access corridor is through the bulk of the psoas muscle. Stimulated electromyographic monitoring helps prevent injury to nerves. Placing large interbody implants can help restore alignment of the spine in both the frontal and sagittal planes. In most studies, LLIF has shown high fusion rates and relatively low complication rates.

Dr. Orr is a spine surgeon in the Center for Spine Health.

OPEN KNEE(S) – GENERATION 2 MAKES VIRTUAL KNEE MODELS, SIMULATION AVAILABLE FOR RESEARCH WORLDWIDE

ELABORATE EXPERIMENTATION YIELDS OPEN-SOURCE VIRTUAL SPECIMENS



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The Open Knee(s) project, a free, downloadable, 3-D biomechanical representation of the knee, has the potential to answer knee specialists' trickiest clinical questions, such as:

- Which ACL reconstruction is best for a particular patient?
- How would patellar alignment stabilize patellofemoral joint movement? Will it increase cartilage contact pressures?
- What change in implant design will reproduce more natural knee movements? Will it fail? Will host tissue be safe?

Open Knee(s)' goal is to provide an open, freely available and collaborative development, testing, simulation and dissemination platform for virtual exploration of the biomechanics of healthy and diseased knees. Our mission, through this holistic approach to biomechanical modeling and simulation, is to advance orthopaedic science and support clinical decision-making. We like to call Open Knee(s) the democratization of modeling and simulation in biomechanics.

Generation 2 expands data

Open Knee(s) – Generation 1, our pilot, was launched in 2010 and clearly demonstrated the interest in such models. Generation 2 launched in 2013 and, when complete, will offer much higher fidelity as a result of far more detailed analysis of additional specimens.

OPEN KNEE(S) IS CREATING
DEPENDABLE, REUSABLE, PUBLICLY
ACCESSIBLE AND SHAREABLE VIRTUAL
KNEE MODELS THAT ARE FAITHFUL TO
SPECIMEN-SPECIFIC ANATOMY AND
MECHANICS

In Generation 2, each of our eight cadaveric specimens will have its own specific virtual replica. These virtual models, which include healthy and diseased/osteoarthritic knee

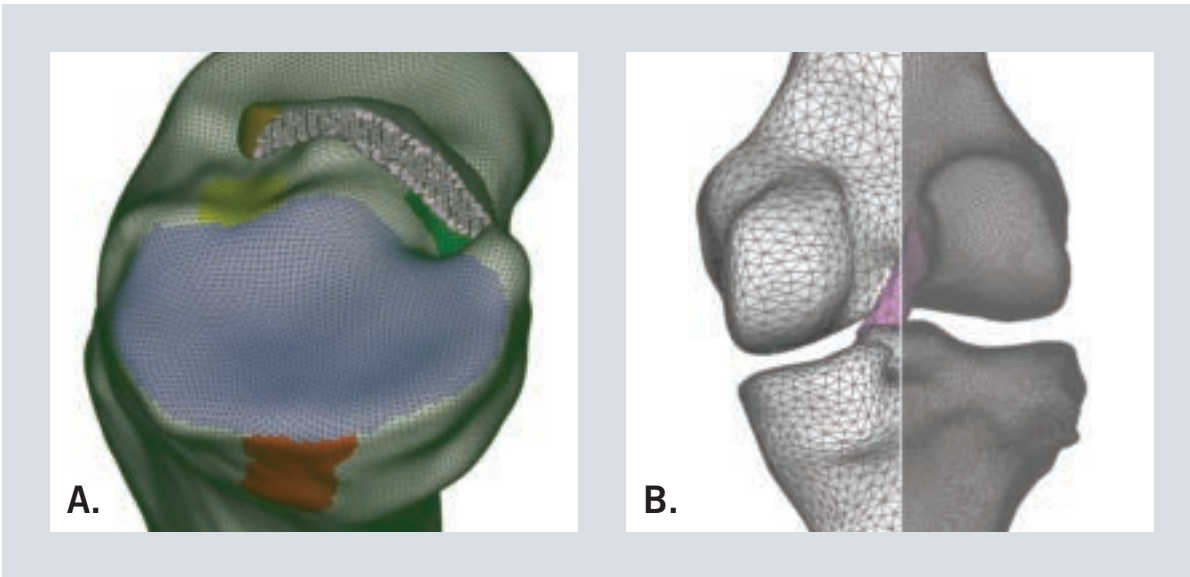
joints representing different genders and ages, have been created through analysis of specimen-specific anatomical imaging and joint- and tissue-level experimental mechanics. We put each cadaveric joint through a battery of robotic tests to quantify joint movement under known loads, where both tibiofemoral and patellofemoral joint mechanics can be fully characterized. Magnetic resonance imaging allows us to reconstruct overall joint geometry and individual tissue boundaries. Tissue mechanical testing — on 30 tissues samples from each knee — provides information on material properties. This elaborate data set will help us assemble and validate very accurate computational virtual representations of the knee. (Figures A, B.)

We are the only group attempting to acquire both joint mechanics data and tissue properties from the same specimen. Anatomical imaging and joint mechanics testing for all specimens are already publicly disseminated on the project site. Tissue mechanical testing and development of models are in progress. Publication of Generation 2 data and models and dependable virtual representations for both tibiofemoral and patellofemoral joints will be available soon.

Popular download

To date, Open Knee(s) has been downloaded about 9,200 times and has been utilized for 37 peer-reviewed articles, abstracts and theses worldwide. Soon to be cloud-based, the open-source environment encourages scientifically and clinically oriented use as well as educational endeavors for those simply curious about knee mechanics.

Developed by researchers in Cleveland Clinic's Computational Biomodeling (CoBi) Core lab, Open Knee(s) is funded through a \$2 million grant from the National Institute of General Medical Sciences, National Institutes of Health. Collaborators include researchers from Case Western Reserve University (Cleveland), Stanford University, University of Utah, Cleveland Clinic Lerner Research Institute and elsewhere. An advisory board of expert physicians oversees our work.

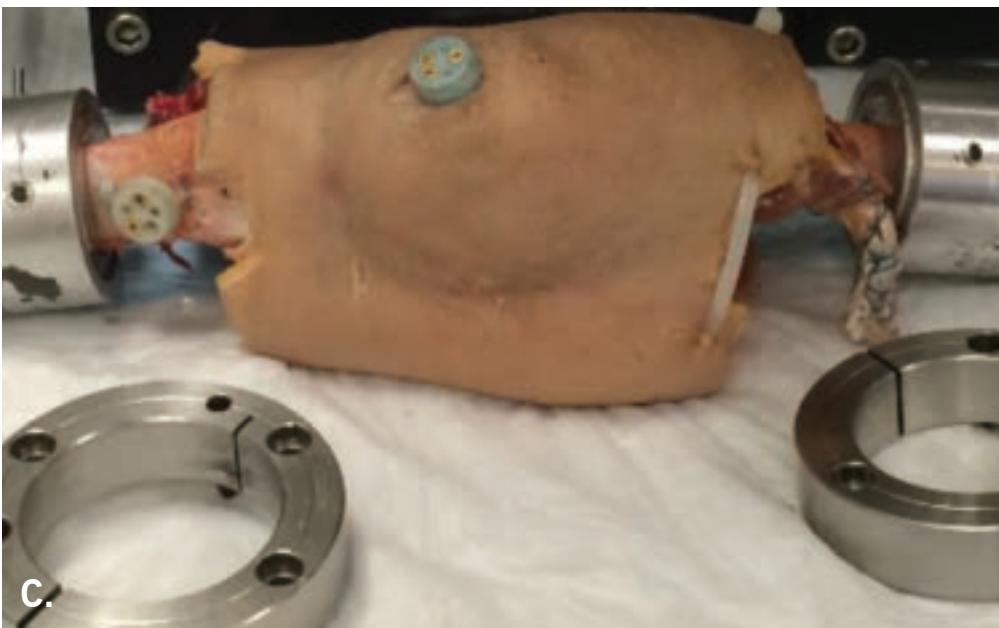


**Figures.
Open Knee(s)**

A. Unsupervised model assembly strategies identify regions where tissues are connected to each other (highlighted). Tibia mesh along with the cross-section of the posterior cruciate ligament mesh are shown.

B. Automated model assembly strategies can help customize components of the knee models with ease, i.e. coarse meshes of tissues can be replaced by finer versions.

C. & D. Cadaveric specimens in preparation for joint testing.



What's next for Open Knee(s)?

We are continuing collection of tissue-level data and development of models. Tissue samples from specimens are frozen for future scientific needs, clinical exploration, injury simulations or even device design. We plan to launch a cloud computing framework in the upcoming year and develop simulations of common disease states, including osteoarthritis, meniscal deficiency and conditions influenced by ligament mechanics.

Hastening the pace of knee research

Open Knee(s) is creating dependable, reusable, publicly accessible and sharable virtual knee models that are faithful to specimen-specific anatomy and mechanics for use by researchers worldwide. We hope this effort helps speed the translation of innovation into intervention and improves clinical care in a cost-effective way.

Funding for Open Knee(s) is provided by the National Institute of General Medical Sciences, NIH (award number R01GM104139).

Dr. Erdemir is a staff member in the Department of Biomedical Engineering, Lerner Research Institute. He leads the Open Knee(s) project.

CARING FOR NEUROMUSCULAR GIANTS AND GENIUSES

CLEVELAND CAVALIERS AND CLEVELAND INDIANS TEAM PHYSICIANS TALK SPORTS MEDICINE



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Dr. Parker (right) with now-retired Cleveland Cavaliers team physician and Cleveland Clinic colleague A.J. Cianflocco, MD.

Richard Parker, MD, and Mark Schickendantz, MD, team physicians for the Cleveland Cavaliers and the Cleveland Indians, respectively, discuss being in the fishbowl, what's different about elite athletes and the quiet room (interviews have been condensed and edited).

Richard Parker, MD

Q. What is it like caring for elite athletes?

My mentor, John Bergfeld [Cleveland Clinic's John Bergfeld, MD, former Head Team Physician for the Cavaliers and Browns], always called players "neuromuscular giants" or "neuromuscular geniuses." They have exceptional physical abilities, but they also compete against other exceptional athletes so that they need to be as close to 100 percent healthy as possible.

Their proprioception is incredible. They routinely jump vertically in the middle of a bunch of people and know how to land and fall. If they have an injury, they can tell you exactly what happened. They can put the scenario into slow motion because they are so aware of their bodies — that's what we mean by being neuromuscular geniuses. These players are truly wired differently. Also, if they do get injured, their ability to recover is phenomenal.



Q. What injuries do you treat most often?

Injuries are inevitable, and I think it's amazing that we don't have more. I think that's a testament to the incredible athleticism of these professionals. We see a lot of macrotraumatic injuries in which the athlete lands incorrectly on an ankle or gets elbowed in the nose. In basketball, we see mostly foot and ankle and then hand injuries, and a fair amount of facial injuries. I work with an incredible team of consultants — in hand, foot and ankle, oral surgery, plastic surgery, you name it.

The second category is overuse injury. We now have testing that helps predict when a player is starting to lose strength in an area and is prone to an overuse injury. If I'm seeing an athlete who is having soreness, or I suspect that he may have a stress fracture or a stress reaction in his right foot, I image both feet. The things I've picked up over the years that have saved the player years of his career are pretty interesting.

The third category is acute injury on overuse. Former Cavs center Zydrunas Ilgauskas is an example. "Z" had an interesting problem. His feet were too small for his body and he had high arches. He had surgery before I was his team physician and it was an excellent procedure, but it didn't heal properly.

When he was injured in 2000, "Z" and I traveled the country to various foot and ankle surgeons to get their opinions. We ended up recommending a procedure that realigned his foot and refixed the fracture, and then somehow sold him and the entire organization on a two-year recovery. We limited minutes, didn't let him play back-to-backs.

He was not happy with me, nor was the coach, but it extended his career. He had several great years with the Cavaliers and retired on his own terms.

Q. What's changed in your practice?

A lot. For instance, we have motion sensors and information available that can predict when somebody is starting to become fatigued and needs to get some rest. The data is getting more and more sophisticated, and coaches buy in.

Q. What's it like being a physician in the spotlight?

When you work with a team like the Cavs, you're practicing in a fishbowl. Everyone second guesses what you do; it's on ESPN, talk radio, the front page of the newspaper. There's a huge commitment of time, of communication, of checking your ego at the door and of really doing what's best for the player. I work with an incredible team of physicians and healthcare providers all focused on the health of these athletes.

Q. Describe being there when the Cleveland Cavaliers won the NBA Championship.

Well, I tweeted a picture of me with the trophy, and I said I couldn't describe it. It was a surreal feeling, especially because it happened so quickly at the end. My job as team physician is to stay focused on the patient, the athlete, and not get wrapped up in the game. I'm pretty good at that during the season, but it was tough during the playoffs. The win was truly surreal.

Dr. Parker is President of Cleveland Clinic Hillcrest Hospital, a staff orthopaedic surgeon and Head Team Physician for the Cleveland Cavaliers since 2000.

Mark Schickendantz, MD

Q. Describe your medical team for the Cleveland Indians.

The head athletic trainer used to oversee everything. Now the senior medical director, a relatively new position in baseball, manages the administrative side of medical care. He and I work side by side to organize care for the players. We have athletic trainers, physical therapists, a strength conditioning coach and nutritionists. We also have a wonderful complement of alternative or nontraditional medical providers. We have had an acupuncturist for several years now, and we offer chiropractic care and massage therapy.

On the physician side, we have a large group, including four surgeons, a medical provider and a primary care sports medicine physician. The beauty of working at Cleveland Clinic is having access to some of the best subspecialists in the world for anything you can imagine. We've got an extensive list of consultants whom we work with regularly.

Q. What's changed over the years?

Our diagnostic capabilities have improved and our understanding of the throwing athlete, in particular pitchers, has evolved. I think we're better at what we do, and over the past five years, we have begun to operate less than we used to. But the most important change is our understanding that certain things in these athletes' anatomy, in particular their shoulders and elbows, are necessary for them to do what they do, and if we overcorrect them, it can be problematic. We've actually become more conservative.

If you look at an MRI of the shoulder of a professional baseball player, there are all sorts of things that are going

to scare you to death. But they don't bother him. In fact, they're necessary for him to do what he does. If you change that, correct it, you've ruined him.

They're wired differently, and it's remarkable to watch. It really is.



Dr. Schickendantz with Cleveland Indians First Base Coach Sandy Alomar Jr.

Q. Tell us more about preventive care in the pros.

We take a holistic approach. We don't just manage orthopaedic or medical needs, but players' nutritional and psychological needs as well. During spring training, athletes have a lecture from a sleep expert. At Progressive Field [home of the Indians], we have a quiet room with comfortable chairs where the guys can take a nap. It's amazing to walk into our athletic training room and see five guys with acupuncture needles in them.

We also offer nutrition services and cooking classes for significant others. If there are certain dietary restrictions, we understand that.

Physical examinations during spring training are amazingly complete. We do a very sophisticated visual analysis, a dental screening — anything you can possibly imagine, we offer our guys. They get good total healthcare, not just injury care, and it's very much a whole-body approach.

Q. Do you love being a team physician?

It's a very different style of practice, and yes, it is exciting. You're certainly much more under the microscope when you're dealing with pro athletes. When agents and coaches and others get involved, you just have to stick to the medicine and always do what's right for your athlete, regardless of the background noise. Never ever bow to pressure from an outside source that is to the detriment of the health of the athlete. Ever. Even if it costs you your job. You have to be willing to do that.

Dr. Schickendantz is in his 26th season as Head Team Physician for the Cleveland Indians, the 2016 American League champions. He also is Director of the Center for Sports Health.

ELEVATING ARTHROSCOPY SKILLS WITH NEW INTERACTIVE CURRICULUM, SIMULATION

HIGH-TECH EDUCATIONAL PROGRAM SCORES WELL



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As orthopaedic surgery faculty members, we have the honor of and responsibility for educating future generations of residents and fellows. Yet most faculty have never received formal instruction in how to teach or plan educational experiences. Recognizing this opportunity 15 years ago led to the genesis of the Orthopaedic Skills Laboratory at Cleveland Clinic.

The laboratory allows staff to work side by side with residents in a wet lab setting, utilizing cadaver specimens to teach surgical skills necessary for developing competence in various orthopaedic surgical techniques. The facility provides the opportunity to elevate mentors' educational abilities, creates a uniform approach to instruction and standardizes implementation of procedural skills for residents and fellows.

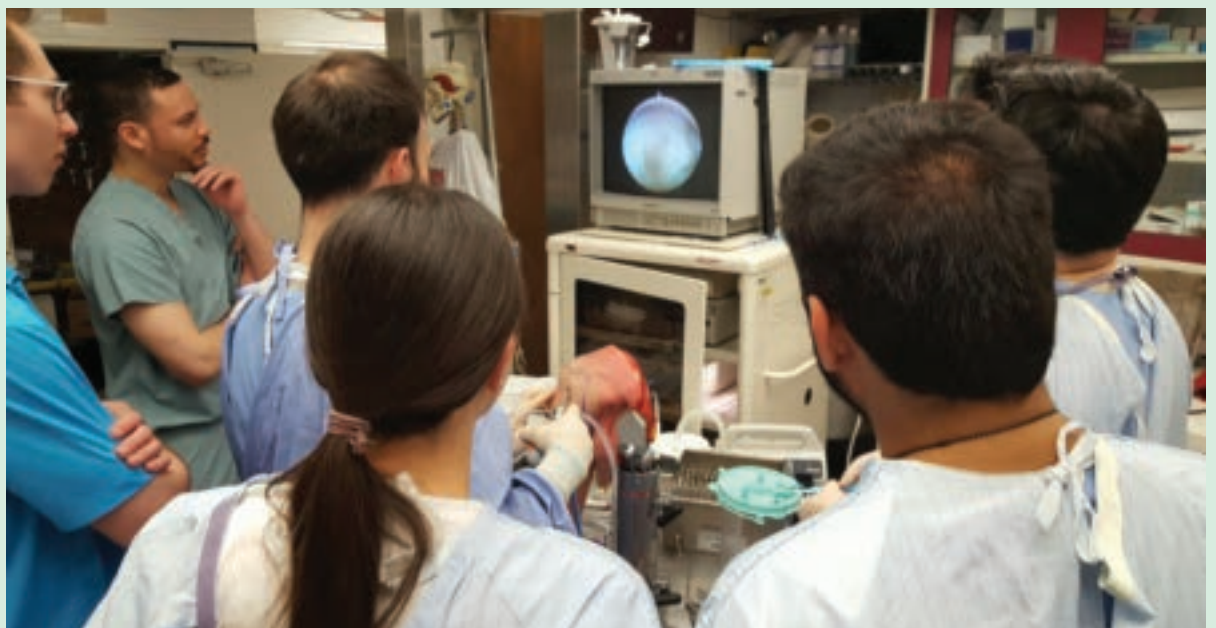
Our Arthroscopy Skills Curriculum, developed shortly after the laboratory was established, has earned the accolades of participants and has been honored externally with a Scholarship in Teaching Award from Case Western Reserve University School of Medicine.

Curriculum and methods need to evolve

A successful curriculum needs to evolve based on evaluation results and changes in resources, targeted learners and materials requiring mastery.

Subjectively, it appeared that we were achieving our goals of successfully teaching residents and fellows how to perform arthroscopic procedures. And faculty learned how to teach within the format of a laboratory procedural skills curriculum. However, we recognized that opportunities were within our grasp to make the program far more objective, effective and validated. It was time for the next step in our program's evolution and to take advantage of a plethora of new teaching technologies.

We began by gathering information from colleagues in various other departments at Cleveland Clinic who were in various stages of developing specific skills laboratories. We then evaluated state-of-the-art arthroscopic simulators and began to develop a validated multimedia, web-based, next-generation curriculum.



Next-gen education arrives

Now, our online curriculum is organized into knee, shoulder and hip modules, with elbow and ankle modules soon to follow. We developed videos of attending surgeons and fellows performing or narrating diagnostic arthroscopies. Interactive medical illustrations were embedded in video to demonstrate neurovascular structures at risk and how to avoid them during procedures. We uploaded still images (normal and pathologic), PowerPoint presentations, academic day lectures and assigned reading from pertinent, evidence-based reference materials.

The arthroscopic simulator is integral to our educational strategy. This objective tool offers various learning opportunities for residents and fellows at all levels of training. Evaluation consists of a pre-test, cognitive online test (multiple choice, short answer), testing of motor skills on simulator, a post-test formulated from a bank of test questions developed in-house and a survey after completion of the course. All test data are assessed prior to a student's progression to more advanced cases.

The Center for Technology-Enhanced Knowledge and Instruction, housed within the Cleveland Clinic Education Institute, was instrumental in the translation of our new curriculum into a web-based digital format.

Skills increase, outcomes improve

Our 44 residents, three sports fellows and three shoulder and elbow fellows, plus 10 sports and shoulder/upper extremity physician assistants, are the primary participants in this annual academic program led by Department of Orthopaedic Surgery staff.

Students' post-tests demonstrate definite improvements in arthroscopy skills as well as better arthroscopic anatomic awareness, with measurable effects. In addition, physical therapists and certified athletic trainers are able to observe procedures in the lab, benefiting secondarily through increased knowledge of arthroscopic anatomy and procedural nuances. This may have even larger implications for patients' postoperative care and rehabilitation.

As we continue to analyze the program's effectiveness and learner feedback, we anticipate further evolution of our Arthroscopy Skills Curriculum. It has already been proven effective, impactful, measurable and relevant, and has resulted in better patient outcomes by elevating the competence of our trainees.

Dr. Saluan is Director of Pediatric and Adolescent Sports Medicine and an Assistant Professor at Cleveland Clinic Lerner College of Medicine.

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SUMMER 2017

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