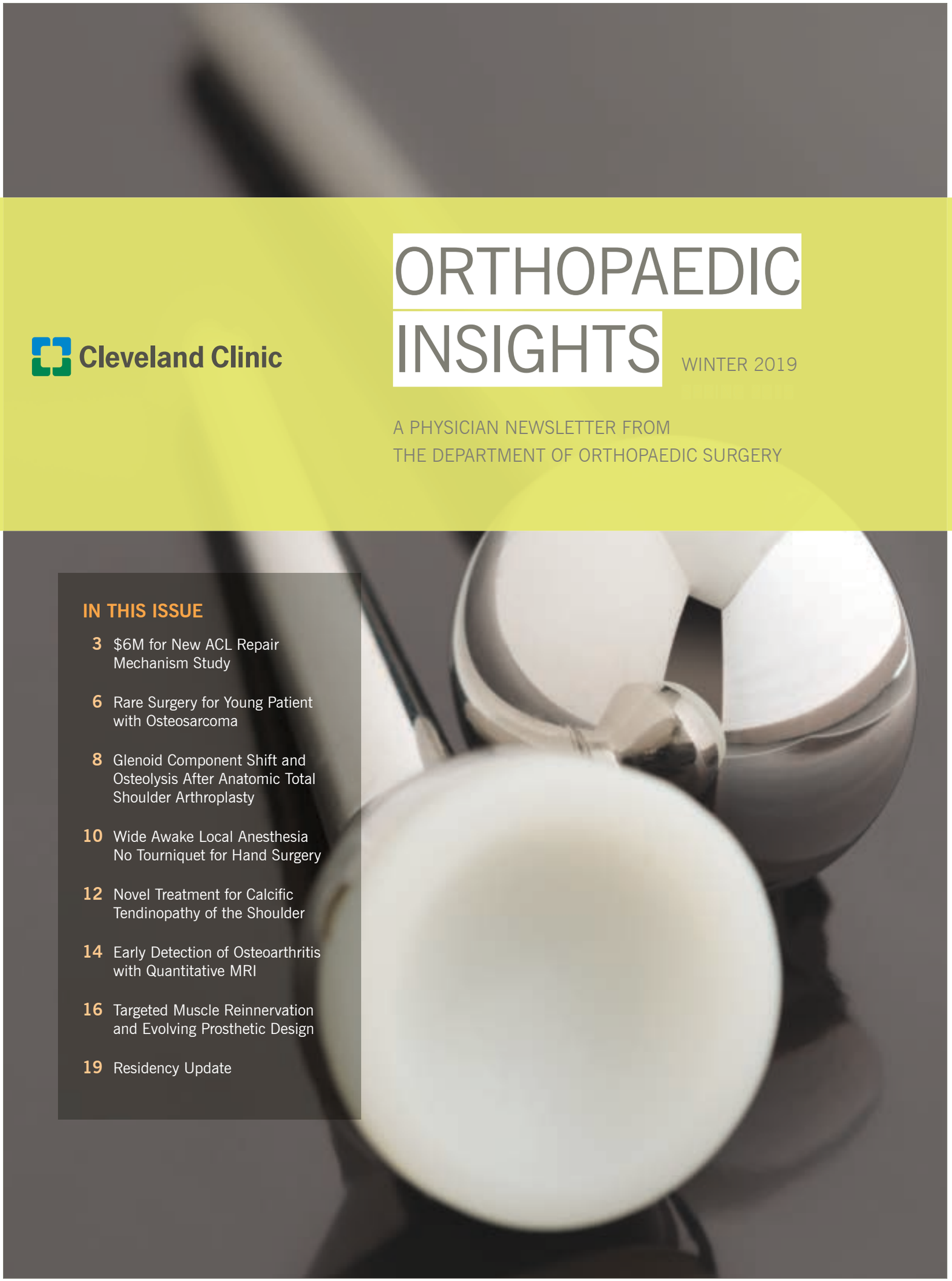
Cleveland Clinic

ORTHOPAEDIC INSIGHTS

WINTER 2019

A PHYSICIAN NEWSLETTER FROM
THE DEPARTMENT OF ORTHOPAEDIC SURGERY



IN THIS ISSUE

DEAR COLLEAGUES

It is my great honor to have been asked to lead Cleveland Clinic's Department of Orthopaedic Surgery — a department that has always put our patients first, pioneering innovative techniques and technologies to treat their injury or disease.

For more than 10 years, we've published *Orthopaedic Insights* to share some of the work being done by our caregivers. I think, like me, you will find the content in this issue especially compelling, including:

- Our cover story on a potential paradigm-changer for common ACL injuries, which could move us from autograft ACL reconstruction surgery to a procedure known as bridge-enhanced ACL repair (BEAR) (p. 3).
- A rare surgery that changed the life of a 4-year-old boy diagnosed with high-grade osteosarcoma in the distal femur (p. 6).
- An overview of the methodology, findings and implications of a study that evaluated glenoid component position and radiolucency using 3D CT imaging analysis methods (p. 8).
- A surgical technique being evaluated for hand and upper extremity operations for carpal tunnel syndrome, trigger finger, cyst removal, tenosynovitis/tendinitis and a variety of other diagnoses (p. 10).
- A novel treatment for calcific tendinopathy of the shoulder. This office-based ultrasound-guided percutaneous ultrasonic tendon debridement procedure is a less invasive alternative to address calcific tendinopathies (p. 12).
- The use of quantitative MRI for early detection of osteoarthritis (p. 14).
- A look at targeted muscle reinnervation, an emerging technique that can reduce the dysfunction and pain that upper extremity amputees experience and help others with painful neuromas stemming from isolated nerve injuries (p. 16).

I am truly in awe of the expertise, inventiveness, collaboration and commitment of this team of professionals. On behalf of the entire team, I extend deep gratitude to Joseph P. Iannotti, MD, PhD, for his servant leadership as our institute Chair and the efforts he made as acting chair of this department in the past year.

I look forward to getting to know you better in my new role and encourage your questions and comments.

> ***"A patient is not dependent on us — we are dependent on them. A patient is not an interruption of our work — it is the purpose of it."***
>
> ***— Willliam E. Lower, MD***
> ***Co-Founder of Cleveland Clinic, 1921***

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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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STUDY OF NEW ACL REPAIR MECHANISM RECEIVES $6M IN NIH SUPPORT

A POTENTIAL PARADIGM CHANGE FOR COMMON ORTHOPAEDIC INJURY

Anterior cruciate ligament (ACL) tears are common injuries in athletes and nonathletes alike. An estimated 400,000 patients each year suffer an ACL injury. Like other intra-articular tissue injuries, ACL injuries don't heal spontaneously. The current gold-standard surgical treatment — autograft ACL reconstruction — stabilizes the knee, but has a number of drawbacks. It compromises uninjured structures to obtain an autograft, results in less than satisfactory outcomes in about 20 percent of cases and leaves patients with a propensity to develop early posttraumatic osteoarthritis (PTOA).

For two decades, a team led by Martha Murray, MD, at Boston Children's Hospital has been researching alternatives based on use of an implanted tissue-engineered scaffold-like device that fosters healing. Successful preclinical studies led the way to two FDA-approved preliminary clinical trials (the first-in-human cohort study, BEAR I, and a small, single-center randomized control trial, BEAR II) and now to the start of a large multicenter, blinded, randomized clinical trial.

The procedure is known as bridge-enhanced ACL repair (BEAR), and it has been shown to achieve knee stability and reduce PTOA in early trials.

$6M NIH grant

The new trial, BEAR MOON, is supported by a $6 million RO1 grant from the National Institute of Arthritis and Musculoskeletal and Skin Diseases, part of the National Institutes of Health (NIH).

The Multicenter Orthopaedic Outcomes Network (MOON) Group was created in 2002 to enroll and longitudinally follow a large population cohort of ACL reconstructions. The NIH-funded consortium includes 18 sports medicine

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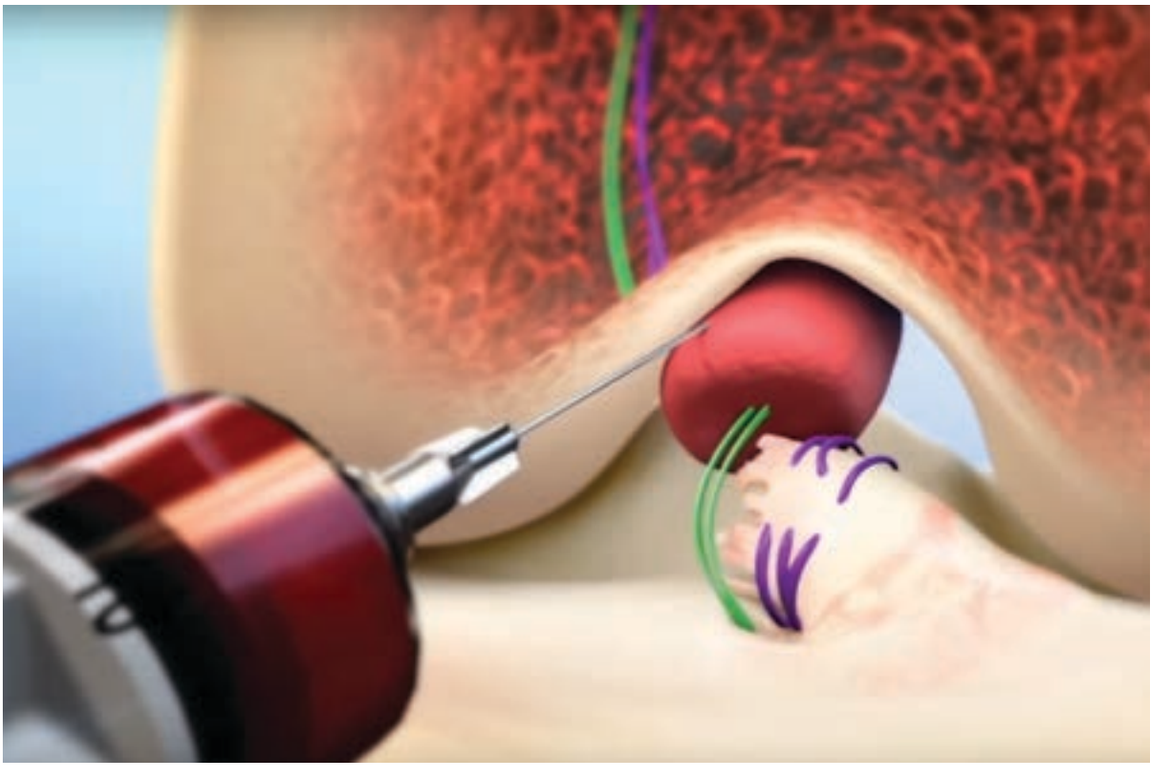

Figure 1

BEAR implant is placed between torn ACL ends. Blood drawn from the patient is added. Torn ACL ends are then pulled into the implant with stitches. ***(Photo credit: Boston Children's Hospital)***

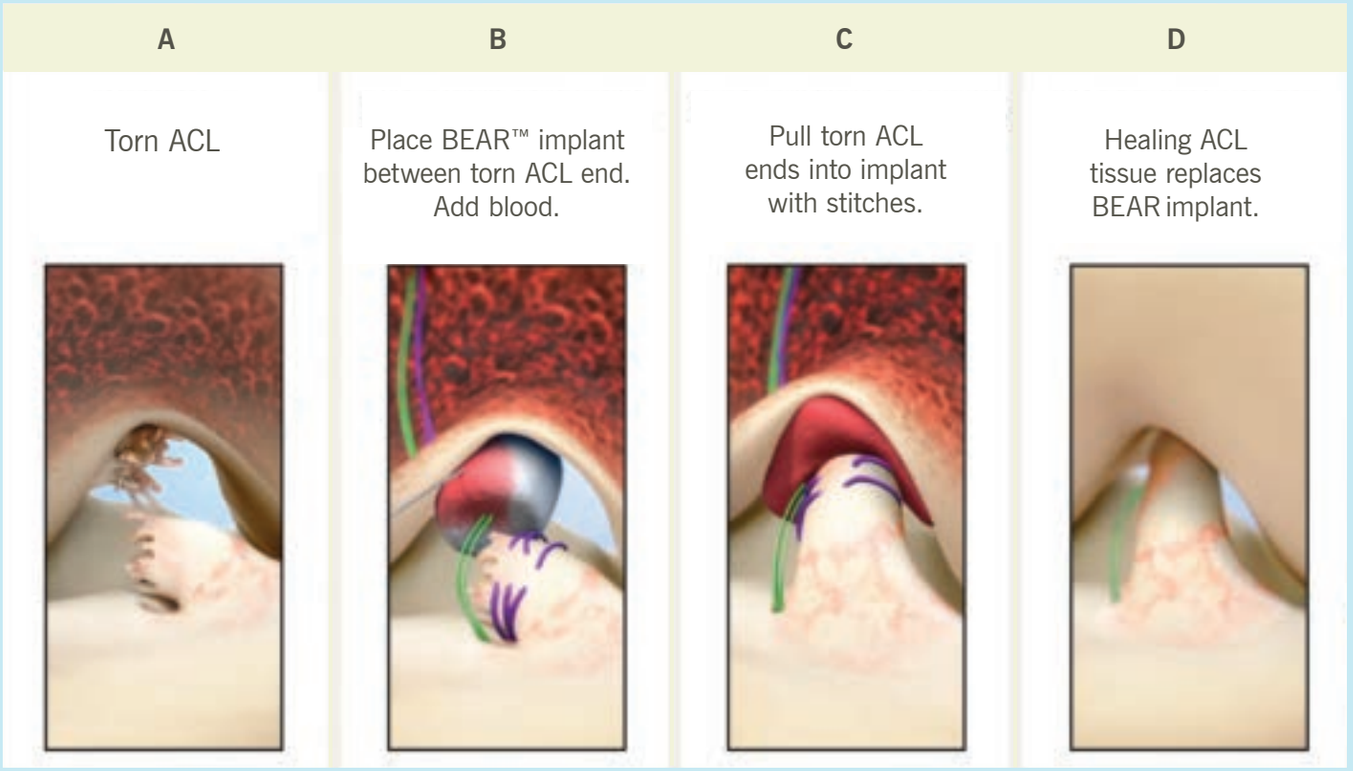

Figure 2. From injury to healing. ***(Photo credit: Boston Children's Hospital)***

physicians across seven sites. The group has enrolled over 3,500 ACL reconstruction patients to establish the largest level I prospective ACL reconstruction outcomes database.

The BEAR MOON study will enroll patients at The Ohio State Jameson Crane Sports Medicine Institute, Washington University Department of Orthopaedic Surgery, Rhode Island Hospital Department of Orthopaedics, Vanderbilt University Department of Orthopaedic Surgery and Cleveland Clinic Department of Orthopaedic Surgery.

BRIDGE-ENHANCED ACL REPAIR (BEAR) HAS BEEN SHOWN TO ACHIEVE KNEE STABILITY AND REDUCE POST-TRAUMATIC OSTEOARTHRITIS IN EARLY TRIALS.

Conventional ACL repair involves replacement of the ligament with autologous tissue harvested from either the hamstring or patellar tendon. It is a complex procedure that has a high rate of success in terms of return to sports and activities of daily living. But the failure rate is high in adolescents. There is some graft site morbidity, and PTOA is not prevented.

With some 400,000 ACL procedures performed annually in this country, BEAR has the potential to be that novel, paradigm-changing technology that prevents graft harvest morbidity and delays PTOA.

The study is recruiting 200 patients, with half undergoing the BEAR procedure and the other half standard autograft patellar tendon reconstruction. Subjects must be between 18 and 40 years of age with a complete ACL tear. The surgery needs to take place within 50 days of injury.

The goal is to demonstrate the noninferiority of BEAR when compared with ACL reconstruction for the key outcomes of anterior-posterior knee laxity and patient-reported outcome using the International Knee Documentation Committee (IKDC) validated measure. Patients will be followed at six months, one year and two years after surgery.

BEAR procedure

In the BEAR procedure, we are not just stitching the ACL together. The magic — the key to making it work — is the scaffold.

The procedure begins with drilling small tunnels in order to place a suture into the ACL fibers and to stabilize the knee. The tissue-engineered scaffold is implanted through a small incision in the knee (Figure 1). Surgeons then pull the stitched ACL tibial stump into the scaffold as the knee is extended. The patient's own blood is applied to the scaffold to provide growth factors and stimulate healing (Figure 2).

Patients should be able to return to normal activities in a few months and to sports in about nine months — a somewhat longer recovery than with conventional ACL surgery.

Expected results

Our group expects earlier improved range of motion and knee kinematics in the short term and no graft harvest morbidity. BEAR's potential long-term advantage is reduced PTOA compared with reconstruction, which has been demonstrated in animal models. Direct costs should be comparable to those of conventional ACL reconstruction, but savings are conceivable as a result of reducing the rate of PTOA.

Our goal in this trial is to see whether we can duplicate the earlier single-center study results on a multicenter and multisurgeon level. While achieving these aims may change the clinical practice of ACL surgery, the impact is potentially even greater. The availability of an FDA-approved scaffold, carrier or delivery vehicle for complex biologic therapies to tissues within joints could speed research translation in multiple areas of regenerative medicine.

WITH SOME 400,000 ACL PROCEDURES PERFORMED ANNUALLY IN THIS COUNTRY, BEAR HAS THE POTENTIAL TO BE THAT NOVEL, PARADIGM-CHANGING TECHNOLOGY THAT PREVENTS GRAFT HARVEST MORBIDITY AND DELAYS PTOA.

Dr. Spindler is an orthopaedic surgeon and Vice Chairman of Research, Cleveland Clinic Orthopaedic & Rheumatologic Institute. He is a principal investigator with the MOON group, as well as the group's founder.

EIlen McErlean, MSN, RN, FAHA, is coordinating this study. Contact her at mcerlee@ccf.org.

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RARE SURGERY HELPS YOUNG PATIENT WITH OSTEOSARCOMA REMAIN ACTIVE

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In September 2014, a 4-year-old boy with pain in his left knee was referred by his pediatrician to Cleveland Clinic's Musculoskeletal Tumor Center/Pediatric Oncology, where physicians diagnosed a high-grade osteosarcoma in the distal femur (Figures 1, 2). Neoadjuvant chemotherapy was provided. The patient received 10 weeks of a multidrug regimen that included methotrexate and adriamycin. Study of the en bloc resected specimen after initial chemotherapy showed necrosis of 90 percent of the tumor cells.

After that initial chemotherapy, we faced a dilemma in terms of reconstruction because of the patient's age and the immaturity of his bone. Treatment options for osteosarcoma include above-knee amputation and limb salvage with an internal expandable prosthesis that can be lengthened under a high-powered magnet. In this case, however, the child was not a candidate for an expandable implantable prosthetic device because such devices are made only for older children with larger bones.

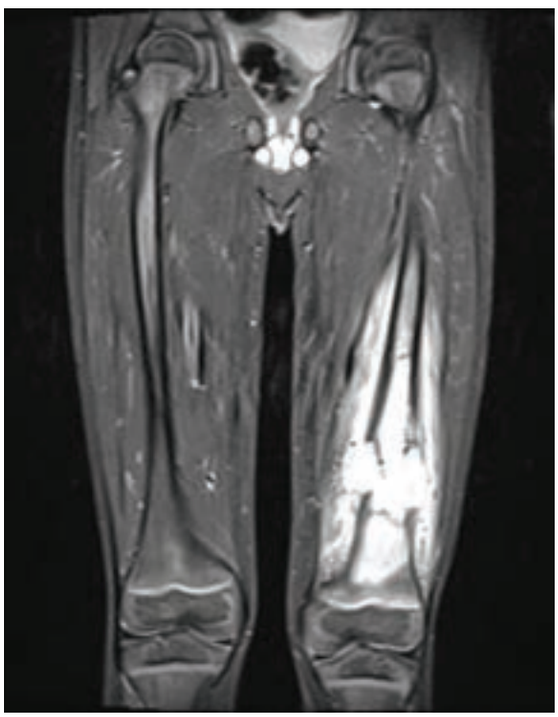
Strange appearance, high functionality

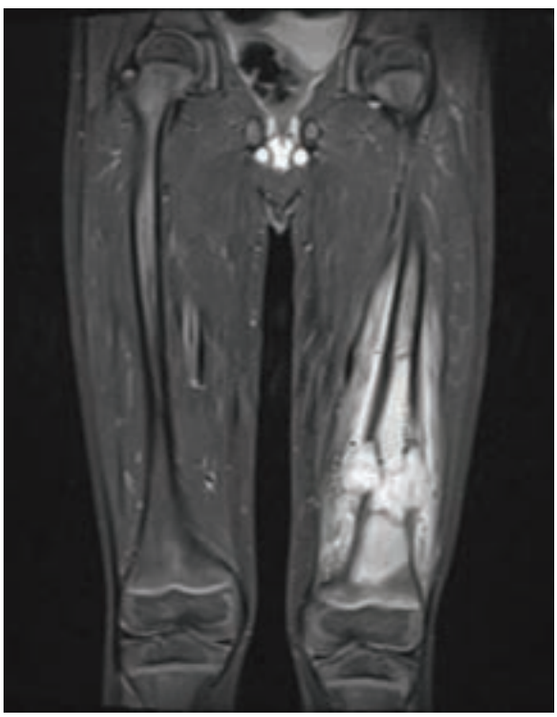
A different limb-salvage surgery called rotationplasty seemed to be the best option. The procedure involves resecting the distal femur while retaining the femoral artery and sciatic nerve. The remaining limb is then rotated 180 degrees and reattached so the foot is pointing backward and becomes the future knee joint.

Rotationplasty is a rare procedure that was first described in the 1930s to treat femoral infection problems in patients with tuberculosis. Later, in the 1940s and 1950s, it was further used to treat children with proximal femoral focal deficiency, a rare birth defect. In the 1980s, European physicians adapted it for musculoskeletal tumors.

Rotationplasty in this situation is the best choice for patients, especially those who want to play sports, because the procedure creates a functional knee-like joint out of the patient's foot and ankle that is far superior to any above-knee amputation fitted with an external prosthesis. Patients who choose rotationplasty have a more serviceable limb than those who choose an above-knee amputation. This is especially true in younger children — ages 3 to 7 — who still have a great deal of growing left to do.

Studies have shown that patients who opt for the procedure have significantly higher functional scores on the Musculoskeletal Tumor Society assessment and health-





Figures 1 and 2

Osteosarcoma in the 4-year-old patient's left femur.

related quality-of-life assessments than patients who opt for an above-knee amputation insofar as they perform as a below-knee prosthetic wearer.

Rotationplasty is still rarely done, however, mainly because many osteosarcoma patients — the largest number of whom are teenagers — do not like the appearance of the backward foot at the end of the stump. In addition, because of their skeletal maturity, such patients are good candidates for reconstruction with metallic prostheses or allograft bone prosthetic replacement.

More chemotherapy

In this case, the rotationplasty was performed in November 2014. The surgery involved cutting out the distal femur to the knee joint, leaving wide margins around the tumor. The superficial femoral artery and the sciatic nerve and its branches were then coiled and the entire tibia was rotated 180 degrees. The distal femur was then inset in the proximal tibia using a metal plate to anchor and support the bone junction through the healing period (Figure 3).

Within about three weeks of the surgery, the patient began a new five-month round of chemotherapy. Such treatment is critical to kill any residual cancer cells shed by the osteosarcoma into the patient's bloodstream before the tumor was removed. Without chemotherapy, a patient with osteosarcoma may have only about a 10 percent chance of survival. With post-surgical chemotherapy — as long as there is 90-95 percent necrosis of tumor cells in response to the neoadjuvant chemotherapy — the five-year survivorship rate is over 90 percent.

The patient finished chemotherapy in May 2015 and was cleared to be fitted for a prosthetic leg that would accommodate his new limb. By January 2017, he was running and jumping and still cancer-free.

Takeaways

Healing — It is difficult for the bones to heal after surgery because chemotherapy must be started within a few weeks of surgery, and the drugs hinder bone regeneration. If a patient has complications (wound healing problems, too close of a margin, infection) during the short healing period before chemotherapy, surgeons may decide to go back and amputate so that chemotherapy is not delayed.

Complications — Adriamycin is a very toxic drug that can cause cardiomyopathy, long-term heart problems and, on rare occasions, death. Methotrexate also can be quite toxic. In addition, chemotherapy drugs may make patients infertile, so it's appropriate to consider sperm or egg banking.

Tumor margins — It's up to the surgeons to get good tumor margins. Poor margins lead to local tumor recurrence with decreasing survival rates.

Symmetry — With younger patients, surgeons must calculate how much growth will occur in the proximal femur, so that when the child is done growing, their rotated ankle matches the level of the knee on the other side.

Dr. Joyce is retired consultant staff in the Department of Orthopaedic Surgery.

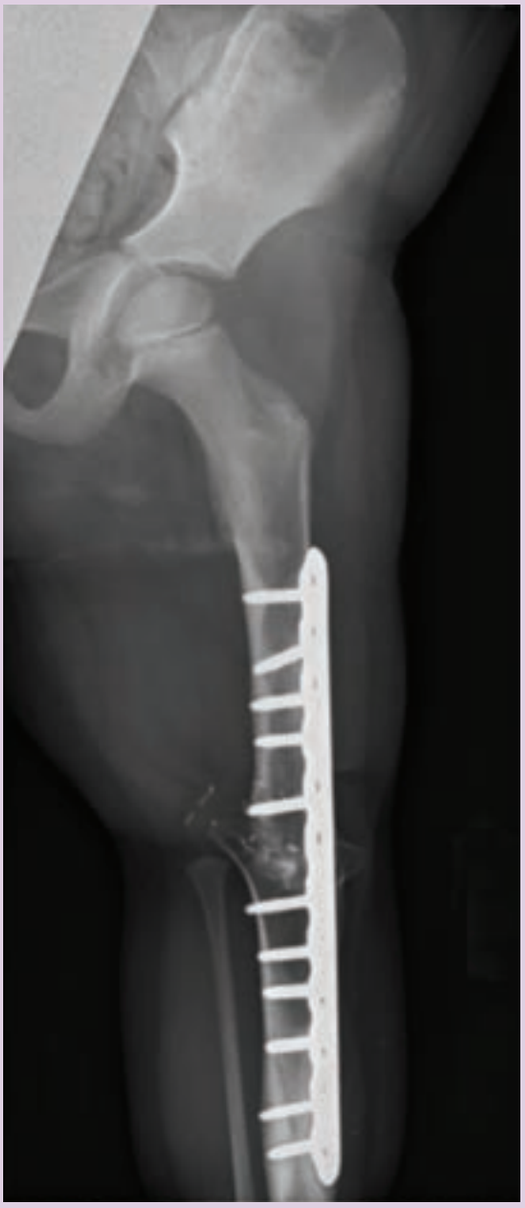


Figure 3

Image showing the plate that was implanted to help the rotated tibia and femur grow together.

ANALYSIS OF GLENOID COMPONENT SHIFT AND OSTEOLYSIS FOLLOWING ANATOMIC TOTAL SHOULDER ARTHROPLASTY

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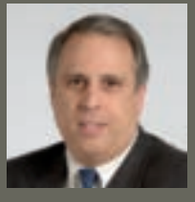

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STUDY EVALUATES GLENOID COMPONENT POSITION AND RADIOLUCENCY USING 3D CT IMAGING

While total shoulder arthroplasty (TSA) is the preferred surgical treatment for advanced glenohumeral arthritis, providing substantial improvement in pain and function, a subset of patients does not experience clinical improvement or sustain a complication. Glenoid component loosening is the most common long-term complication of anatomic TSA and a common reason for revision surgery. While an association between glenoid component loosening on plain radiographs and worse clinical outcomes has been shown at longer follow-up, the significance of early radiographic changes has not been established, nor have the factors associated with glenoid component loosening been well-defined.

Our group has developed and validated three-dimensional (3D) computed tomography (CT) imaging methods with metal artifact reduction (MAR) techniques for postoperative analysis after anatomic TSA that allow for precise and accurate determination of implant position of a polyethylene glenoid component, with the ability to detect subtle changes in component position or loosening over time. Although such movement may be clinically silent in the short term, its presence may be predictive of later, more obvious component loosening and/or premature clinical failure. Therefore, the purpose of this study was to evaluate glenoid component position and radiolucency using our 3D CT imaging analysis methods with minimum two-year follow-up.

Methodology

One hundred patients who underwent anatomic TSA with a polyethylene anchor peg glenoid component were prospectively enrolled for sequential CT scanning and analysis; including preoperative CT (CT1), early postoperative CT within three months of surgery (CT2) and postoperative CT performed at minimum two-year follow-up (CT3). All patients were also evaluated with plain radiographs and Penn Shoulder Scores (PSS) at minimum two-year follow-up. On the postoperative CTs, the location of the glenoid and humeral head components were detected based on four metal markers embedded in the pegs of the glenoid component and a volumetric center fit to the humeral head component, using 3D image analysis software. This technique was used to determine glenoid component version, inclination and joint line position as humeral head alignment. Evidence of glenoid component central anchor peg osteolysis (CPO) or radiolucency was assessed on postoperative CT3. Glenoid component shift was defined as a change in component position of ≥ 3 degrees version and/or inclination from CT2 to CT3. Factors associated with CPO and/or shift were assessed with univariate analyses.

Results and implications

Forty-eight percent of patients showed evidence of glenoid component shift on CT3: 25 with increased inclination alone, 14 with both increased inclination and retroversion or anteversion, six with increased retroversion alone, and three with increased anteversion alone (Figure 1). CPO was present on CT3 in 14 patients, with only 12 of 48 (25 percent) patients with component shift having CPO. Four groups of patients were, therefore, identified: (1) no shift and no CPO (N = 50), (2) no shift and CPO (N = 2), (3) shift with CPO (N = 12), (4) shift without CPO (N = 36).

Preoperative joint line medialization ($P = 0.003$), glenoid component absolute rotational (combined version and inclination) shift ($P < 0.0001$), and glenoid component medialization (medial translational shift) ($P = 0.0002$) were significantly different across the four groups, with cases having both shift and CPO associated with greater preoperative joint line medialization and greater component shifts (Figure 2). Walch classification was also significantly different across the four groups ($P = 0.02$), particularly with respect to CPO. A2 (3/13, 23 percent) and B3 (6/15, 40 percent) glenoids had higher CPO rates than did A1 (1/32, 3 percent) and B2 (2/29, 7 percent) glenoids. PSS were not significantly different across the four groups at minimum two-year follow-up ($P = 0.51$).

Postoperative 3D CT imaging analysis demonstrates that shift of a polyethylene glenoid component commonly occurs following anatomic TSA, with increased inclination the most common direction of shift. This cohort demonstrates the novel finding that most cases of glenoid component shift at minimum two years postoperatively show bony integration

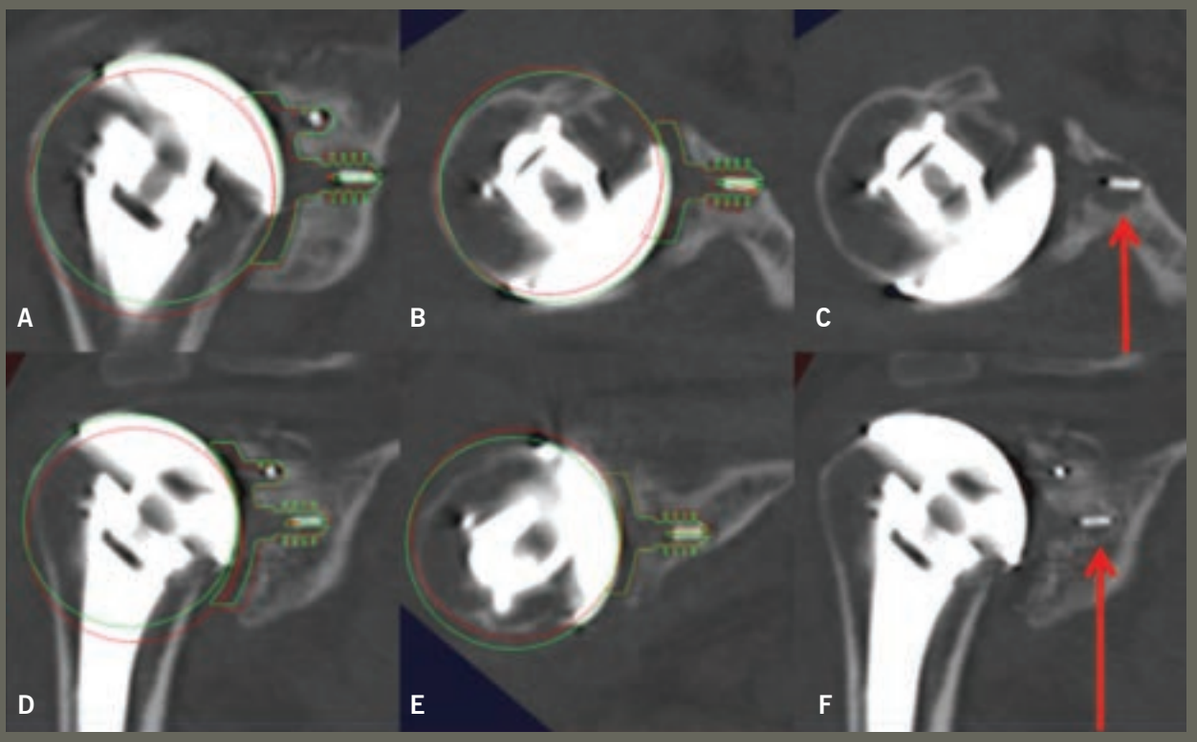

Figure 1

Digital templates of the position of the glenoid and humeral head components on the immediate postoperative CT (Red) and two-year follow-up CT (Green) are superimposed on the two-year follow-up CT in two patients (A-C, D-F). In the first patient (A-C), the glenoid component has shifted into increased inclination (A) and retroversion (B), and central anchor peg osteolysis is seen on the two-year follow-up CT after the digital templates are removed (C). In the second patient (D-F), the glenoid component has shifted into increased inclination (D) with stable version (E), and bone integration around the central anchor peg is seen on the two-year follow-up CT after the digital templates are removed (F).

around the central anchor peg without osteolysis (36/48, 75 percent), consistent with a stable implant. In contrast, cases of glenoid component shift with CPO (12/48, 25 percent) have larger absolute shifts and significantly more implant medialization over time, which suggests early implant loosening and subsidence that raise concern for eventual implant failure. CPO was found to be associated with preoperative joint line medialization, assessed both by millimeters of bone loss and Walch type (A2, B3 glenoids). These findings are not associated with a decrease in patient-reported outcomes or increased revision surgery across patient groups at current short-term follow-up. Longer-term follow-up and larger patient cohorts are needed to confirm whether the combination of early glenoid component shift and CPO place an implant at risk for clinically relevant loosening, while early shift in the absence of CPO does not.

Dr. Ricchetti is a staff orthopaedic surgeon and Center Director for Shoulder Surgery in the Department of Orthopaedic Surgery. Dr. Jun is project staff in the Department of Biomedical Engineering. Dr. Patterson is project staff in the Department of Orthopaedic Surgery. Dr. Derwin is staff at the Lerner Research Institute, specializing in biomedical engineering. Dr. Iannotti is Chief of Staff for the Cleveland Clinic Florida Region.

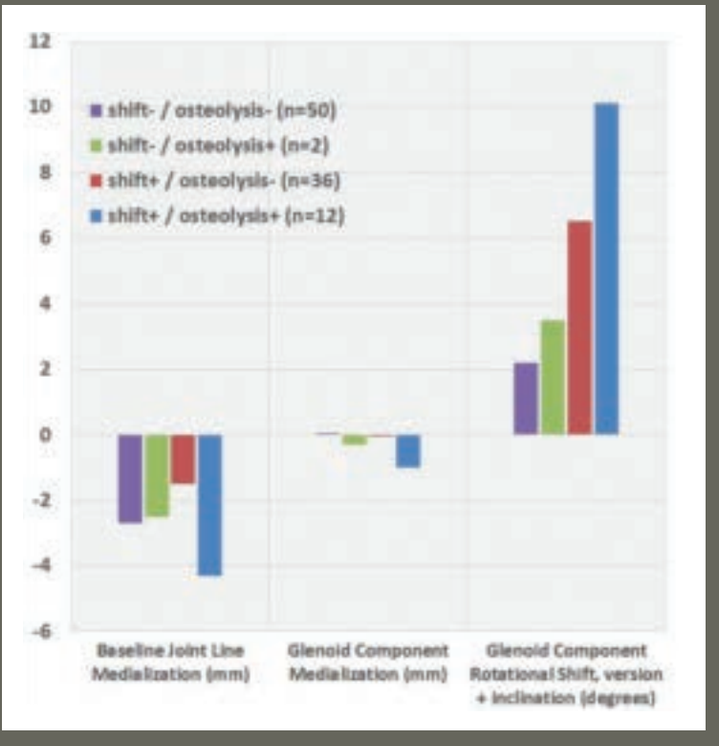

Figure 2

Cases having both glenoid component shift and central peg osteolysis at two years (N = 12/100) were associated with significantly greater baseline joint line medialization, greater component medialization and combined rotational shift (version and inclination). Joint line data are means; component data are medians.

WALANT (WIDE AWAKE LOCAL ANESTHESIA NO TOURNIQUET) IN HAND SURGERY

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The common and universally accepted practice of hand surgery consists of applying a forearm or arm tourniquet to allow for a bloodless surgical field. The operative site is often injected with local anesthetic, and sedation is needed to offset the pain generated by the applied tourniquet. Recently, Donald Lalonde, MD, and others have championed the idea of injecting lidocaine with epinephrine as an alternative to a tourniquet and sedation. This is known as the WALANT (wide awake local anesthesia no tourniquet) technique.

WALANT can be applied during both routine and, with experience, complex procedures in the upper limb. Surgical cases can be accomplished in the office setting when appropriate, and patients can actively participate in the procedure when needed (especially helpful during tendon repairs and transfers). Monitoring the patient is not indicated, and eliminating operating room and anesthesia costs significantly diminishes the overall cost of care. Patients may leave immediately after the surgical procedure, without the negative side effects and inconveniences of sedation.

How WALANT is performed

WALANT is performed by injecting 1 percent lidocaine with 1:100,000 epinephrine into the planned area of incision and surgical dissection, which provides up to four hours of local anesthesia and vasoconstriction. Often, 8.4 percent bicarbonate is added to diminish the discomfort of the injection. Bupivacaine and ropivacaine are avoided, given their higher potential for cardiotoxicity. For shorter cases, it is recommended that two or three patients be injected prior to taking the first patient in for surgery, to allow time for the epinephrine to reach maximal vasoconstriction (26 minutes on average).

EVALUATING THE REPAIR AND CORRECTING ANY DEFICIENCIES PRIOR TO CLOSURE IS A GAME CHANGER IN HAND SURGERY.

The safety of local epinephrine injections into the hand has been debated for decades but is now considered safe. Thousands of fingers have been injected with the above agents without digital necrosis or other concerns. A secondary layer of protection is phentolamine rescue for digits that remain white. However, the reported incidents of needing phentolamine rescue are essentially zero. Regarding safe dosing of lidocaine with epinephrine, a 7 mg/kg maximum is recommended. This allows for safely injecting 50 cc of 1 percent lidocaine with 1:100,000 epinephrine into the average 70 kg patient.

Incorporating WALANT in your practice

Learning to incorporate WALANT into your own surgical practice should occur in a stepwise fashion. Trigger finger release is the most common initial procedure to learn the technique and gain confidence in using epinephrine in the digits. Initially, these cases can be performed in the operating room setting with the fallback of anesthesia and tourniquet use. As confidence builds, other common procedures can be attempted — e.g., carpal tunnel release or de Quervain's release, with eventual application in office-based procedural rooms.

Flexor tendon repair is the procedure that achieves the most clinical benefit from application of WALANT. Patients can actively flex the digit immediately following repair. This allows surgeons to scrutinize the repair site for gapping. It also provides an opportunity to evaluate the bulk of the repair and any "hanging up" on the remaining digital pulleys. Plus, the patient's having direct visualization of their digit flexing and extending improves the recovery process.

Evaluating the repair and correcting any deficiencies prior to closure is a game changer in hand surgery.

WALANT is a technique I have slowly begun to incorporate into my own surgical practice. I look forward to expanding our use of WALANT to take advantage of the convenience,

cost savings and improved outcomes for tendon repairs and transfers. I also anticipate WALANT being incorporated into bundled care plans for common hand and wrist procedures. I owe a debt of gratitude to Dr. Donald Lalonde for being a great educator and promoter of WALANT; much of this article derives from his lectures and papers on the subject.

Dr. Maschke is Director of the Upper Extremity Center.

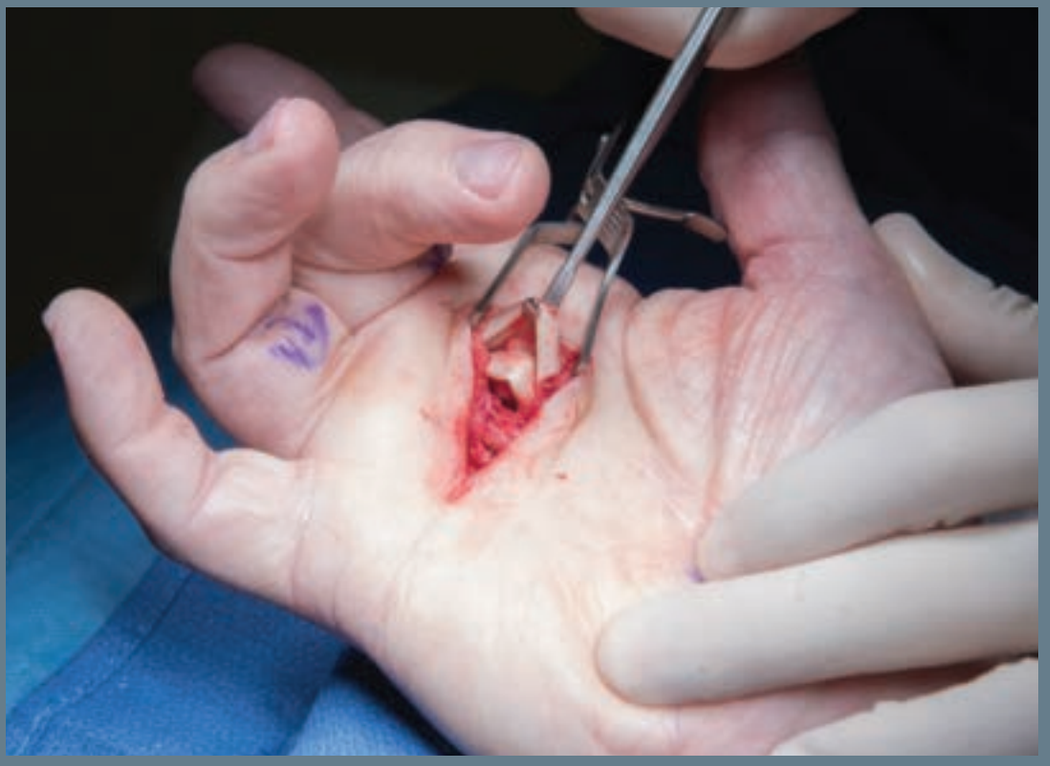

Figure 1. Treatment for trigger finger of middle and ring fingers. Release has been performed and tendons surgically mobilized. Patient is able to demonstrate active finger movement without restriction or discomfort, demonstrating to the surgeon that surgery has been satisfactorily completed.

NOVEL TREATMENT FOR CALCIFIC TENDINOPATHY OF THE SHOULDER

ULTRASOUND-GUIDED PERCUTANEOUS ULTRASONIC TENDON DEBRIDEMENT

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Calcific tendinopathy of the shoulder can be a painful and debilitating condition. While several nonoperative treatments have been employed to alleviate this condition (physical therapy, corticosteroid injections, percutaneous lavage, two-needle barbotage procedure and extracorporeal shock wave), arthroscopic surgical debridement is ultimately chosen for many patients with this painful condition.[1]

Novel treatment

We suggest the office-based ultrasound-guided percutaneous ultrasonic tendon debridement procedure as a novel, less invasive alternative to address calcific tendinopathies of the shoulder. This procedure uses a thin metal needle probe that vibrates at 20,000 rpm along with saline irrigation to gently dissolve and aspirate the calcific deposit while leaving the native normal tendon unaffected.

We have performed more than 400 ultrasound-guided percutaneous ultrasonic tendon debridement procedures. More than 40 were specifically used to treat calcific tendinopathy of the shoulder.

While this procedure has been performed across the country for six years, no studies have been published outlining its use for treatment of calcific tendinopathy of the shoulder.

Case series

Here we present a case series of three patients with calcific deposits of the shoulder. The patients had calcific deposits of the:

- Supraspinatus tendon.
- Subscapularis tendon.
- Pectoralis major tendon.

All patients had symptoms of shoulder pain and a reduced range of motion for at least three months. All failed to receive relief from physical therapy or an ultrasound-guided percutaneous lavage procedure with corticosteroid injection.

Each patient underwent an ultrasound-guided percutaneous ultrasonic tendon debridement procedure. At four weeks post procedure, they all demonstrated improvement in pain and function and did not progress to further interventional treatment.

All of these patients are at least six months out from the procedure with sustained results. Similar results have been achieved in all patients we have treated with the same protocol.

Case 1

This 45-year-old woman had a large calcium deposit of the supraspinatus tendon that caused significant impingement and resulted in superior glenohumeral widening and inferior glenohumeral degenerative changes. Four weeks after treatment with ultrasound-guided percutaneous ultrasonic tendon debridement, she had complete resolution of symptoms, near complete resolution of calcium deposition on plain imaging and did not progress to further interventional treatment.

Case 2

This 57-year-old woman had a calcium deposit of the pectoralis major tendon that caused pain with reaching and pushing in almost all directions. Four weeks after treatment with ultrasound-guided percutaneous ultrasonic tendon debridement, she had complete resolution of symptoms, complete resolution of calcium deposition on plain imaging and did not progress to further interventional treatment.

Case 3

A 52-year-old man had a calcium deposit of the subscapularis tendon that caused pain while overhead serving in tennis and with general overhead activity. Four weeks after treatment with ultrasound-guided percutaneous ultrasonic tendon debridement, he had significant reduction of pain and resolution of calcium on plain imaging. By three months, he was able to return to playing tennis without pain.

Future directions

Based on our 40+ cases using ultrasound-guided percutaneous ultrasonic tendon debridement for the treatment of calcific tendinopathy of the shoulder, we are very optimistic about this option for treating patients experiencing this debilitating condition.

We also find it extremely helpful in the treatment of chronic degenerative tendinosis of the shoulder, elbow, hip, knee, foot and ankle.

Working with the OrthoMiDaS Episode of Care (OME) team here, we are developing a specific OME tendinopathy module to help produce a prospective cohort that will allow us to longitudinally track outcomes of these procedures. We welcome your candid discussion regarding this novel therapy and look forward to presenting future outcomes of a larger sample of patients.

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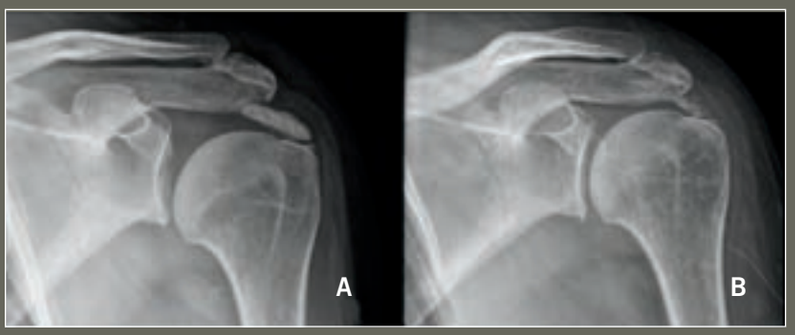
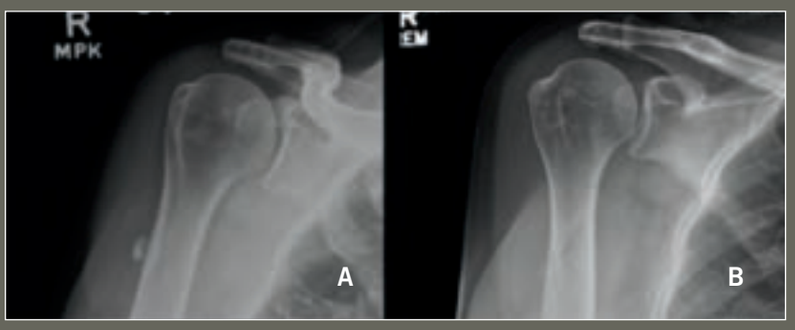
Drs. King and Genin, sports medicine and medical orthopaedic physicians, are on staff in the Sports Health Center and Joint Preservation Center.



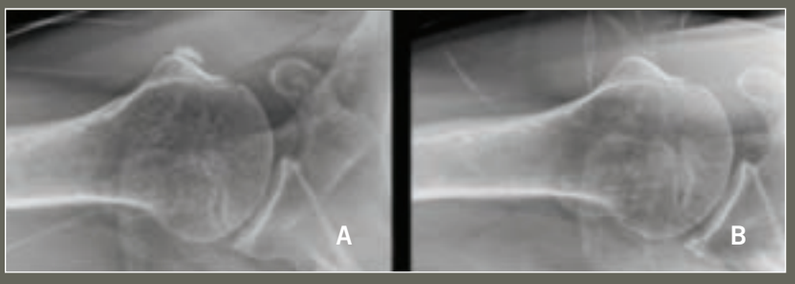
CASE 1

Image A: Before, Image B: After



CASE 2

Image A: Before, Image B: After



CASE 3

Image A: Before, Image B: After

EARLY DETECTION OF OSTEOARTHRITIS WITH QUANTITATIVE MRI

LEADING-EDGE TECHNOLOGY WILL IMPROVE DIAGNOSIS AND PROGNOSIS

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Osteoarthritis (OA) affects more than 27 million people in the United States and has been recognized as one of the fastest growing medical conditions worldwide. Ongoing efforts on novel pharmacological therapies continue, but there are no disease-modifying OA drugs (DMOADs) to slow or halt cartilage degeneration.

One of the hurdles in developing DMOADs is the lack of sensitive and reliable noninvasive biomarkers to efficiently detect treatment effects. Such biomarkers would also help identify patients at risk for developing OA or at an early stage of disease when prevention strategies, such as weight loss, diet changes and physical exercise, are shown to be most effective in slowing disease progression.

Finding innovative solutions

A focus of the newly formed Program of Advanced Musculoskeletal Imaging (PAMI) is to develop novel quantitative MRI techniques for improving early diagnosis and prognosis for OA and post-traumatic OA (PTOA).

We have developed 3D quantitative MR $T_{1\rho}$ and T_2 imaging techniques that can detect biochemical changes within the collagen-proteoglycan matrix of articular cartilage at early stages of degeneration. We have observed significant correlations between MR $T_{1\rho}$ measures with proteoglycan concentrations and biomechanical and histological evaluation of specimens harvested from patients who underwent total knee arthroplasty. MR T_ρ values also were elevated in lesions confirmed with arthroscopic evaluations in patients with acute knee injuries such as anterior cruciate ligament (ACL) tears.

In patient cohort studies, we observed significantly higher $T_{1\rho}$ and T_2 values in patients with OA and knee injuries as compared with healthy controls. Most interestingly, baseline cartilage $T_{1\rho}$ and T_2 have been shown to predict cartilage morphologic lesion development and patient-reported outcomes (such as pain) at one-, two- and three-years after ACL reconstruction. These results suggest that $T_{1\rho}$ and T_2 may serve as promising biomarkers to improve early diagnosis and prognosis of cartilage health and OA.

Addressing challenges that remain

Despite promising results, challenges remain, including lack of standardized acquisition and quantification methods, and long acquisition times. Multicenter trials using cartilage $T_{1\rho}$ and T_2 imaging have been primarily limited to single-vendor MR systems, thereby eliminating pulse sequence and RF coil differences between manufacturers. To address these issues, we have performed a multicenter, multivendor cross-validation study of cartilage $T_{1\rho}$ and T_2 imaging, sponsored by the Arthritis Foundation. Outcomes will pave the way for large-scale multivendor, multisite trials for OA using advanced quantitative MRI.

In addition, we have developed an atlas-based, voxel-based relaxometry analysis that will enable evaluation of very focal changes that would otherwise be masked by conventional region of interest-based methods. We also have been working on developing fast imaging and automatic analysis techniques to facilitate clinical translation of cartilage $T_{1\rho}$ and T_2 imaging. Using MR-compressed sensing and parallel imaging techniques, adaptive to cartilage signal, we have shown acquisition time can be shortened by four times without sacrificing image quality and quantification accuracy (with $T_{1\rho}$ and T_2 quantification error < 1 percent).

We also are developing deep learning techniques for fully automatic cartilage segmentation and have achieved 89 percent accuracy by combining a conditional generative adversarial network and a convolutional neural network, which outperformed leading-edge automatic cartilage segmentation using deep learning techniques. Combining fast imaging techniques with automatic tissue segmentation and quantification will significantly advance efforts toward clinical translation of quantitative cartilage MRI techniques.

Finally, we are optimizing the $T_{1\rho}$ and T_2 sequences on research-dedicated MR scanners, and expect to soon add fast and reliable compositional imaging sequences to routine clinical protocols on clinical scanners, which will allow us to correlate clinical outcomes with compositional maps acquired prospectively as part of routine care.

Dr. Li is the Director of the Program for Advanced Medical Imaging in the Department of Biomedical Engineering at Cleveland Clinic Lerner Research Institute. Dr. Winalski is a diagnostic radiologist and the Clinical Director of the Program for Advanced Medical Imaging. Dr. Spindler is an orthopaedic surgeon and sports medicine expert at Cleveland Clinic.

Figure 1

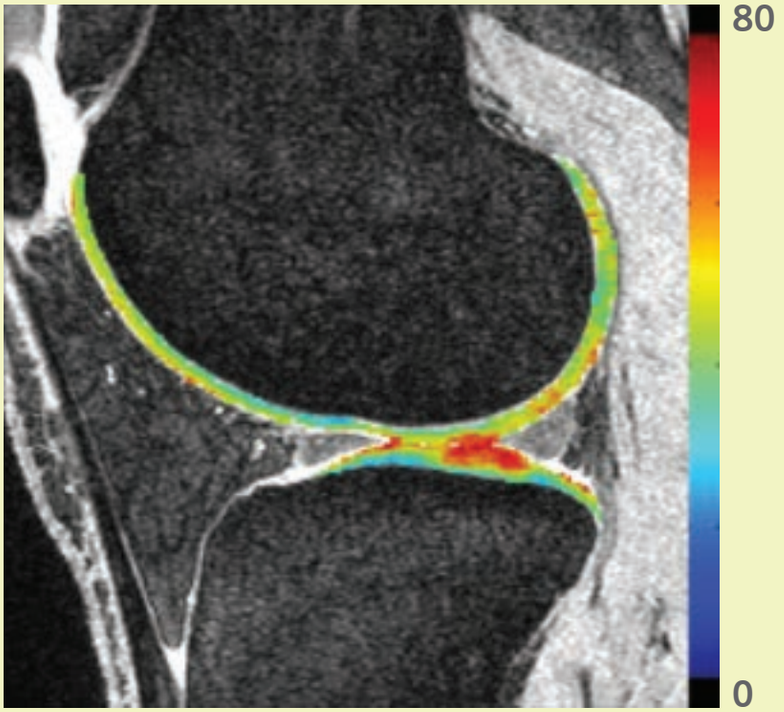


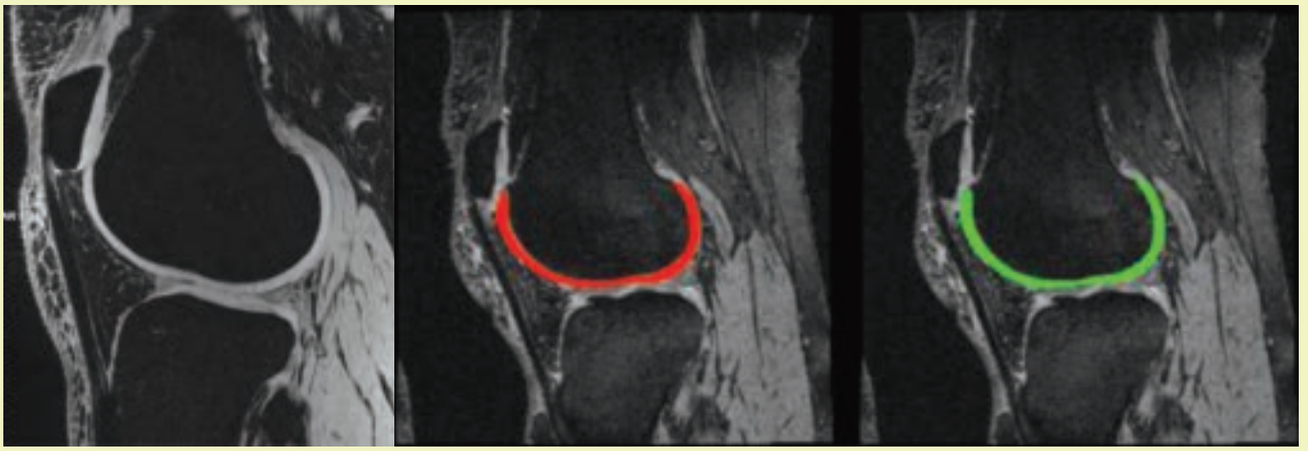
Figure 1

3D MRI $T_{1\rho}$ maps revealed early cartilage degeneration in lateral tibia and lateral femoral condyle cartilage. $T_{1\rho}$ imaging probes changes within cartilage collagen-proteoglycan matrix during early degeneration prior to morphologic changes occur.

Figure 2

Example images of automatic cartilage segmentation using machine learning methods. Red: expert manual segmentation; Green: automatic segmentation with the developed deep learning method combining a conditional generative adversarial network and a convolutional neural network.

Figure 2



TARGETED MUSCLE REINNERVATION AND EVOLVING PROSTHETIC DESIGN

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The number of amputees in the United States (lower and upper extremity) is expected to triple by 2050.[1] In 2005, nearly 41,000 people were living with upper extremity amputations, most commonly caused by high-energy trauma.[2] And at any given time, nearly 20 million Americans suffer from peripheral nerve injury caused by trauma and medical disorders.[3] Nerve injuries alone account for approximately $150 billion in annual health-care costs in the U.S.[4]

The increasing prevalence of amputation, coupled with the fact that upper extremity amputation and nerve transection injuries can be severely disabling and painful, has led to the development of new, innovative approaches in postamputation medicine. This is especially important in the context of upper extremity amputations, which have been shown to produce an even greater degree of disability than lower extremity amputations.

Potential for significant impact, pain reduction

Targeted muscle reinnervation (TMR) is one such emerging technique. TMR can reduce the dysfunction and pain that upper extremity amputees experience, and help those who have painful neuromas stemming from isolated nerve injuries. A significant reduction in neuroma and phantom limb pain has been an unexpected and welcome benefit of TMR.

Combined with evolving prosthetic design technology, TMR provides a promising new avenue to reduce disability for upper extremity amputees and adds to our toolbox for treating these patients.[5]

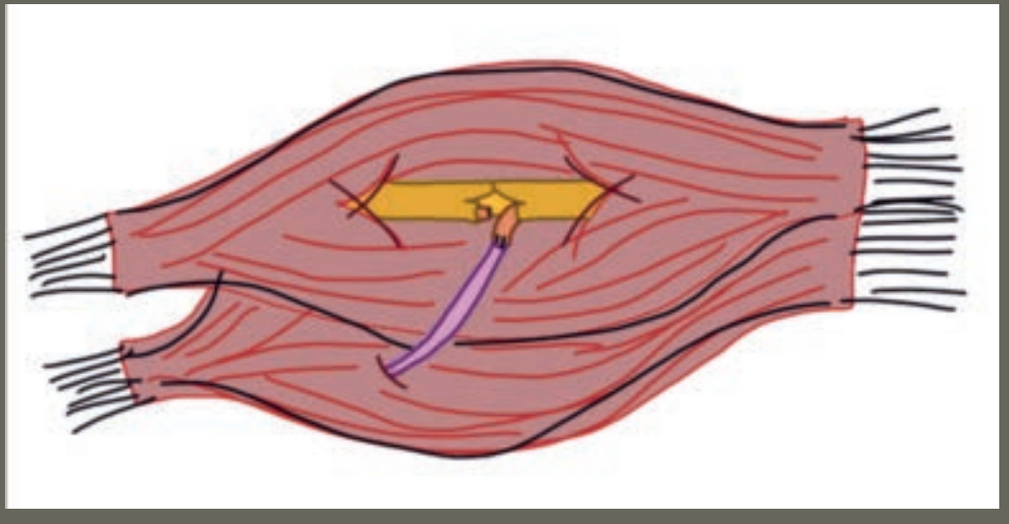
Principles of targeted muscle reinnervation

Kuiken and Duamanian, in the early 2000s, described TMR for proximal upper extremity amputations at or above the elbow to improve myoprosthetic control.[6] This surgical technique uses strategic nerve transfers to either reinnervate a denervated muscle group or to create multiple points of innervation in a proximal muscle segment to aid in prosthetic control.

The myoelectric signaling from newly reinnervated muscle segments is picked up by transcutaneous electrodes and used to control advanced prosthetic devices. Motor control of hand and wrist function is also transmitted through these transfers because of retained neural information within the amputated nerve and its cortical connection. This allows for intuitive and enhanced control of a prosthetic limb.

Indications for TMR include:

- Significant neuroma pain that has failed medical management.
- Prevention of phantom limb pain in amputation patients.
- The need for improved prosthetic control.



CASE STUDY

A 40-year-old female was seen in our practice for surgical consultation for management of chronic pain after a below-elbow amputation. Her limb pain, refractory to all modes of medical management, limited her ability to wear a standard prosthesis.

Her amputation stump exhibited four focal points of pain correlating to positive Tinel's sign over the areas of pain (Figure 1).

After discussion with the patient and her pain management team, we decided to explore her below-elbow stump with neuroma resection and targeted muscle transfers. We felt this had great potential to address her chronic pain and provide her with the enhanced muscle response needed to accommodate an advanced myoelectric prosthetic fitting, if she desired.

In surgery, we found neuromas of the median, ulnar, radial sensory and lateral antebrachial cutaneous nerves. All were resected until we achieved visualization of healthy nerve under loupe magnification. The resected back lateral antebrachial cutaneous nerve stump was placed in a blind-ended nerve wrap and buried deep in muscle (Figure 2).

We then performed three nerve transfers, each with a connector-assisted repair, consisting of two epineutrial 8-0 nylon microsutures oriented at 180 degrees to each other, with fibrin glue reinforcement and a nerve protector wrapped around the repair site and detensioned.[8] The following nerve transfers were performed:

- Distal ulnar nerve to motor branch of the flexor carpi ulnaris (Figure 3).
- Median nerve and anterior interosseous nerve transfer to motor branches of the flexor digitorum profundus (Figure 4).
- Radial sensory nerve transfer to the motor branch extensor carpi radialis longus.

Postoperatively, the patient has had significant resolution of her chronic pain in her amputation stump, and she is able to tolerate a prosthesis for her below-elbow amputation.

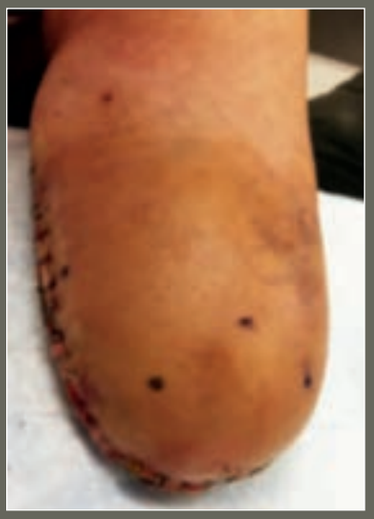


Figure 1. Image of below-elbow stump with marked neuromas.

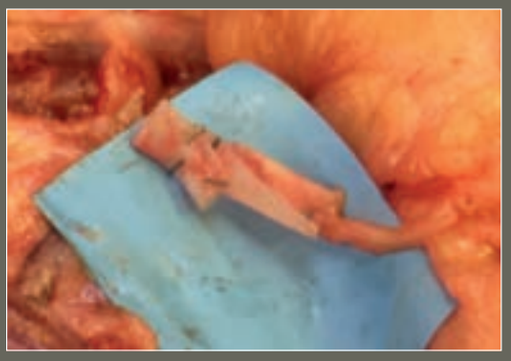


Figure 2. Intraoperative picture of blind end wrap.

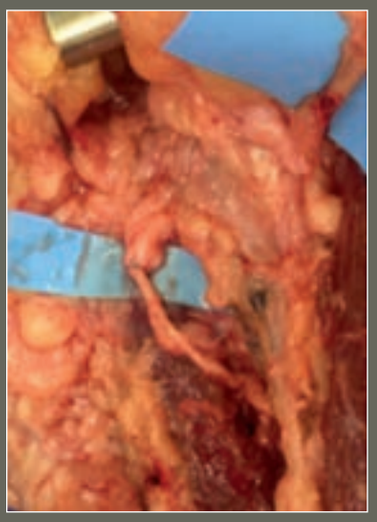


Figure 3. Distal ulnar nerve to motor branch of the flexor carpi ulnaris.

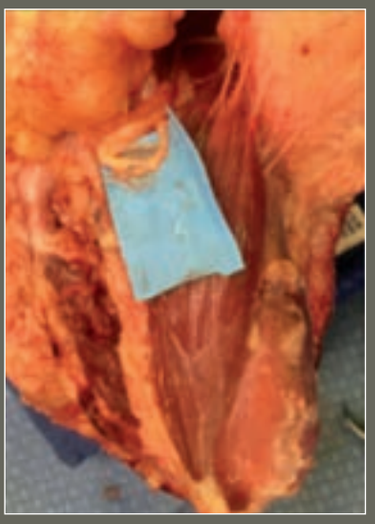


Figure 4. Median nerve and anterior interosseous nerve transfer to motor branches of the flexor digitorum profundus.

Patients with amputations proximal to the wrist are candidates for TMR if they do not have brachial plexopathy or proximal nerve injury. In proximal, above-elbow amputations or shoulder disarticulations, the goals of TMR are to restore elbow flexion and extension and hand open and close actions.

Nerve transfer patterns

Selection of nerve transfer patterns depends on the level of the amputation, available nerve transfers and target musculature.

For example, in transhumeral (TH) amputations, TMR is used to create hand close and hand open control signals while preserving native innervations that perform elbow flexion and extension.[7] The remnant median nerve is transferred to the short head of the biceps for hand close action, and the distal radial nerve is transferred to the lateral head of the triceps for hand open action. This process can also be modified to include wrist control. This reinnervation allows for intuitive control of four discrete motor functions (hand close and open, elbow flexion and extension), which creates more natural, versatile prosthetic limb functioning.

Where do we go from here?

Nerve transfers for forequarter amputation and TH amputation have been well-described. However, the optimal selection of nerve transfers for transradial amputees is still evolving along with technologic advancements of prosthetic devices. A multicenter trial is underway to further evaluate TMR as an option for treating and preventing neuroma and phantom limb pain.

TMR is transforming our traditional treatment for patients with amputations, offering a means of reducing the incidence of neuroma formation and phantom limb pain. In addition, TMR is successful in ameliorating existing chronic neuroma pain resistant to nonoperative treatments. As our understanding improves about how TMR decreases pain, we will be able to prevent pain and suffering and reduce the total cost of care for patients with amputations.

Dr. Evans is staff in the Orthopaedic Surgery Department's Upper Extremity Center.

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RESIDENCY UPDATE 2018

It was a dark and stormy night, and I had been struggling with my latest journalistic assignment. I had writer's block and had it bad. "Ugh," I groaned, as I yanked the paper out of my circa-1960 Smith Corona, crumpled it dramatically and unceremoniously threw it to the floor. "My work is so formulaic, derivative, unimaginative and trite!" I exclaimed to no one in particular. I lit another Camel and pushed back from my desk in my small and dark fifth floor walk-up in the Bronx, in an attempt to clear my head.

"You're making stuff up again, Kuivila," semi-seethed Beth, our marketing manager, as she read the first paragraph of my latest offering for *Insights* entitled (quite cleverly and for the tenth-plus year in a row) "Residency Update."

"True, I don't smoke," I admitted.

"And no one uses typewriters, and you could never survive in the Bronx — and yes, smoking kills. What is wrong with you?!"

"I fear mundanity."

"That isn't a word. Besides, formulaic sells — look at Tom Clancy and John Grisham."

"And ELO and Boston ..."

"Exactly, so get busy and finish this article. I'm feeling like I'm in a scene from *Groundhog Day* because we have this conversation every year."

And with that, she was gone, leaving me to contemplate my *Groundhog Day*-esque existence.

It is true that our existence does cycle. We are head-on into a new academic year, while just a few short months ago, we had a tremendous graduation weekend. We hosted Cleveland Clinic alum and current Director of Orthopaedics at Cincinnati Children's Hospital Jim McCarthy, MD, as our visiting professor, who helped us bid farewell, adieu and hasta la vista ba-by to 10 supersolid graduating chief residents — who are off to their respective fellowships:

FROM THE MAIN CAMPUS PROGRAM

Kevin Bigart, MD, Adult Reconstructive Surgery (Rush University Medical Center, Chicago).

David Brigati, MD, Adult Reconstructive Surgery (University of Texas at Austin).

Reid Chambers, DO, Pediatric Orthopaedics (Cleveland Clinic).

J**ason Ho, MD,** Shoulder Surgery (Rothman Institute at Thomas Jefferson University, Philadelphia).

Jennifer Peterson, MD, Adult Reconstructive Surgery (Cleveland Clinic).

Rachel Randall, MD, Pediatric Orthopaedics (Nationwide Children's Hospital, Columbus).

Timothy Wagner, MD, Adult Reconstructive Surgery (New England Baptist, Boston).

FROM THE SOUTH POINTE PROGRAM

John Childs, DO, Orthopaedic Foot & Ankle (Orthopedic Associates in Grand Rapids, Michigan).

Perry Hooper, DO, Orthopaedic Sports Surgery (Cleveland Clinic).

Michael Kolosky, DO, Orthopaedic Sports Surgery (Massachusetts General Hospital).

As you can see, of the 10 kicked out of the nest, three did return on Aug. 1 as well-regarded Cleveland Clinic fellows. We are happy to have them for one more year. It honestly isn't at all like when your college grad moves back home to live in the basement.

On July 1 (universally recognized as the worst day to get sick in the United States, BTW), we welcomed nine future orthopaedic surgeons.

TO THE MAIN CAMPUS PROGRAM

Michael Erossy, MD, a native of Olmsted Falls, Ohio, and graduate of Northeast Ohio Medical University.

Anton Khlopas, MD, who hails from Elmwood Park, Illinois, and graduated from Saba University School of Medicine.

Anas "A.J." Minkara, MD, originally from Lexington, Kentucky, and a new alum of University of Cincinnati School of Medicine.

Prashant Rajan, MD, a product of Mentor High School in Mentor, Ohio, and of Harvard Medical School.

Andrew Swiergos, MD, born and reared in Louisville, Kentucky, and educated at the nearby University of Louisville Medical School.

William Zuke, MD, late of Highland, Indiana, and a graduate of Indiana University School of Medicine.

TO THE SOUTH POINTE PROGRAM

William Gaines Cumbie, DO, a native of Montgomery, Alabama, and 2018 graduate of Philadelphia College of Osteopathic Medicine.

Bryan Demyan, DO, like the Wright brothers, he is from Dayton, Ohio; unlike Wilbur and Orville, he graduated from Lake Erie College of Osteopathic Medicine.

George Yakubek, DO, from Warren, Ohio, by way of Kansas City University of Medicine and Biosciences.

This summer we also welcomed back **Vahid Entezari, MD,** Residency Class of 2017, as he joins the Department of Orthopaedic Surgery Staff in the Section of Hand and Upper Extremity, having completed a fellowship in shoulder and elbow surgery at Thomas Jefferson University Hospitals in Philadelphia.

Brendan Patterson, MD, has taken over the reins as Department Chair, assuming the duties of **Michael Mont, MD,** who left in February for Lennox Hill in NYC.

With a hint of melancholy, we tip our surgical caps to **Joe Iannotti, MD, PhD**, who is stepping down as ORI chair for the challenge of becoming Chief of Staff at Cleveland Clinic Florida. Over the last 18 years, Joe's firm hand on the tiller — first as Department Chair and then as the ORI Chair — has been a stabilizing and energizing force. During his time here, the department has nearly quadrupled in size and markedly expanded its footprint and scope. We will miss the broad and polished skill set he brought to the department.

Upon final reflection, I guess you could say that formulaicism isn't all that bad; our formula in orthopaedics at Cleveland Clinic is to attract bright and hardworking med school grads, give them a solid five-year residency education and send them into the world to fine fellowships en route to stellar careers. So, if it is "déjà vu all over again," as Yogi Berra once intoned, that's really OK. For explanation, look no further than Yogi's own life — 10 World Series championship rings as a near-lifetime Yankee. Some things never, truly, get old.

Dr. Kuivila, a pediatric orthopaedic and scoliosis surgeon, is the Vice Chairman for Education in the Orthopaedic & Rheumatologic Institute and serves as Program Director of the main campus Residency Program.

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