Retrieval Analysis Reveals Damage Modes for Metal-on-Metal Total Hip Replacements

Wear damage and particle debris found

Treating FAI: Arthroscopy and Open Surgery Equally Efficacious in Most Patients

First study to compare structural & mechanical corrections

Cerebral Blood Flow Velocity Preserved During THA Under Hypotensive Epidural Anesthesia

Study shows HEA does not reduce blood flow to the brain

Custom Total Hip Arthroplasty in Skeletal Dysplasia

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Patients Who Should Not Undergo Surgery for a Snapping Hip Tendon

Patients with structural instability are not good candidates

The Use of Performance-Based Tests for the Preoperative Evaluation of Total Hip Arthroplasty

Results of physical tests and self-evaluation found to have only mild to moderate correlation.
Recently, both clinical and broad public concerns have arisen regarding metal-on-metal (MoM) total hip replacements. To help determine how the MoM implants might create these unique difficulties, HSS launched the first study of its kind investigating MoM damage using retrieved hip implants. The team could analyze real-life damage and identify factors that could contribute to MoM implant failure, especially particle debris from implant wear.

Led by HSS Hip Service Chief Douglas E. Padgett, MD, and Director of Biomechanics Timothy M. Wright, PhD, the investigators studied 46 failed MoM implants removed during revision surgery.

Despite the claim that MoM bearings are wear resistant, microscopic examination and qualitative analysis of the retrieved femoral and acetabular MoM components showed considerable surface damage, both in extent and severity,

Surface damage means that during use in the body, metal has worn off the implant. Known as particle debris, these microscopic remnants can stay affixed to implant surfaces causing grating or be released into the body.

Either way, particle debris can trigger implant loosening and osteolysis, a condition that leads to implant failure. Osteolysis and pseudo-tumor like reactions were the most common revision diagnoses of the implants studied.
The researchers used light microscopy to examine the cup sockets and ball heads of the retrieved implants. 98% of the cups and 93% of the heads showed moderate to severe scratching. When viewed under the light microscope, moderate to severe pitting was evident in 43% of the cups and 67% of the heads.

In a healthy hip, a femur bone moves in a natural pelvic socket, cushioned by cartilage. Lack of cartilage is painful, and a main cause for needing a hip implant, which replaces this natural ball and socket. Metal-on-metal implants derive their name from the fact that both the ball head replacing the top of the femur bone and the socket replacing the pelvic cup are metal. Thus, when hips move, metal meets metal.

The researchers found “wear patches” – areas in which metal had lost its sheen – within 40º of the superior pole of the femur replacement heads and 5% of the replacement pelvic cups. Loss of sheen occurs when metal wears off the implant surface. That worn metal could become harmful particle debris. The high occurrence of wear patches consistent with the location of the highest contact force (at the pole) suggests the sheen was worn off during use, when metal met metal as people moved.

MoM hip replacements were intended to be highly resistant to wear. This resistance was supposed to prevent metal-on-metal friction that would occur in every day movements from producing harmful debris. This study finds real life wear results to differ from this intended goal. Further study will investigate the clinical implications of these wear particle findings.
A bony bump on the upper end of the femur bone can prevent the thigh from moving freely in the hip socket. As people move, the bump wears down the hip socket rim and damages the joint cartilage, creating both pain and risk for early hip arthritis.

At the HSS Center for Hip Preservation, this condition, known as femoro-acetabular impingement or FAI, is first treated by conservative measures. If needed, the bony bump and structural mechanics can be corrected by surgery. Two approaches – open surgery and less-invasive arthroscopy – have been shown equally effective in improving symptoms and returning athletes to play. But no studies have compared the actual structural results.

Now, in the first study of its kind, HSS has shown arthroplasty is equal to open surgery in effective structural and mechanical corrections to FAI for most patients.

The study enrolled 60 male patients under 40 with symptomatic FAI. 30 were treated with open surgery, 30 with arthroscopy. X-rays taken both before and after surgery were compared.

For most of the 60 patients studied, arthroscopy matched open surgery for successful results. Both approaches repaired the spherical shape of the femur head allowing free movement without rim damage. Both corrected the angle and degree of separation between the sphere and the socket. However, if the bony thigh bump is in one, difficult to reach place – the anteroposterior (AP) alpha angle – open surgery produces better correction of the spherical head. But for the vast majority of patients, arthroscopy is just as successful as open surgery in restoring bone mechanics in FAI.
There is an anesthetic technique that can be used during total hip arthroplasty (THA) that reduces surgical blood loss, reduces post-surgical blood clots, lowers mortality rates, and has shown both preservation of postoperative cognitive function and absence of stroke following procedures. Yet, despite all these proven benefits, this technique — hypotensive epidural anesthesia (HEA) — is not widely used for total hip arthroplasty (THA).

Part of the reluctance is concern HEA may reduce blood flow to the brain. A recent collaboration between HSS surgeons and anesthesiologists has shown that it does not.

This study is the first to demonstrate how HEA preserves cerebral blood flow. The researchers measured the rate of cerebral blood flow velocity (CBFV) of 50 patients receiving HEA during total hip replacement. The CBFV was continually monitored throughout surgery, as was another key measurement — mean arterial pressure (MAP). Peak blood flow velocity in the middle cerebral artery was measured by transcranial Doppler ultrasonography.

Doctors want blood flow to the brain to stay at good, safe levels during surgery and blood pressure to stay down. In the study, HEA allowed both.

MAP declined by 40% after the induction of HEA and peak CBFV increased by 10%. This trend in MAP and peak CBFV remained constant throughout HEA. Other standard heart, neural, and blood pressure measurements taken throughout the 50 surgeries were also good. This study shows HEA is a safe anesthesia technique, with many benefits, to use for THA.
Skeletal dysplasia is an umbrella term for a group of genetic conditions that result in adults being significantly shorter than average height. The condition is also known as dwarfism. There are over 300 dysplasias, affecting size and shape of limbs, trunk, and skull.

Because the condition is characterized by aberrant cartilage and bone development, people with skeletal dysplasia often need hip replacement at an early age, and usually require custom hip implants. The Kathryn O. and Alan C. Greenberg Center for Skeletal Dysplasias at HSS has pioneered many innovations in medical care for people with skeletal dysplasia, including custom implants.

A recent HSS study sought to assess the outcomes of using custom implants in total hip arthroplasty (THA) for people with skeletal dysplasia about 3 years after surgery. Surgeries on 14 hips in 9 patients with genetic dwarfism were reviewed. All had received custom titanium implant stems made by using computed tomography (CT) scans of the pelvis and femurs to guide the manufacture. Mean age of the patients was 36.5 years (range 15-50 years) and mean height was 48 inches (range 42-55 inches). The research team reviewed x-rays, looking for migration, osteolysis, fracture, and restoration of leg length. Pre- and postoperative Harris hip scores (HHS) were compared.

The analysis showed good midterm outcomes for patients with a variety of skeletal dysplasia, confirming that using custom implants in THA does create good results for people with skeletal dysplasia.

Three hips (21%) required revision: two for stem migration and one for osteolysis. Eleven hips (79%) were stable with signs of good integration of bone and implant. No fractures, nerve damage or dislocations occurred. Significant osteolysis was seen on three radiographs. All patients walked independently, and mean HHS improved from 45 (24-58) to 71 (47-89). All leg length discrepancies were restored to within 3 mm of equal.
Running along the lower spine, the long psoas muscle joins the lower back to the upper inner thigh. The muscle is essential for flexing the hip and moving the leg. The psoas tendon attaches the muscle to a bony protrusion on the thigh bone, where the leg bone ball meets the hip socket. The psoas tendon is one of two hip flexor tendons that attaches to this boney protrusion.

Sometimes a teenager – or young adult – has a pelvis that grows faster than the psoas tendon. Because tendons cannot stretch, the too short tendon becomes so tight it painfully snaps over the pelvis during walking or other activity.

If conservative measures do not bring relief for this condition – known as snapping psoas tendon – the tendon can be released surgically. Small slits are cut in the psoas tendon allowing it reach slightly farther and the muscles to elongate, easing tension.

Now, an HSS study has identified young patients who should not have surgery for snapping psoas tendon. Patients with structural instability in the hip region, specifically femoral anteversion, are not good candidates for surgical release of the tendon. Because even though the stretched psoas tendon is causing pain, it is still providing some structural support. Surgically releasing the tendon, erases that support.

The missing support can cause a delayed return to daily activities after surgery and result in inferior surgical outcomes. In the study, twice as many patients with high femoral aversion had to undergo revision surgery than patients without the condition.
Femoral anteversion is a structural condition affecting how the hip and leg bones connect. At the top of long femur thigh bone is an area that slants towards the pelvis, known as the femoral neck. The ball at the end of the neck fits in the socket of the hip bone. For most people the center of the femoral neck points to the center of the hip socket. In femoral anteversion, the center of the femoral neck leans toward the front of the socket. This causes the knee and foot on the affected side to rotate internally or twist toward the midline of the body.

The study identified 67 patients who underwent arthroscopic lengthening of a symptomatic psoas tendon – either in isolation or in conjunction with treatment for another condition called hip impingement – at HSS, from 2006 to 2009. CT scans showed 19 of these patients had high anteversion of their femurs.

Before and after surgery, all 67 patients were evaluated by two common tests: the Modified Harris Hip Score (MHHS) and Hip Outcome Score (HOS) questionnaires. The tests assess a patient’s ability to carry out specific activities involving the hip in two main areas: daily living and athletics. Evaluated activities include things like climbing stairs, running and jumping.

Before surgery, patients with anteversion scored significantly worse on athletic actions than patients without the condition, but there were no differences in daily living scores. After surgery, the 19 patients with anteversion scored significantly worse in both athletic and daily living activities on the MHHS questionnaire, though the HOS scores were similar to the patients without anteversion.

For young patients with femoral anteverision, the study suggests alternative treatment strategies to surgical psoas tendon release should be considered.
Before a hip replacement, a patient’s functional ability is usually assessed by one of two approaches to standard testing. One approach is self-evaluation. Patients answer questions on standard forms, commonly the Western Ontario McMasters Universities Osteoarthritis Index (WOMAC) and the Short Form-36 (SF-36).

Another approach is physical performance assessment using the two-minute walk or the get-up-and-go test. Patients walk up and down a designated corridor for two minutes and physical results are recorded. Or patients get up from a chair, walk for three meters, and return to the original position, and the time it takes to perform the tasks are noted.

A recent HSS study – the first to compare these approaches – found the methodologies are not interchangeable. The results of the different tests have only mild to moderate correlation. Using both physical tests and self-evaluating questionnaires should be considered for a fuller picture of a patient’s functional performance capacity before total hip arthroplasty (THA).

162 patients scheduled to have THA at HSS completed the WOMAC and SF-36 questionnaires and performed both the two-minute walk and timed get-up-and-go tests. Multivariate analysis showed only mild to moderate correlation between the test results. The highest correlation was found between performance-based tests and the physical function measurements of the SF-36. Reported results that had higher association with the two-minute walk test were using a walking aid, being female and the presence of other painful lower extremity joints. While the timed get-up-and-go test was significantly associated with reporting age and additional painful lower extremity joints. Fuller testing provides a more complete functional assessment.
Bilateral Total Knee Arthroplasty: Risk Factors for Major Morbidity and Mortality

First study to identify factors – review of 206,573 surgeries

Comparing Mobile versus Fixed-Bearing Implant Design: Retrieval Analysis of Polyethylene Inserts

How mobile-bearing implants continue to show lack of superiority to fixed-bearing

Arterial Supply to the Patella: A Qualitative and Quantitative Anatomy Study Using Gadolinium-enhanced MRI

New findings on blood supply to the knee

Synovitis and Arthroscopic Partial Meniscectomy: Two-Year Post-Surgical Outcomes

Following outcomes of patients whose OA was discovered during surgery, not on x-rays before the procedure

The Lack of Correlation Between Radiographic Findings and Knee Cartilage Integrity

Relying on joint space width can overlook cartilage damage
Replacing both knees in the same operation – called bilateral total knee arthroplasty (BTKA) – carries more risk than surgery replacing just one knee. Yet, specific factors contributing to this increased risk have been unknown – until now.

Reviewing a national database representing an estimated 206,573 elective BTKAs, an HSS study found that the presence of congestive heart failure and pulmonary hypertension were the most significant risk factors associated with increased odds for adverse outcome in BTKA.

While other comorbidities can contribute, those two conditions ranked as the highest risk factors. Other contributors to adverse outcome included age – over 75 – and being male.

HSS performs more knee replacements than any other hospital allowing a highly experienced team of surgeons, anesthesiologists, and scientists to collaborate on this large, in-depth analysis. From the extensive review, of the Nationwide Inpatient Survey, collected from 1998 to 2007, the team identified 42,003 database entries to use in their multivariate analysis of elective BTKA. The results found, nationwide, a 9.5% overall risk for major in-hospital complications and mortality for BTKA.

The study was part of the Center for Education and Research in Therapeutics (CERTs) outcomes research created by the National Institute of Health to set the standards for the nation for most effective practices and procedures.
With over 16,000 retrieved implants available for study, the HSS Department of Biomechanics can test and evaluate past designs to help guide innovations of the future. Of special interest to the Lab is separating implant design reputation from real-life function.

While mobile-bearing (MB) knee implants have been theorized as superior to fixed-bearing (FB), HSS studies of retrieved implants have shown this not to be the case.

In an earlier study, HSS surgeons, bioengineers, and scientists analyzed 42 retrieved implants and found MB total knee replacements did not offer superior wear damage over fixed.

Now, a new investigation included retrieved liner inserts from 25 mobile-bearing and 33 fixed-bearing implants of the same design. Again, the overall damage score was significantly higher in the MB group.

As expected, backside damage was dramatically increased in the MB group. Interestingly, the post in the MB group had less damage than the post in the FB group.

Overall, this study does not support the theoretical superiority of the MB TKA design.
Disruption of arterial blood supply to the patella bone, either from surgical exposure or injury, has been considered a factor in post-treatment knee pain and complications.

Before this HSS study, there was no clear consensus on exactly where the primary blood supply to the patella entered the knee. Now, quantitative and qualitative data confirm that the dominant arterial system enters the patella at the inferior pole.

The HSS Trauma Service has developed a research methodology that injects gadolinium into the arteries of fresh-frozen cadaver specimens – in this case, 16 knees. Using custom software, 3D gradient echo sequences of the patella are captured by magnetic resonance imaging (MRI). The gadolinium allows an uptake analysis of the volume flowing from each artery to be revealed, and comparing the MRIs shows the main supply. Then, a urethane polymer is injected into the specimens, and they are dissected to relate vascularity of the soft tissues outside the bones to the MR findings.

Analysis of the MR images shows the largest contributing artery to the patella entering at the inferior pole in 100% of specimens. In 75% of the specimens, this dominant flow entered inferomedially, meaning from a location just below the middle of the knee.
Based on their findings, the team recommends several surgical procedures to protect the patella blood supply:

- Arthrotomies, especially medial, should be made with the inferior polar contribution in mind.
- The deep arterial ring should be preserved, including the infrapatellar anastamotic network.
- Soft tissue flaps should stay superficial to the periosteal layer covering the anterior surface of the patella, as this is where the dorsal anastamotic network is located.
- In fractures, the inferior pole patellectomy should be avoided to preserve vascularized bone.

This study serves as a model for future research to analyze the affects of fractures and surgical approaches on quantitative patellar enhancement.
Biopsies taken during surgical repair of damaged joint tissues can reveal evidence of osteoarthritis (OA) not detectable in pre-surgical x-ray imaging. Established OA has been associated with longer surgical healing and poorer outcomes. But what about previously undetected OA? Does OA first discovered during surgery also mean poorer outcomes for that procedure? In this study, the answer is no.

In a recent two-year follow-up of patients whose OA was not evident on x-rays, but discovered during arthroscopic partial meniscectomy, poorer outcomes did not occur. Further, those patients’ self-perception of improvement in pain, and function, was comparable to patients who did not have OA.

Two years ago, in an earlier study, 33 patients with no evidence of OA on their radiographic imaging underwent arthroscopic partial meniscectomy to repair a torn meniscus of the knee. The meniscus is one of two crescent-shaped cartilage “cushions” in each knee that help protect bone ends and distribute weight during movement.

Despite no evidence of OA on their pre-surgical imaging, 43% of the patients showed evidence of synovitis in tests on samples taken during the procedure. Of the group with synovitis, a majority (80%) had evidence of OA on direct cartilage examination. Synovitis is arthritic inflammation of the synovial membrane of the knee. The synovial membrane surrounds the knee joint and both produces and encapsulates synovial fluid—an almost clear, viscous fluid that lubricates
the joint, reduces friction during movement, and nourishes the cartilage in the knee.

Synovitis hurts. The inflamed membrane hurts; it also starts producing more synovial fluid which causes swelling, and more pain, because the extra fluid is held inside the inflamed membrane.

The patients whose synovitis was first discovered during surgery actually reported greater pain before the meniscectomy than did the patients with no synovitis. The presence of pain, and other symptoms, was associated with expression of the CCL19 gene and the CCR7 receptor in the synovial tissue.

The most recent study showed that, over time, at multiple follow-up points, including the latest review at 2 years, the patients whose synovitis and OA were first discovered during the meniscus repair, did not have poorer outcomes. Importantly, they experienced pain relief and improved function comparable to patients without synovitis or OA, indicating that these patients are responsive to surgical intervention.

Pain and other symptoms were measured by the Lysholm score—a patient questionnaire measuring knee-specific symptoms and dysfunction. Lysholm scores at 16 weeks, 1 year and 2 years after the arthroscopy showed increased satisfaction with the results.

The results of this 2-year follow-up do not match the poorer outcomes usually associated with patients whose OA is evident on x-rays before surgery. It is possible that longer follow-up is needed to identify patients who develop progressive knee symptoms, or increased arthritis, after surgical intervention for meniscal tears.
In planning a knee replacement, surgeons use as much diagnostic imaging information as possible. When considering a unicompartmental knee arthroplasty - where only one compartment, not the total knee, is replaced – joint space width (JSW) is a major factor determining treatment. Normal JSW on x-rays is often considered to indicate lack of cartilage damage from osteoarthritis (OA).

A recent HSS study compared the pre-operative JSW measurement from imaging to the actual OA conditions found in the patient’s knee. Findings showed that relying on JSW, alone, can overlook cartilage damage. Knee compartments that JSW indicated were unaffected, turned out to actually have OA.

The knees of 60 patients undergoing total knee replacement were x-rayed before surgery to determine their JSW. After the joint was removed for replacement, each knee compartment that had appeared unaffected on imaging was examined physically.

Using common rankings – the Collins, Mankin, and Kellgren and Lawrence scores – no correlation was seen between JSW measured by imaging and the physical and visual histological assessment made of cartilage conditions in actual knee joint compartments. Knee compartments with normal JSW actually had OA damage.

Because knee cartilage integrity cannot be fully determined before surgery, this study suggest that relying on JSW, alone, to choose unicompartmental arthroplasty may overlook disease in seemingly unaffected knee compartments.
Revision ACL Reconstruction in Skeletally Mature Athletes Younger Than 18 Years

Study shows only 52% of patients return to same level of pre-surgical activity

Comparison of ACL Tunnel Position and Graft Obliquity with Transtibial and Anteromedial Portal Femoral Tunnel Reaming Techniques

3-D models show AM results closer to natural anatomy

Contact Stress Patterns Across the Tibial Plateau During Gait: Effect of ACL Injury

Distinct loading patterns found in intact and ACL-ruptured knees

“Practice Makes Perfect” in ACL Reconstruction

Experienced ACL surgeons create better outcomes
Young, active, skeletally mature patients are known to have higher failure rates after primary ACL reconstruction. What has not been established is how often these younger patients could expect to return to pre-injury activity levels after revision ACL reconstruction, and if the surgery could successfully restore knee stability. A new HSS study has answers.

The study showed that knee stability for young, athletic, skeletally mature patients can be successfully restored after revision ACL reconstruction. However, only 11 out of 21, or 52%, of the patients were able to return to their prior level of activity or sport.

The patients studied all had initial ACL reconstruction between the ages of 12 and 17. Then, between the ages of 13 and 18, all patients had revision ACL reconstructions - by single-stage transosseous revision. Reasons for failure of the first surgery were primarily injuries and accidents.

The patients were followed-up at a minimum of two years, some for as long as 63 months. At the last follow-up, scores on standard tests that could indicate likely return to play showed 19 of 21 patients had a negative or IA Lachman score, and 20 of 21 had a negative pivot shift. Two patients reported subjective knee instability. Two had repeat revision reconstruction for failure.

The study shows that younger patients requiring revision ACL reconstruction can expect satisfactory restoration of knee stability, but return to previous levels of play is not likely for all patients.
Almost 850 ACL reconstructions are performed each year at HSS. This high patient volume allows HSS surgeons to not just advance reconstruction techniques, but also document which techniques yield better outcomes. The HSS ACL Patient Registry has over 2500 patients and is growing.

Modern ACL reconstruction involves replacing the entire injured anterior cruciate ligament (ACL) with a new tendon graft. The new graft is made from a tendon harvested from the patient’s own hamstring, quadriceps, or patella region, or an allograft tissue from a human donor. In order to connect the new graft, surgeons have to make a narrow tunnel through the leg bones. This necessary tunnel making is called reaming.

There are different reaming techniques using different tunnel locations and angles. But no matter the technique, the goal of ACL surgery is to recreate – as closely as possible – the natural knee’s anatomy and functional dynamics. That’s why ACL surgery is called “reconstruction”. Surgeons are trying to “reconstruct” the natural knee.

A recent collaboration of HSS surgeons and radiologists found that in single bundle ACL reconstruction, using the anteromedial (AM) reaming technique for creating the portal femoral tunnel restored native ACL anatomy more fully than the transtibial (TT) technique.
The 30 patients in the study all received single bundle ACL reconstruction at HSS, using tendon grafts harvested from their own bodies.

Using high-resolution magnetic resonance imaging (MRI) scans of the knees and imaging analysis software, 3-D models were created of all the patients' knees. By mirroring and superimposing the 3-D models, the results could then be compared and contrasted with each other and natural knees.

The comparisons showed that both techniques can capture, with similar accuracy, the native footprint of how the ACL graft connects the femur thigh bone to the knee.

However, in order to allow for later femur reaming, the TT technique requires a significantly greater posterior placement of the tunnel through the tibia bone of the lower leg. The 3-D models revealed that reconstructed ACL's in the TT technique group were further behind the natural ACL placement giving the TT grafts a decreased sagittal obliquity – or less natural angle – than the ACL of a healthy knee.

In the AM technique, the tibia tunnel is drilled without need to accommodate subsequent femoral tunnel reaming. This gives the AM technique more accurate tibial tunnel position, not as far behind the natural location as the TT placement, and thus, the AM graft also recreates a more natural sagittal graft obliquity than the TT technique can.

The TT has been used for three decades, the AM technique is newer. And as this study shows, advancements can create more natural knee anatomy in ACL reconstruction.
Surgical treatment of a damaged *anterior cruciate ligament* (ACL) is known as a “reconstruction.” Surgeons hope to “reconstruct” as closely as possible the dynamics of a natural knee. Every advance in understanding the most detailed complexities of the functional dynamics of a natural knee aids reconstruction.

Now, an HSS study has established the patterns of loading on articular cartilage in the natural knee, both when the ACL is intact and when the ACL is ruptured.

The study found that in intact knees, during the activity of walking (gait), 3 distinct loading patterns of contact stress consistently recurred on the knee’s tibial plateau. Once the ACL is ruptured, 70% of the knees deviated from this natural pattern.

9 cadaver knee specimens were wired with sensors. A mechanical simulator put all the knees through tests applying axial force, rotational torque, and flexion-extension that mimic a knee carrying the weight of a human body in motion. During the simulated gait cycles, the 200 electronic feedback points of the sensors - called sensels - sent information about when, where, and how cartilage experienced force of contact.

A custom software program used the data from each individual sensel to calculate the common patterns of contact stress to the cartilage. The knees were put through 20 cycles of simulated motion. Then the ACLs were ruptured, the tests repeated, and each of the 200 sensels reported the stress patterns, revealing any changes that occurred.

Analysis of the pooled sensel data suggested there is, on average, a 15% difference in loading patterns from intact to ACL ruptured knees.
Two special cartilage discs called menisci cushion the meeting of the tibia shin bone and the femur thigh bone in the knee joint. The sensors were inserted under the menisci and attached to the surface of the tibial plateau. The tibial plateau is the flattened area at the top of the shin bone. ACLs have two bundles of ligament tissue. Each bundle inserts into different places in the plateau, then connects deep into a notch in the femur bone of the thigh.

The 3 distinct loading patterns of intact knees found the greatest points of contact stress to be:
- **Pattern I**: Two peak stress profile locations in the posterior region of the lateral plateau.
- **Pattern II**: A single pronounced peak located at the posterior periphery of the medial plateau.
- **Pattern III**: A single pronounced peak trailed by smaller peaks located around the menisci.

In the ruptured ACL knees, 4 common stress patterns were found, including the same 3 distinct patterns observed in the intact knees, but at a higher magnitude. This increase in magnitude was particularly pronounced in plateau areas often damaged by ACL injury: the posterior aspect of the medial plateau and the posterior aspect of the lateral plateau. The fourth pattern also occurred in an area frequently damaged after ACL rupture: the central region of the medial plateau.

Not only can this new knowledge of cartilage stress help us to understand why specific areas of the knee become damages after ACL injuries, but it also can inform surgical reconstruction. Further, while it is well known that injury can lead to osteoarthritis (OA), how this occurs is not fully known. Knowing the normal contact stress patterns on cartilage during movement and how ruptured ACLs create deviations from those patterns can aid research seeking to reveal the causes of OA development as a result of previous injury.
Somewhere between 100,000 to 200,000 anterior cruciate ligament (ACL) reconstructions are performed every year in the US. While ACL is a common procedure, it requires considerable technical skill and thorough, dedicated training.

In orthopedic surgery, research has established that hospitals with higher volume and surgeons with more experience in specific procedures have better outcomes. A recent HSS study examined the other end of the spectrum and asked: *Does lack of experience in ACL reconstruction result in more revision surgeries?* The results were dramatic.

Reviewing 12,778 ACL reconstructions by 320 surgeons identified in the NY State Department of Health SPARCS database from 1996 to 2006, the study found that a surgeon’s first 10 career ACL reconstruction cases were 5.1 times more likely to result in subsequent re-operations.

The revision risk remains 3.7 greater from cases 11 to 60 in a surgeon’s career, before declining to 3.0 for cases 61-120, and 1.4 for cases 121-150. There was a slightly decreased risk with sports fellowship training, but this was not significant.

This striking demonstration that “practice makes perfect”, and that a Sport Medicine fellowship has little effect, suggests considering further training prior to the independent practice of ACL surgery. These surgeons could receive intensified supervision throughout their clinical training and early career surgeries, improving both patient outcomes and medical cost savings.
HSS Rotator Cuff Research

Full-thickness Supraspinatus Tears are Associated with More Synovial Inflammation and Tissue Degeneration Than Partial-thickness Tears

For the first time, size of tear found to relate to increased synovial inflammation and tissue degeneration

Bone Marrow-derived Mesenchymal Stem Cells Transduced with Scleraxis Improve Rotator Cuff Healing in a Rat Model

Scx-transduced MSCs may improve rotator cuff tendon healing and reduce the incidence of re-tear

The Effect of Muscle Paralysis Using Botox on the Healing of Tendon to Bone in a Rat Model

Botox impacts collagen, muscle strength, and mechanics in healing of rotator cuff repair

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HSS Research Menu  
Rotator Cuff Studies
The four muscles in the shoulder that comprise the rotator cuff each have a tendon that can be torn by accident or excessive overhead motion. The most commonly torn of the four tendons is the supraspinatus.

The painful, limiting condition of rotator cuff disease can progress rapidly in some patients, and not at all in others. Smaller, partial-thickness tendon tears have better clinical outcomes than larger, full-thickness tears, for reasons not fully understood. A suspected reason is that larger tendon tears produce more inflammation, but until now, that size relationship had not been established.

Recently, an HSS study determined that full-thickness tears of the supraspinatus tendon of the rotator cuff correlated with greater inflammation and tendon degeneration than tears that went only partially through the tendon.

The research involved 60 patients who underwent arthroscopic surgical repair of tears in their supraspinatus tendons. During surgery, tissue samples were taken from the rotator cuff synovium, bursa, torn supraspinatus tendon, and the neighboring, intact subscapularis tendon. The tissue samples were examined on a cellular level.

Inflammation can degrade tissues, including tendon and cartilage. Increased expression of enzymes known to be involved in tissue degradation – specifically MMP-1,
MMP-9, and MMP-13 – were found in the samples taken from the supraspinatus tendons with full-thickness tears.

Those tendon samples, as well as samples taken from the neighboring subscapularis tendon of patients with full-thickness tears, showed greater vascular endothelial growth factor and loss of collagen organization.

Both are indications that the tendons were degenerating and could become increasingly less capable of stabilizing their muscles, resulting in more limited movement and pain.

For the first time, this HSS study shows that increased synovial inflammation and tissue degeneration correlate with the tear size of the supraspinatus tendon. This new understanding can help inform design of novel and effective treatments to limit the advancement of rotator cuff disease and to improve clinical outcomes.
After surgical repair, torn rotator cuff tendons heal by developing a scar tissue interface at the site where they were inserted and reattached to bone. This scarred interface is no longer all tendon tissue and does not have the same biological properties, strength, or resiliency as original tendon. It can tear more readily than original tendon, thus increasing the chance of failure in even the most skillful repairs.

Seeking ways to improve tendon-to-bone healing has long been an area of vigorous investigation by the HSS Sports Medicine and Shoulder Service, led by Co-Chief Scott A. Rodeo, MD. The research team has explored possibilities of using mesenchymal stem cells - or MSCs – to improve tendon regeneration at the site of repair.

Made in the bone marrow, MSCs are cellular precursors that have the potential to develop into a range of different tissues, including bone, cartilage, and tendon, depending on the body’s needs. A transcription factor called Scleraxis (Scx) is thought to specifically direct MSCs to develop into new tendon.

A recent HSS study has found that an application of MSCs genetically modified with Scx can augment rotator cuff healing at early time points in rats.
Animals were sacrificed at 2 weeks and 4 weeks after surgery for evaluation to see if fibrocartilage and collagen fiber organization indicated healing was producing more tendon-like tissue with less scar development. Biomechanical testing was also performed to determine the structural and material properties of the healing site tissue.

At 2 weeks, examination of the healing tissue found no differences between the two MSC application groups in terms of microscopic cellular structure. However, the Scx group did have better scores in testing ultimate stress-to-failure and stiffness.

At 4 weeks, the Scx group showed more fibrocartilage at the healing attachment site and could also withstand higher load and stress levels than the group that had received MSCs with no Scx.

Biologic augmentation of acutely injured rotator cuffs with Scx-transduced MSCs may improve rotator cuff tendon healing and reduce the incidence of re-tears. However, further studies are needed to determine if this remains safe and effective in larger models.
The Effect of Muscle Paralysis Using Botox on the Healing of Tendon to Bone in a Rat Model

When torn tendons of the rotator cuff are surgically repaired, even the most skillful repair, over time, can tear again. The biology of tendon tissue healing can cause the failure. At the site where the tendon was surgically inserted and attached to the shoulder bone, the healing tendon interface does not have the same properties, strength, or resilience of original, uninjured tendon. Excessive tension due to shoulder motion can cause a repeat tear.

HSS surgeons and scientists are continually collaborating on new ways to improve tendon-to-bone healing of rotator cuff repairs and reduce the rate of re-injury. A recent HSS study investigated how injecting botulinum toxin A (botox) at the repair site might affect early healing in rotator cuff repair.

While the research team suspected botox could increase collagen, a desired outcome, they also theorized a potential downside. Botox paralyzes muscles. While it was theoretically possible that lack of stress from not moving could improve early tendon healing, it was more likely that, over time, the paralyzed muscle might show decreased mechanical properties. Weakness from not moving could show up at later points in the tendon healing. And if weakness did occur, it was unknown whether it would last.

The researchers performed rotator cuff repair surgeries on the torn supraspinatus tendons of 132 rats. 66 animals received injections of botox into the supraspinatus muscle before repair. The other 66 animals were in a control group that underwent repair surgery, alone, with no botox.
Rats were euthanized for study at 4, 8, and 24 weeks after repair surgery. The healing tendons were evaluated by visual, cellular, histologic, biomechanical, and micro-computed tomography (microCT) analyses.

The theorized beneficial result of botox did occur. The healing site of the tendon-to-bone interface in the botox group did show formation of a more normal tidemark and increased collagen fiber organization than the control group.

The potential mechanical difficulties also occurred, but primarily at 8 weeks, and did not appear to last.

At 8 weeks, the botox tendons could not bear as much weight as the control group, as shown by having a lower rate of load to failure. However, at 4 and 24 weeks, tendons from the two groups showed no significant difference in their ability to bear weight load to failure.

The muscle that had received the botox injection was significantly decreased in weight at 4 and 8 weeks, but recovered by 24 weeks. MicroCT analysis did show the botox group to have significantly less bone volume, total mineral content, and total mineral density at 8 weeks.

The rapid healing of the rat rotator cuff likely makes it difficult to realize any benefits that might have occurred from reduction in strain from not moving.
Zone of Injury of the Medial Patellofemoral Ligament After Acute Patellar Dislocation

61% of MFPL injuries were detachments from the patella

Long-term MRI Follow-up After Posterior Spine Fusion for Adolescent Idiopathic Scoliosis

High patient satisfaction and minimal transitional level lumbar disc degeneration found

Ultrasound is Reliable Imaging Modality for Developmental Dysplasia of the Hip Screening in Six-Month-Old Children

X-ray shown not to be required for accurate diagnosis

Comparison of Multiplanar Fluoroscopic Imaging and CT for Measurement of TT-TG Distance in Patellar Instability

“Gold standard” of CT scan matched with 66% less radiation

Lenke 1 AIS Curves: Where to Stop and How Does It Affect Shoulder Balance? Selective vs Non-Selective Thoracic Fusions

Comparing fusion with and without PT curve
Active kids, especially if they play sports, can fall and hurt their knees. Dislocation of the kneecap – or patella bone – is a common traumatic injury.

The patella is attached to the femur bone of the thigh by the medial patellofemoral ligament (MPFL). Stabilization by the MPFL helps the patella resist shifting out of place, laterally, when the knee moves. But if the MPFL is injured in a fall or accident, with stabilization gone, the patella moves out of place, dislocated. Until now, the “zone of injury” in patella displacement – meaning where the MFPL is most likely to be injured – has not been well documented.

A collaboration of HSS orthopedic surgeons and radiologists reviewed the magnetic resonance imaging (MRI) scans of 43 children and adolescents, under 18, who had suffered primary dislocation of the patella bone of the knee.

The research team found that of the two ends of its patella-femur connection the MFPL is most likely to detach from the patella. 61% of the MFPL injuries were detachments from the patella. Just 12% of the detachments were from the femur bone. Another 12% had detachment at both ends of the ligament. 15% of the children had injury at multiple locations or no identifiable injury.

This new “zone of injury” knowledge has important implications in helping guide surgeon reconstructing the MFLP in the knees of injured children and adolescents.
Since the 1990’s, curvature of the spine caused by scoliosis has been treated by modern spinal fusion techniques. The high tech fusion materials and pedicle screws allow the spine to be corrected in a much more natural way than the 1960’s treatment of steel rods implanted along the spine.

*Adolescent idiopathic scoliosis* – or AIS – develops in children aged 10 to 18, for unknown reasons. It is hallmarked by curvature in more than one place in the spine. Until now, few studies have evaluated the long-term results of modern spinal fusion treatment in AIS.

A recent HSS study of 20 patients with AIS who had spinal fusion surgery at an average of 11.8 years earlier, showed excellent long term results. The young patients had been experiencing a relatively normal, pain free lifestyle.

Reviewing all spinal fusions performed at HSS on patients with AIS from 1991 to 1997, the research team identified 33 patients for the study who were 21 or younger at the time of surgery. The patients were contacted and asked to have follow-up exams specifically for the study, and 20 agreed.

All of the patients had received *posterior spinal fusion*, meaning the surgeon had approached the spine from the patient’s back, and not the older approach from the front or side. All fusions had been in the lower back between vertebra T12 and L3.
There has been existing concern in the field that, long term, the spinal area just below the fusion surgery would wear out – due to potential increased stress resulting from the fusion just above it. This simply did not happen.

Magnetic resonance imaging (MRI) scans of all patients found that the area of the spine adjacent to the fusion did not show any major degeneration. Mild degenerative changes were noted in almost every patient, but severe changes were not evident.

No patients reported significant lower back pain. No patients took analgesic medications for their pain, with the exception of four patients (20%) who took occasional non-prescription non-steroidal anti-inflammatory drugs. All patients had good functional scores and maintenance of balance.

The investigators note that while there is much research in the field looking for new technologies that do not use fusion, this study – demonstrating such good long term results and high patient satisfaction – would suggest spinal fusion is already an excellent choice of treatment for AIS.
Newborns who present with signs that they may develop structural hip abnormalities as they grow – known collectively as *developmental dysplasia of the hip*, or DDH – are usually screened by ultrasound to determine their condition. Ultrasound is accurate, and it prevents exposing newborns to ionizing radiation.

At age 6 months, standard procedure has been to screen the current status of the possible DDH by using x-ray. It was thought that the infants’ growing bones would have reached a point of development that only x-ray could accurately picture. This point is known as *ossifying nucleus*, referring to the natural process of areas of softer cartilage changing into harder, thicker bone.

Now, an HSS study has determined that ultrasound can reveal reliable and accurate images for diagnosing the status of DDH in infants aged 5-to-7 months. Exposure to the ionizing radiation of x-rays can be delayed. Despite ossifying nucleus, ultrasound can accurately reveal abnormalities.

35 infants at high risk for DDH, aged 5-to-7 months, were prospectively screened by both standard AP pelvis x-ray, and bilateral, non-stress ultrasound. Physicians reviewed the images independently. One group of doctors reviewed sonograms, another reviewed the x-rays. 34 babies were deemed normal, using both sonogram and x-ray, independently. The one baby found to have hip dysplasia, was also diagnosed on both ultrasound sonogram and x-ray.

Despite the appearance of ossific nucleus in the hips of 33 of the 35 babies, ultrasound provided good quality images with 100% diagnostic correlation to x-ray in all the 5-to-7 month old babies in the study.
When diagnosing knee problems or injuries in children, doctors have considered computerized tomography (CT) scans to be the “gold standard” imaging technique. CT scans allow accurate measurement of any misalignment in the child’s kneecap at the center of the knee.

There is a natural groove at the end of each leg bone into which the patella bone can slide when the knee bends and straightens. This groove is called the trochlea. Measuring the distance between the trochlea and the patella bone is an important diagnostic measurement used to assess misalignment. If the distance varies from normal, the patella bone cannot properly slide into the trochlea groove. This measurement is known as tibial tubercle-trochlear groove (TT-TG) distance. CT scans provide accurate TT-TG measurement, but they use radiation. Doctors would like to limit exposing children to ionizing radiation whenever possible.

New research by an interdisciplinary team of HSS orthopedic surgeons and musculoskeletal radiologists has found that using multiplanar fluoroscopic imaging to measure TT-TG distance provides the accuracy of CT scans with a 66% reduction in radiation.

Eight matched pairs of cadaver knees were imaged by both conventional CT scan and multiplanar fluoroscopic imaging. Measurements were taken of TT-TG distance and radiation levels. Excellent agreement was found in comparing the TT-TG distance measured by each imaging technique. Yet, multiplanar fluoroscopic imaging provided this same degree of accuracy with exposure to 66% less ionizing radiation.
When children between the ages of 10 and 18 develop scoliosis for unknown reasons, they are diagnosed with adolescent idiopathic scoliosis or AIS. The child’s spine is curved in more than one place.

There is classification system used in diagnosing AIS – called Lenke Classification – that indicates the type and pattern of spinal curving. There are six different Lenke types, each designated by a number, from Type 1 to Type 6.

To help straighten the spine, Lenke 1 AIS is treated with modern spinal fusion. Some doctors include an upper spinal area called the proximal thoracic (PT) curve in the fusion aiming to improve shoulder balance. However, fusing more curve can reduce movement flexibility. It also lengthens surgery time, thus increasing risks, including neurological risks, bleeding, and medical costs.

A recent HSS collaboration of HSS specialists in pediatric and spinal orthopedic surgery compared two groups of patients with Lenke 1 AIS treated by spinal fusion – 13 patients with the PT curve included in their spinal fusion and 9 patients where the PT curve had not been included.

Comparison of x-rays and outcomes showed no differences in PT curve correction or shoulder symmetry between the two groups. Including the PT curve in spinal fusion did not improve outcomes for the patients.
The research team reviewed 148 consecutive cases of patients with Lenke 1 AIS who had been treated with spinal fusion. 22 patients met the study criteria of having Lenke 1 curve type treated by fusion with posterior pedicle screw fixation.

The 22 patients were divided into two groups. Group 1 consisted of the 9 patients whose spinal fusion did not include the PT curve, as they had spinal fusion to the upper end vertebra or one level higher. Group 2 were the 13 patients whose fusion did include the PT curve – with fusion 2 or 3 levels proximal to the upper end vertebra.

The average age in both groups was 14 years (range 10-17). The average time of follow-up was 28 months (range 24-36) in Group 1 and 30 months (range 24-47) in Group 2.

Using x-rays, standard measurements were taken of all the patients’ spines before surgery, six weeks after surgery, and again at final follow-up. These measurements included the PT curve, main thoracic (MT) curve, T1 tilt, clavicle angle (CA) and shoulder height difference (SHD).

There was no significant difference between the 2 groups in pre-operative angles. While Group 2 had larger pre-operative PT curves, these curves were also much more flexible.

After surgery, findings demonstrated no differences in PT curve correction or shoulder symmetry between the two patient groups, indicating no significant benefit to incorporating the PT curve in the spinal fusion of Lenke 1 AIS patients. Not including the PT curve in surgery can potentially avoid increased implant cost, neurological risk, bleeding, and operative time.
Risk Factors for Postoperative Infection Following Posterior Lumbar Instrumented Arthrodesis

Review of 3218 surgeries identifies new risks and confirms others

Duration of Symptoms Has No Correlation to Disease Severity in Cervical Spondylitic Myelopathy

Longer symptoms not associated with more severe condition

Myelomalacia on MRI is Poorly Correlated with Severity of Disease in Cervical Spondylitic Myelopathy

MRI evidence of myelomalacia shown not to indicate severity of condition but can indicate who benefits from surgery

Surgical Intervention for CSM Based on Nurick Grade Affects Symptom Improvement

Patients at Nurick Grade 2 shown to benefit most from surgery
Patient safety is a hospital-wide vigilance at HSS, which helps the hospital maintain one of the lowest infection rates in the world. With the aide of data from HSS’s large patient volume and significant patient registries, interdisciplinary research teams can uncover infection risk factors for specific surgical procedures. Patients who match those risk factors can then be even more carefully monitored.

To relieve intractable back pain – often occurring as a result of injury – when conservative measures have failed, surgeons can use bone grafts to strategically fuse damaged areas of the spine. Technically known as an arthrodesis, the fusion can stop the pain.

Recently, an HSS study identified high risk factors for infection after a fusion surgery called posterior lumbar instrumented arthrodesis. Reviewing 3218 such procedures performed at HSS between 2000 and 2008, the research team used a multivariate logistic regression model to evaluate the independent associations of potential risk factors for postoperative surgical site infection in the spine.

New risk factors identified were osteoporosis, chronic obstructive pulmonary disease, and dural tears. The strongest risk factors shown in the study were obesity and a history of chronic obstructive pulmonary disease. Other risks included intraoperative blood loss, ten or more people in the operating room, history of diabetes and coronary heart disease.

Only 84 patients developed any infection over the 8 year period. But armed with this new information, HSS surgical teams aim to make that already low 2.6% infection rate, even lower.
Problems that occur along the spine are medically known as myelopathies. As people age, one of the most common myelopathies happens in the cervical neck area. Bones and discs that cushion and separate the vertebrae in the neck can degenerate, compressing the spinal cord, and causing pain. Known as cervical spondylitic myelopathy, or CSM, this condition is the most common spinal cord damage found in aging.

Recently, an HSS study showed that the length of time patients have been suffering from CSM does not correlate with the severity of the progression of the condition. However, those patients who did not improve after surgery had a longer duration of symptoms, before surgery, by approximately six months.

259 patients who had surgery at HSS for CSM between 2000 and 2010, were identified for the study. The research team compared the length of time the patients had CSM before surgery, the severity of their symptoms before surgery, and the degree of improvement after surgery. The Nurick scale—a six-grade standardized ratings system based on walking ability and pain—was used to rate the patient’s severity of symptoms. Higher Nurick grade indicates worse symptoms and condition.

Data analysis revealed that higher Nurick grades did not correlate with longer duration of CSM symptoms. However, those that improved at least one Nurick grade after surgery had 6.1 months shorter duration of symptoms than those who stayed the same or worsened with surgery,
The most common spinal cord damage that occurs as people age is a painful neck area condition known as *cervical spondylitic myelopathy* - or CSM. Any spinal cord damage that radiologists can see on magnetic resonance imaging (MRI) is known by the medical term *myelomalacia*. Not all patients with CSM have myelomalacia on their MRIs. Further, it has not been established if presence of myelomalacia on a patient’s MRI correlated with severity of a patient’s CSM.

Now, an HSS study has found two new significant associations with visible myelomalacia on MRIs in patients with CSM. Myelomalacia evident on MRIs is not associated with disease severity in CSM. However, patients with CSM who had myelomalacia evident on their MRIs were found less likely to improve with surgical intervention than patients with no myelomalacia.

259 patients who received surgery for CSM at HSS from 2000 to 2010 were studied. A standard test used to assess gait abnormalities including patient function and pain and how it relates to being able to work is called the Nurick grade. Nurick scores range from 0 to 5, with grade 5 being the most severe condition.

Of the 259 patients studied, myelomalacia was present on 51%, 35%, 11% and 3% of patients with Grade 1, 2, 3, 4 Nurick scores, respectively. Higher scores did not correlate with greater evidence of myelomalacia on MRIs. The average range of follow-up of the 259 patients after surgery was almost 15 months. After surgery, follow-up MRIs showed myelomalacia present in only 5 patients. Yet, overall, only 27% of the patients with pre-operative myelomalacia had improvement in their Nurick scores after surgery.
In recent studies of the most common spinal cord damage that occurs in aging – *cervical spondylitic myelopathy,* or CSM – HSS has made several interesting new discoveries about treating the painful neck condition. Neither duration of CSM symptoms nor evidence of spinal cord damage on MRIs were found to correlate with severity of the condition. However, patients who did have spinal cord damage visible on their MRI’s were found less likely to improve by surgical intervention. (To view those studies, just tap blue link to Spine Research Menu, on left)

Now, a new HSS study has shown which patients with CSM are most likely to benefit from surgery when conservative measures have failed to bring relief. Patients with a Grade 2 score on a standard test called the *Nurick grade* were found to have greatest improvement from surgical intervention for CSM.

Nurick grades, which range from 0 to 5 are a standardized assessment of how CSM is affecting a patient’s ability to walk, work, and function. Higher Nurick scores mean more severe, likely more painful conditions. Nurick scores at grade 4 and 5 indicate the patient’s condition prevents employment.

258 patients who were treated surgically for CSM at HSS from 2000 to 2010, were included in the study. Before surgery, 110 patients were scored at Nurick grade 1, 90 grade 2, 48 grade 3 and 10 grade 4. After surgery, at least one Nurick grade of improvement was found in 60% of the grade 2 patients, 50% of grade 3 patients, 15% of grade 1, and 10% of grade 4. Patients with grade 2 and grade 3 were most likely to be relieved of all CSM symptoms.
Higher Activity Level after Mosaicplasty than Microfracture for Cartilage Defects of the Knee

Comparison of two cartilage repair techniques shows higher activity scores for patients treated with OAT mosaicplasty.

Multiple Pathways in Cartilage Metabolism Converge Upon the Regulation of One Enzyme: MMP-13

Three different cellular pathways all converge upon regulation of one enzyme: MMP-13.

Cartilage Degeneration and Subchondral Bone Changes due to In Vivo Cyclic Compression Depend on Load Level, Duration, and Anatomical Location in the Adult Mouse Tibia

Exploring possible co-ordination of cartilage and bone tissue degeneration in mouse model.
A damaged joint is at increased risk for developing osteoarthritis (OA). Be it from the lasting impact of an old sports injury or the daily strain of carrying the excessive weight of obesity, physical joint damage can trigger structural and cellular changes in both bone and cartilage that can eventually – sometimes at a surprisingly early age – lead to signs of OA.

Though this increased risk of OA is well established, not all aspects of the tissue changes leading up to it are completely known. Most research has studied either bone or cartilage independently. Now, an HSS collaboration has investigated whether degenerating structural and cellular changes that lead to OA might somehow be coordinated in bone and cartilage.

Studying the impact on mice of bearing different mechanical weight loads, the investigators found interesting hints of possible coordination of cartilage and bone degeneration: Stiffening bone may contribute to thinning of the cartilage layer that cushions the joint.

6 weeks of bearing a heavy load caused thickening in the subchondral cortical bone of the mice. This stiffer bone could increase stress on the cartilage. Extra stress on the cartilage cells could, in turn, provoke cartilage degeneration, resulting in cartilage thinning.
26 male mice were divided into two groups. One group bore mechanical load (9.0N) twice the weight of the other (4.5N). Only the left tibia of each mouse was subjected to any weight of mechanical load. The right tibia served as control. Animals were euthanized for study at 1, 2, and 6 weeks. Their tibia joints were dissected, analyzed, and compared. MicroCT scans were taken to detect changes in composition and structure.

Cartilage damage was clear: heavier load and longer duration accelerated the extent and severity of cartilage damage. Different aspects of bone composition had different reactions to load. Loading caused an increase in the cortical bone immediately beneath the cartilage, but the deeper regions of cancellous bone actually decreased in volume and thickness.

Bearing high loads for long duration caused the mice to show early signs of developing OA in both cartilage and bone. These included joint space narrowing, osteophyte formation, cartilage matrix damage, and localized subchondral bone thickness. The mechanisms by which load produces the coordinated changes in the cartilage and bone requires further investigation.

Research with noninvasive tibial loading including kinematic analysis, pharmacologic intervention, and genetic mouse models can help reveal mechanical and biological factors responsible for bone and cartilage adaptation and how they contribute to OA.

Knowledge of any coordination of the degeneration of bone and cartilage in development of OA can, one day, lead to targeted, coordinated therapeutic interventions to two key tissues at once.

For his work on this study, Frank Ko received the Kappa Delta ORS Travel Award given annually to a Cornell graduate student for orthopedic research.
For patients with osteoarthritis (OA), one aspect of the condition is not hard to understand: Less cartilage equals more pain. For doctors and scientists searching for OA treatments, full understanding of the pathways of cartilage destruction, cartilage growth, and the problems created by cartilage’s inability to repair itself remain some of the most complex molecular mysteries in medicine.

Now, an HSS study has determined particular signaling points and mechanisms in 3 essential cartilage processes – loss by wear-and-tear, inflammation damage, and the growth of new cartilage cells – that show how all the differing cellular pathways converge upon regulation of one enzyme: MMP-13.

### MMP-13 – Enzyme of Cartilage Break Down

MMP-13 is one of a class of zinc-dependent endopeptidases called matrix metalloproteinases – abbreviated MMPs. Endopeptidases are enzymes that break apart the peptide bonds in molecules somewhere in the middle, not the end, of the chain of amino acids holding the protein bonds of the cell together. Even more specifically, MMP-13 is the major type II, collagen-degrading collagenase, that breaks down collagen in cartilage.

While stress, wear-and-tear and inflammation all use different ways to initiate similar cellular pathways to impact cartilage, at some point, their damage results in cartilage loss. That’s when, the HSS team found, MMP-13, the enzyme of collagen cartilage break down, is signaled to join the process.
The unique way that cartilage forms new cells also involves MMP-13, but as part of how the process can go awry. Chondrocytes start as mesenchymal stem cells. These stem cells differentiate to start the process of becoming either new cartilage or new bone. Chondrocytes make a scaffold of a collagen-rich matrix across which new chondrocytes grow.

A major challenge in cartilage repair is that no consistently reliable way has been found to encourage new chondrocytes to survive and grow across any matrix or scaffolding, natural or tissue-engineered – though several promising possibilities have been developed by HSS collaborations of doctors, scientists, and bioengineers. Knowing how and where MMP-13 is involved in the break-down of cartilage can help find new ways to stabilize it.

Being involved in so many essential cartilage processes, MMP-13 is an important target for developing new, far-reaching arthritis therapies. The HSS Laboratory for Cartilage Biology headed by Mary Goldring, PhD, continually aims to uncover new therapeutic possibilities as they seek to unravel the intricate cellular steps of cartilage creation and destruction, from beginning to end.

Using their innovative investigatory approach including unique models of primary human and mouse chondrocytes, cell lines, and mouse genetic models to manipulate gene expression, the team can pinpoint new molecular targets for therapies, as well as develop new strategies for new cartilage growth and tissue engineering.
There are two surgical techniques used to treat cartilage defects in the knee that have had limited information about direct comparison of their outcomes. One technique is called osteochondral autograft transfer (OAT) mosaicplasty and the other is known as microfracture (MFX). In mosaicplasty, small pieces of undamaged cartilage tissue from the joint are used for repair. In MFX, tiny fractures are made in the underlying bone, releasing bone marrow cells to help build new cartilage.

To compare the outcomes of the two techniques, 96 patients with full thickness cartilage defects were identified from the HSS Cartilage Patient Registry. 48 patients had been treated with mosaicplasty and 48 with MFX. In both groups, 32 patients were male and 16 patients were female. Average age of patients at time of surgery was 29.7 (range 15-49) for the OAT group versus 32.5 (range 15-46) for the MFX group.

Comparing knee function scores at one, three, and five year intervals, both techniques provided similar improvements in general health outcome and knee function at mid-term follow-up. However, patients treated with OAT mosaicplasty maintained a superior level of athletic activity compared to those treated with MFX.

Three established tests were used for scoring knee function: Short Form-36 (SF-36), Knee Outcome Survey (KOS), and the International Knee Documentation Committee (IKDC) Marx activity score. At last follow-up, all patients showed improvement from baseline pre-surgical conditions in KOS and SF-36 scores. But patients treated with OAT mosaicplasty showed significantly higher IKDC Marx activity scores at all 3 points in time of comparison.
Early Detection and Treatment of Wear Particle-Induced Inflammation and Bone Loss in Mice Using Novel HPMA Copolymer Conjugates

Novel system can both detect & treat early osteolysis

MicroCT Morphometry Analysis of Cancellous Bone: Intra- and Inter-System Reproducibility.

How all MicroCT measurements are not alike

Conditional Inactivation of the CXCR4 Receptor in Osteoprecursors Reduces Postnatal Bone Formation Due to Impaired Osteoblast Development

Receptor shown to help regulate osteoblast development

Loss of Transcription Factor Early Growth Response Gene 1 Results in Impaired Endochondral Bone Repair

Regulating ossification in endochondral bone fracture repair

Haptic Robot-Assisted Surgery Substantially Improves Accuracy of Wide Resection of Bone Tumors

Comparing manual and robot-assisted techniques
Healthy bone replaces itself in a complex process. There is a coupling between the cells that remove old bone (osteocytes) and the cells that make new bone (osteoblasts). As old bone is removed, new bone cells begin as stem cells in the bone marrow – called mesenchymal stem cells or MSCs. The MSCs differentiate into new osteoblasts, which will eventually make strong new bone.

Osteoporosis is a condition of low bone density. Bones grow thinner, because osteoclasts are more active but not enough osteoblasts are making enough new bone. Finding a treatment that creates a safe, reliable way to encourage new osteoblasts to keep forming healthy new bone is a main goal of bone research.

One aspect of the intricate molecular mechanisms of bone formation that has not been completely understood is the involvement of proteins called transcription factors. During cell reproduction, transcription factors bind to specific DNA sequences inside genes and regulate the transfer of that genetic information to RNA. In bone building, an important transcriptional factor is early growth response gene 1, or EGR-1.

A recent HSS-led study has produced genetic evidence that both sex and skeletal site are critical determinants of EGR-1 activity, and that site-specific action of EGR-1 may contribute to the mechanical properties of bone.

Bones of mice who were bred to have no EGR-1 were compared to bones of wild type mice with intact EGR-1. Both groups had both male and female mice, matched in number and age.
Microscopic and molecular analysis was performed using micro-computed tomography (micro-CT) and Fourier transform infrared imaging (FTIRI), respectively.

The medical term for bone tissue, especially when it is being analyzed at a cellular level in scientific studies, is osseous tissue. There are two main kinds of osseous tissue: spongy and compact. The spongy tissue is also known as trabecular or cancellous bone.

In the study, the trabecular bone in the femurs of the male mice with no EGR-1 demonstrated osteopenic characteristics marked by reductions in bone mineral density (BMD) and bone volume fraction (BV/TV). In contrast, the female mice with no EGR-1 showed no loss of normal BMD or BV/TV.

Morphological analysis revealed the male mice with no EGR-1 had fewer trabeculae, which are microscopically small, rod-like struts of cancellous bone. The EGR-1 deficient female mice weren’t missing quantity of trabeculae, but their trabeculae were thinner than normal.

Analysis of a broad range of standard compositional bone properties in the femurs of the EGR-1 deficient mice showed no appreciable variation from normal, nor significant difference between the males and females. But unexpectedly, their rib bones displayed distinct osteopenic traits that were particularly pronounced in female mice.

Showing the results of what happens to bone when mice have no EGR-1 to regulate transfer of genetic information, this study provides genetic evidence that both sex and skeletal site are critical determinants of EGR-1 activity, and that its site-specific action may contribute to the mechanical properties of bone.
Early Detection and Treatment of Wear Particle-Induced Inflammation and Bone Loss in Mice Using Novel HPMA Copolymer Conjugates

Around the globe, over 1,500,000 joint replacements are performed annually. In about 10% of these arthroplasties – as the surgeries are known medically – a condition called osteolysis develops. Osteolysis can create bone loss that leads to implant loosening, which leads to implant failure. Then, revision surgery must retrieve the failed implant and replace it with a new one.

Osteolysis is an inflammatory reaction by the immune system to tiny particles that have worn off the joint replacement implant and are now either sitting on the surface of the implant or are in the surrounding tissues. Known as “wear debris” or “wear particles” these tiny remnants are difficult to detect. The inflammation of osteolysis is also difficult to diagnose at an early stage when treatment might prevent revision surgery.

HSS has one of the few dedicated osteolysis academic research programs where surgeons, scientists, and bio-engineers join together to seek the causes and potential cures of the condition.

Now, a novel, injectable polymer “nanoparticle” has been shown to not just reveal early signs of implant wear debris but also be able to treat the inflammation of osteolysis in a mouse model.

In an exciting collaboration, HSS experts in osteolysis and the cellular science of bone joined scientists at University of Nebraska Medical Center, where the nanoparticle molecules were developed. The molecules resulted from modifying a system previously used to deliver chemotherapy agents to cancer cells by specifically targeting sites of inflammation.
The collaborators now sought to use the inflammation-seeking nanoparticles to detect the inflammation of osteolysis.

Mice who had developed inflammatory reactions to wear debris particles were injected with nanoparticle molecules that had been tagged with a fluorescent marker. Technically, this combination is $N$-(2-hydroxypropyl)methacrylamide (HPMA) copolymer-based optical imaging contrast agent (P-IRDye).

Under microscopic analysis, the glowing nanoparticles could be seen gravitating to the osteolysis inflammatory cells in tissue samples of the mice.

When the researchers attached medication to the nanoparticles, the drugs were delivered directly to the inflammatory sites.

Currently, in clinical treatment of osteolysis, once signs of the condition are visible on x-rays and MRIs and patients have begun to experience pain, few treatments can prevent new surgeries. Reliable early detection could help change this. The collaborators will continue to explore the exciting promise of this unique system that could both detect osteolysis and deliver targeted medication to treat it.
Microcomputed tomography – also known as microCT – allows scientists to x-ray tiny slices of a subject in cross-sectional scans that can be compiled to create a 3-D model. The ultra-high resolution images are used in bone research to create many essential quantitative and qualitative measurements about the structure and composition of bone. MicroCT is used to measure bone mineral density, for example.

There are three main manufacturers of microCT technology. What is not known is how the measurements taken from the different systems compare. Can measurements taken from a 3-D model made with one system match those made from a model created by another system? A new study says no.

In a recent HSS collaboration, researchers found that different microCT systems produce different results. Measurements taken from microCT scans of the same subject on different machines did not always agree.

A microCT 3-D imager is made of voxels, which is short for “volume pixels”. Just as pixels describe the smallest electronic unit of a flat image, as well as a way to indicate image size and resolution, voxels are similarly used in 3-D.

In the study, microCT scans and 3-D models were made of the same cancellous bones from mice femurs on 3 systems. Scans were completed in triplicate at both 12μm and 8μm voxel size.
The greatest differences across the systems were found in assessing the trabeculae in the bones.

*Trabeculae* are tiny, often microscopic, beam or rod shaped elements that are part of the structure of *cancellous* bone. Cancellous is spongy bone. The size, shape, and quantity of trabeculae is a common, important information in bone research. Having over a 200% discrepancy in measurements of trabeculae would not aid discovery.

Variations between the trabecular number measured from the 12μm and 8μm voxel sizes varied from none to 20%, depending on the system. However, bone volume fraction and trabecular separation values were similar across all 3 systems.

Where comparing intra-system consistency of images made on different machines of the same system, consistency improved for some bone composition values, but not for trabeculae measurements. Different machines from the same system did not result in machine-to-machine agreement of trabeculae numbers.

The study indicates that trabecular morphometry measurements should not be directly compared across microCT systems. Conditions, including voxel size, should be chosen based on the specific microCT system and the measurements of main interest.
There are stem cells in the bone marrow that can eventually develop into a range of new tissues including new bone, cartilage, or tendons. They are called mesenchymal stem cells or MSCs. When MSCs start the complex process of becoming bone, they differentiate into new bone cells called osteoblasts.

Now, HSS scientists have found that a specific molecular receptor is required for new osteoblasts to continue development into healthy bone. This receptor is the Cystine (C)-X-C motif chemokine receptor 4 – or CXCR4 receptor. When the CXCR4 receptor was inactivated in mice, osteoblasts did not develop properly into new bone.

The CXCR4 receptor is a chemokine receptor. Chemokines send molecular signals that guide the migration of cells. The signal can attract a concentration of cells towards it. The study showed that without the CXCR4 receptor, the necessary chemokine signal wasn’t being received, and cells weren’t migrating towards their proper participation in bone development.

When compared to wild type littermates, the CXCR4 deficient mice developed smaller, osteopenic skeletons with lower bone mineral density and a slower mineral apposition rate. The progressive development of the maturing osteoblasts was arrested. Participation in certain known stages of bone building was at insufficient levels to create healthy bone. Both type I collagen α1 and osteocalcin were reduced.
Primary cultures of the osteoblasts from CXCR4 deficient mice showed impaired reaction to some bone morphogenetic proteins (BMPs) – growth factors in the body key to bone building. BMPs send signals to osteoblasts triggering stages of bone development.

The mice had no CXCR4 receptors, so unlike their wild type littermates, their developing bone cells were not growing in a manner that indicated receiving sufficient signals from BMP6 or BMP2. Thus, the CXCR4 receptor must be necessary to receive signals from the BMPs. Without sufficient BMP signals, not enough osteoblasts were differentiating from the MSCs of the mice to become new replacement bone.

This study is the first to show that CXCR4 functions in postnatal bone development via regulating osteoblast development in cooperation with BMP signaling, and that CXCR4 acts as a necessary component to receive the cellular signals required for healthy bone formation.
Loss of Transcription Factor Early Growth Response Gene 1 Results in Impaired Endochondral Bone Repair

After a fracture, bone repairs itself by a process called *endochondral ossification*. At the places where the bone is broken, cushiony cartilage transforms – or *ossifies* – into harder bone tissue.

Ossification is how all bones form when a fetus grows a skeleton inside the uterus. In adults, only some bones – like the long bones of the arms and legs – are formed through ossification, which classifies them as *endochondral* bones. But all bones, endochondral or not, heal fractures through ossification. Every uncovering of a new aspect of the cellular complexities of ossification brings knowledge that can help advance treatments in bone fractures and bone repair.

A recent HSS-led study has provided genetic evidence that the transcription factor *early growth response gene 1* – or EGR-1 – is a regulator of ossification in endochondral bone fracture repair.

Transcription factors are proteins that bind to DNA during cell reproduction to direct the transfer of the cell’s genetic information to RNA. EGR-1 is known to be a transcription factor involved in the growth of new bone and to modulate repair in vascularized tissue that conducts blood flow.

The research team studied 28 days of rib fracture healing in two groups of mice. One group was bred without EGR-1. The other was a control group of wild type mice with EGR-1 naturally intact.
Ossification proceeded as expected in wild type mice. The mice without EGR-1 experienced a similar sequence of healing, but it had abnormalities.

Seven days after fracture, a persistent accumulation of fibrin – an insoluble protein involved with blood clotting – was observed between the fractured bones of the EGR-1 deficient mice. It remained until 14 days after fracture.

Bone heals by forming a callus at the place of fracture. In the mice with no EGR-1, the callus was abnormally enlarged and showed increased deposition of mineralized tissue at fourteen days after fracture. Other abnormalities at that same time included cell deposits near the callus. As the callus ossified it was also associated with being hyper-vascular.

Despite these impairments, by 28 days after fracture, repair in the callus of the EGR-1 deficient mice was similar to that in wild type mice, showing EGR-1 is not required for ossification to complete. However, the abnormalities found in the process of healing in the ribs of the mice with no EGR-1 does provide genetic evidence that EGR-1 helps regulate the ossification process of endochondral fracture repair.
Haptic Robot-Assisted Surgery Substantially Improves Accuracy of Wide Resection of Bone Tumors

HSS orthopedic surgeons frequently collaborate with cancer surgeons - often in long standing research partnerships - to develop surgical strategies that result in malignant bone tumors being removed with clean margins in ways that could save a patient’s use of their foot or leg or hand.

Now, for the first time, a new study has tested using Haptic Robot technology to assist in the wide resection of bone tumors. The research found that the touch-sensitive robots do increase accuracy of measurements, precision of cutting, and correlation with the optimum resection of the tumor determined in pre-operative strategies.

Currently, when surgeons translate pre-operative strategies to operating room decisions, they use simple rulers and imprecise techniques such as gross identification of anatomic landmarks. As a result, inconsistencies may cause surgeons to compromise tumor margins by not taking enough tissue, or unnecessarily removing too much joint surface or ligament attachment.

In the study, six pairs of cadaver femur bones had identical tumors outlined on three dimensional reconstructed images. A tumor fellowship-trained surgeon performed the indicated wide resections removing the tumor on each femur using the standard manual technique on one specimen, and using the haptic robot-assisted technique on the other.
The research team developed a novel technique that attaches a haptic robotic arm to the surgeon’s oscillating saw. The planned resection is plotted into the robotic software, so the arm can indicate the exact location for cutting. The surgeon still has precise control of the oscillating saw used to make the resections, but the robot arm pinpointing the locations helps prevent the surgeon from straying from the pre-defined plan.

Comparison of deviations from the pre-operative plan at two categories of greater than 3mm or greater than 5mm, showed the haptic robot-assisted technique was significantly more accurate than the traditional manual technique.

The number of times the haptic robot-assisted technique had deviations greater than either distance was zero. While the manual surgeries had deviations of more than 3 mm in 100% of the surgeries, and greater than 5 mm deviations in 40%.

This first study to report on using haptic robot-assisted technology to assist in wide resection of simulated primary bone tumors indicates substantial potential benefit. Further studies, including comparing and combining the system with recently introduced computer navigation technology in the HSS Computer Assisted Surgery Center, can explore this potential even more.
The Obesity Paradox: Obese Patients Less Likely to Develop and Die from Respiratory Distress Syndromes After Surgery

Surprising post-surgical benefit of obesity found using data from 9 million operations.

Study Identifies Patients at Risk for In-Hospital Falls

First study to investigate factors that could increase patient risk for falls after hip or knee replacement.


Nationwide numbers document the dramatic shifts over the decade.

MRI after Arthroplasty: Comparison of MAVRIC and Conventional Fast Spin-Echo Techniques

Prototype Multi-Acquisition Variable-Resonance Image Combination technique is useful additional sequence.
As pioneers of regional anesthesia, the HSS Division of Anesthesiology has long been aware of the rise in ambulatory surgeries. A recent HSS-led analysis of data from the National Survey of Ambulatory Surgery, from 1996-2006, covering common knee and shoulder procedures, shows just how dramatic the surgical shift has been.

Reviewing over 1,500,000 procedures, the research team found that ligamentoplasties – including ACL reconstructions – increased 66%. Meniscectomies in the knee rose 51%. Shoulder arthroscopies – including rotator cuff repairs – climbed a stunning 324% from 93,105 procedures to 418,188.

The study also revealed increased use of peripheral nerve blocks for each procedure: from 1.5% to 13.7% for ligamentoplasties; from 0.6% to 9.8% in meniscectomies; and from 11.5% to 23.9% for shoulder arthroscopy.

Neuraxial anesthesia – including central techniques like epidurals – fell in usage over the time period: from 13.6% to 7.3% for ligamentoplasties and from 11.8% to 6.3% in meniscectomies.

The demand for anesthesiologists with expertise in peripheral nerve blocks will only increase. As educators teaching regional anesthesia to doctors around the globe, HSS will continue to help fill the increasing need, now, and for decades to come.
The innovative pulse sequencing techniques allowing clear MRIs of joint replacements despite the presence of implant metal were pioneered by the HSS Division of Magnetic Resonance Imaging, directed by Hollis G. Potter, MD.

Now, in a combined effort with scientist Kevin M. Koch, PhD, of the Applied Science Laboratory of General Electric Health Care, the team has pioneered a new prototype technique for performing MRIs on patients with joint replacements called Multi-Acquisition Variable-Resonance Image Combination, or MAVRIC.

A recent HSS-led study comparing MAVRIC to the conventionally used pulse-sequencing technique when performing MRIs on patients who have had hip, shoulder, or knee replacements, showed that the MAVRIC technique can supply new, additional information. MRIs using the MAVRIC technique were able reveal changes that indicated developing synovitis and osteolysis that the traditional Fast Spin-Echo (FSE) technique, alone, did not.

Sometimes after joint replacement, microscopic particles wear off the implant and trigger an inflammatory reaction. A condition called osteolysis develops. Osteolysis can lead to implant loosening and revision surgery to replace the implant. The development of synovitis – inflammation of the synovial membrane surrounding the joint – can indicate potential osteolysis.

In the study, two sets of MRIs – using both the MAVRIC and FSE techniques – were performed on 122 patients who had total joint arthroplasty: 74 hip replacements, 27 shoulder replacements, and 21 knee replacements.
The images were subjectively graded for how well they visualized important areas of the joints: the synovium, the prosthesis-bone interface, and hip abductors or supraspinatus tendons in the shoulder. The presence of synovitis, osteolysis, or supraspinatus tendon tear was recorded.

Visualization of the synovium was significantly better on MAVRIC images than on FSE images of the hip, shoulder, and knee. Synovitis was detected only on the MAVRIC images of 9 patients (12%) who had undergone hip arthroplasty and 5 patients (18%) who had undergone shoulder arthroplasty.

Visualization of the periprosthetic bone – the bone surrounding the implant – was significantly better on MAVRIC images of the hip, shoulder, and knee. Osteolysis was detected only on the MAVRIC images of 12 patients (16%) who had hip replacements, 6 (22%) who had shoulder replacements, and 5 (24%) who had knee replacements.

In the shoulder images, visualization of the supraspinatus tendon was significantly better on MAVRIC images. Tears in the shoulder tendon were found in twelve patients (44%). Those tears were detected only on MAVRIC images.

MAVRIC complements the information on FSE images after arthroplasty and is a useful additional sequence, particularly when there is concern about surrounding adverse tissue reactions, including synovitis and, periprosthetic osteolysis, or the presence of a rotator cuff tendon tear.
The recovery period from any surgery includes a risk of developing lung inflammations that leads to respiratory insufficiency (RI) or adult respiratory distress syndrome (ARDS). Because ARDS prevents enough oxygen from getting into the blood, it is life-threatening.

Now, an HSS-led study, reviewing 9 million operations, shows that obese patients are not only less likely to develop respiratory syndromes, they are also less likely to die from the conditions.

This is a surprising finding as not only are obese patients at greater risk for other surgical complications, they are also generally assumed to have more difficult recoveries after surgery and poorer long-term outcomes.

Using the large Agency for Healthcare Research and Quality (AHRQ) database, the team identified 9 million patients, from 1998 and 2007, who underwent common surgical procedures known to have a high risk of leading to RI/ARDS. These high-risk operations include orthopedic procedures like spine surgeries, neck surgeries, and hip and knee replacements.

Incidence of RI/ARDS was 1.82% among obese patients and 2.01% among non-obese patients. Of those obese patients who did develop RI/ARDS patients, only 5.45% died, versus 18.72% mortality for the non-obese patients.
Further, the need for mechanical ventilation, which may indicate more severe cases of RI/ARDS, was lower in obese than in non-obese patients (50% versus 55%). In-hospital mortality in those requiring intubation was also lower in obese patients, 11% versus 25%.

Why obesity offers respiratory syndrome protection is unknown, but the researchers have three theories:

1) Built-In Nutrition: Obese people may have more energy stores or better nutritional status to help them get through an acute illness.

2) Inflammation Protection: Fatty tissue may have some advantageous effect in the setting of a high inflammatory state, possibly neutralizing the molecular messengers called cytokines that signal for inflammation.

3) Extra Vigilance: Doctors are often more vigilant with obese patients, because they worry the patients will have more health problems. Thus, extra attention might lead to spotting indications of respiratory complications sooner, and more aggressive treatment.

ARDS has a very high mortality rate, and in the last 20 or 30 years, very few interventions other than the use of improved ventilator settings have made any impact on the mortality. The research team hopes the discovery of the “obesity paradox” will help open new avenues of research for preventing and treating the deadly condition.
Through innovative research, HSS continually seeks new insights into ways to improve the hospital’s already superlative record of field-leading patient safety. One area of concern in orthopedic surgery is in-hospital falls. While patient falls are extremely rare at HSS and infrequent across the nation, they can result in serious consequences. Zero falls is every hospital’s goal.

Recently, an interdisciplinary team of anesthesiologists, surgeons, and scientists reviewed the largest inpatient database available in the US – from the Agency for Healthcare Research and Quality (AHRQ) – to examine in-patient falls specifically after hip and knee replacements.

Using statistical modeling, comparing data on patients who fell to patients who didn’t, the team found pulmonary circulatory disease posed the greatest risk.

Other factors that indicated an increased risk for falling after hip or knee replacement included:

- Being male
- Being older
- Belonging to a minority race
- Undergoing revision joint replacement surgery.
- Congestive heart failure
- Clotting or bleeding disorder,
- Liver disease
- Neurologic disease,
- Electrolyte/fluid abnormalities
- Recent weight loss.
Patients at Risk for In-Hospital Falls

Interestingly, some conditions associated with other surgical risks did not increase risk for falling. Those included obesity, hypothyroidism, uncomplicated diabetes and cancer.

Postoperative complications including deep vein thrombosis, adult respiratory distress syndrome and pulmonary embolism were also associated with higher fall rates, although it remains unclear if they were the reason or the consequence for this event.

During the study period – 1998 to 2007 – the team found the nationwide rate of in-hospital falls increased from 0.4 percent to 1.3 percent. Possibly mandatory reporting of in-hospital falls raised the numbers. The fact that hospital patient population is getting sicker may have contributed,

Patients often fall they decide, on their own, they want to get up – to use the bathroom or just be out of bed. They may ignore doctor’s orders or do not ring for assistance.

Now, armed with this new information, hospitals can identify patients who have higher risk for falling. Those higher risk patients can be even more carefully monitored, visited more often by staff, and watched for any tendencies to just get up on their own. And that zero falls goal can be met at HSS every year.
Operative Treatment of Acetabular Fractures in an Older Population Through a Limited Ilioinguinal Approach

Comparing 2-window limited ilioinguinal approach to the traditional 3-window approach

Endosteal Strut Augment Reduces Complications Associated with Proximal Humeral Locking Plates

Benefit of adding second column of support to locking plate repair

Quantitative Assessment of the Vascularity of the Talus with Gadolinium-Enhanced Magnetic Resonance Imaging

New findings on blood supply to the talus bone
In order to reach and repair fractures, orthopedic surgeons open surgical “windows” to the fracture site allowing controllable access to perform necessary procedures.

One surgical technique surgeons use when treating fractures in the socket of the hip joint is called a limited ilioinguinal approach. “Limited” refers to the number of windows. The full ilioinguinal approach provides for 3 surgical windows using a wider exposure. However, the “limited” approach uses only 2 surgical windows.

A recent HSS study compared the limited ilioinguinal approach to the traditional 3-window approach in repairing hip socket fractures in an older population and found no significant differences in the outcomes and that both approaches resulted in good patient outcomes.

However, the limited approach significantly decreased both surgical time and amount of blood loss, important improvements that can reduce risk and translate to lighter impact on the body and easier recovery after surgery.

Fractures occurring within the socket of the hip joint are called acetabular fractures. Between January 1992 and January 2006, 143 patients 55 years of age or older were surgically treated for acetabular fractures at HSS. 41 were treated using either a limited ilioinguinal approach or the traditional ilioinguinal approach.
There were no significant differences with regards to injury severity in the 41 study patients. Comparing the patients outcomes after surgery, at a minimum 2-year follow-up, both surgical approaches produced equivalent results. Functional scores on standard outcome surveys were comparable. As was the overall rate of patients requiring secondary hip replacement (26.8%).

The limited ilioinguinal technique led to good patient outcomes, comparable to the traditional technique, but was associated with substantially less surgical time and blood loss. This study suggests that the limited ilioinguinal approach is an effective technique for treatment of this injury.
Surgeons can repair a shattered bone by reassembling the fractured pieces and attaching them to a reinforcing piece of specially shaped steel. Known as a *locking plate*, the steel literally does just that: lock the bone pieces in place, allowing healing and function.

Locking-plate technology has greatly advanced quality of complex fracture repairs, but it can develop complications. Establishing a second column of support for the fracture in addition to the locking plate may reduce complications and improve clinical outcomes.

An HSS study recently reviewed 38 complex fractures of the humerus bone in the shoulder that were repaired with both a locking plate and the addition of an endosteal strut. Results showed low rates of complications and high rates of good clinical outcome.

The research team reviewed the cases of 38 patients whose shoulders were treated at HSS for proximal humerus fractures by surgical attachment of a steel locking plate augmented by the additional support of an endosteal cortical allograft strut. X-rays were taken and standard tests were performed at a minimum of 49 weeks after surgery.

Complications were low. No patient had intra-articular screw cutout or penetration. No bone death occurred by blood loss in complete osteonecrosis. One patient had partial osteonecrosis. One lost reduction. Scores on standard fracture repair tests were good. Disabilities of the Arm, Shoulder, and Hand (DASH) score was 15 (range, 0–66.4). The mean Constant-Murley score was 87 (range, 51–95).

The study shows that augmenting a locking plate with a second support can be advised in repairing proximal humerus fractures.
Bone, like all living tissue, will die without sufficient blood supply. Known as osteonecrosis, this bone cell death can occur as a result of injury, like during a fracture. If the main arteries supplying a joint are severed or damaged, they cannot deliver enough blood to keep the bone tissue viable.

In fractures of the talus bone in the ankle, osteonecrosis has been reported as being as high as 8-20%. Now, a recent HSS study has brought new understanding to the blood supply of the talus bone.

The study showed the contribution of 3 arteries: 47% of the blood supply to the talus came from the posterior tibial artery. 36.2% came from the anterior tibial artery and 16.9 % from the peroneal artery. Previously, these contributions were not fully known. In addition, a rich interosseous and anastomotic network between main contributory arteries was found.

Finding that a substantial portion of the blood supply to the talus enters posteriorly helps explain why not all talar neck fractures lead to osteonecrosis.

The HSS Orthopaedic Trauma Service has developed an investigatory model to help determine blood supply that injects gadolinium into pairs of cadaveric specimens to allow volumetric uptake analysis. Magnetic Resonance Imaging (MRI) captures 3D gradient echo sequences of the gadolinium in each artery using custom software.

continued, click/tap here
The images are compared and contrasted through quantitative analysis revealing relative contributions from each artery. After a urethane polymer injection, the specimens are then dissected to confirm MRI findings and allow for further evaluation of contributing arterial branches.

This study used the investigatory model with ten pairs of cadaver specimens to reveal new details of how blood supply is contributed to the talus bone of the ankle.

The talus was divided into four geographic quadrants for quantitative MRI assessment. In three of the quadrants – the anterolateral, posterolateral, and posteromedial quadrants – the posterior tibial artery was shown to be the greatest contributor. Only in the anteromedial quadrant was the contribution of the anterior tibial artery greatest. The peroneal artery did not make the greatest contribution in any quadrant.

The entire weight of the body is transmitted through the ankle and talus to the foot, making this region vital for human locomotion. These new findings will help surgeons better prevent loss of blood supply in talus bone fractures.
Reconstruction of the Symptomatic Idiopathic Flatfoot in Adolescents and Young Adults

Surgical reconstruction relieves pain and allows young patients to participate in sports.

Correction of Medial/Lateral Subluxation of Lesser MP Joints with Extensor Brevis Transfer/MP Release

Adding the Extensor Brevis technique successfully improved MTP angle and range of motion.

Percutaneous Internal Fixation of Proximal Fifth Metatarsal Jones Fractures (Zones II and III) with Charlotte Carolina Screw and Bone Marrow Aspirate Concentrate: An Outcome Study in Athletes

Technique can provide a predictable return to play with few complications.
Reconstruction of the Symptomatic Idiopathic Flatfoot in Adolescents and Young Adults

Active young people who have flatfeet can develop painful conditions that prevent participating in their favorite sport. There is some discussion, however, about using surgical reconstruction to relieve symptoms in feet that may still be growing.

A recent HSS study has shown that flexible flatfoot reconstruction surgery in symptomatic adolescent and young adult patients can reduce pain and improve function, including the ability to participate in sporting activities.

In the study, 16 flexible flatfoot reconstruction surgeries were performed on 10 patients ranging in age from 10 to 22 - mean age 15.6. All the reconstructions were performed using a surgical technique that combines medializing calcaneal osteotomy and lateral column lengthening. Other surgical procedures added as needed in individual feet included flexor digitorum longus transfer in 9 feet, medial column stabilization in 8 feet, and gastrocnemius recession in 8.

The final follow-up visit for the patients was at an average of 5.2 years (range, 2 to 10). Satisfaction scores among the patients was self-rated as “excellent” in 15 feet and “good” in one. Mean scores on the American Orthopaedic Foot & Ankle Society (AOFAS) test improved on average from 49.1 to 93.4. Only one patient reported a postoperative restriction in sports. Significant improvement in the arch of the feet was shown on x-rays in both the AP talonavicular coverage angle and lateral talar-first metatarsal angle.

Flexible flatfoot reconstruction in symptomatic adolescent and young adult patients can reduce pain and improve function, and increase the ability to participate in favorite activities, including sports.
Correction of Medial/Lateral Subluxation of Lesser MP Joints with Extensor Brevis Transfer/MP Release

Between the tips of the toes and the ball of the foot are the longer toe bones called the metatarsals. The connecting joints of the metatarsal bones – known as metatarsal-phalangeal (MTP) joints – are involved in most aspects of human locomotion, from balance to movement.

Over time, the MTP joints can become deformed for many reasons. These include bunions, autoimmune conditions, congenital problems exacerbated by overly constrictive footwear, hammertoes, stress, osteoarthritis, and sports injury. Partial dislocation of the joint is known as a subluxation.

When pain and damage of MTP subluxations cannot be successfully addressed by conservative measures, surgical correction can bring relief.

Recently, the HSS Foot Service demonstrated the effectiveness of an innovative surgical technique for correcting particular subluxations of the lesser MTP joints. (“Lesser” means not the big toe.) Called the Extensor Brevis Transfer/MP Release, the technique can be added to more common techniques like plantar plate release, when other procedures, alone, would not correct the MTP deformity.

Adding the Extensor Brevis Transfer/MP Release technique was shown to successfully improve MTP angle and range of motion.

The team also used a toe-specific survey to capture more detailed information concerning shoe wear, impingement on adjacent toes, and patient satisfaction.
In the survey, 18 of the 20 patients in the study reported they were either “highly satisfied” or “satisfied” with the results and would undergo the procedure again.

Technically, the surgery involves releasing the extensor brevis tendon proximally and passing it through drill holes in the proximal phalanx and metatarsal neck to replicate the collateral ligament. Then the tendon is secured to the dorsal metatarsal with a screw post. If the toe remained elevated, a plantar dermodesis was added.

Combined with a plantar plate release the procedure is powerful, and minimal release of the medial or lateral plantar plate and not over-tightening the transfer is recommended.

The extensor brevis tendon transfer technique in conjunction with a plantar plate release can successfully correct medial and lateral deviation in the lesser MTP joints. It can be considered when MTP and partial plantar plate release are insufficient to correct the deformity.
Injured athletes have one thing in common: they want to know if they’ll be able to play again. For athletes who experience a common foot injury called a Jones fracture, now, because of a surgical repair technique, the answer is likely to be “yes”.

Medically known as a proximal fifth metatarsal fracture, a Jones fracture happens at the base of the little toe where it joins the foot. To repair the injury in athletes, surgeons often use a technique called internal fixation. Yet, internal fixation can result in nonunions and screw breakage, in part because of screws and hardware not specially designed for the procedure, as well as poor blood supply.

Now, an HSS-study has reviewed the outcomes of 26 athletes with Jones fractures (in zones II and III) who were treated with percutaneous internal fixation using a specialized screw and adding bone marrow aspirate concentrate to augment the poor biological environment in this area.

Only 2 of the 26 athletes did not return to their previous level of competition.

At a mean follow-up of 20 months, outcome scores improved significantly on all standard tests, including the Foot and Ankle Outcome Score and both the physical and mental components of the SF-12 scores. X-rays showed fractures healed at a mean time of 5 weeks after surgery (range 4-24).
One patient experienced a delayed union, and 1 healed
but later refractured.

For athletes with Jones fractures, this study shows that
surgical repair with percutaneous internal fixation using a
specialized screw and bone marrow aspirate concentrate
provides a predictable return to play with few complications.

However, more research must be done to determine
the exact efficacy of bone marrow aspirate concentrate,
including the mechanisms by which it acts to promote
healing. In addition, further refinement of the hardware
used to treat these injuries may be beneficial.
New Tool to Measure Outcomes Could Help Improve Arm Surgery for Devastating Nerve Injury

Standardizing simultaneous assessment of nerve, muscle, and joint recovery can aid international collaborations.

Comparison of Nerve Transfers and Nerve Grafting for Traumatic Upper Plexus Palsy: a Systematic Review and Analysis

Data strongly favors traditional nerve grafting for restoration of improved shoulder and elbow function.

Imaging and Electrodiagnostic Work-up of Acute Adult Brachial Plexus Injuries

Testing to guide treatment options.

Does Posteromedial Chondromalacia Reduce Rate of Return to Play After Ulnar Collateral Ligament Reconstruction?

Potentially lower rate of return to play for athletes with PMC who also require UCL reconstruction.

HSS Research Menu

Arm Studies
Exiting the spinal cord in the neck, the complex web of nerves that direct movement and sensation throughout the entire upper limb is called the brachial plexus.

The nerves of the brachial plexus join repeatedly before terminating in several peripheral branches supplying the muscles of the shoulder, arm, and hand. Each nerve root contributes to several peripheral nerves, and vice-versa. This interwoven complexity contributes to highly variable patterns of injury and challenges in repair.

Further complications ensue from the unfortunate reality that in adults, brachial plexus nerves are most commonly injured in high speed vehicle crashes, like motorcycle accidents, that result in devastating injuries. Falls from tall heights and high impact sporting injuries also result in brachial plexus injuries.

The new HSS Center for Brachial Plexus and Traumatic Nerve Injury uses an integrated multidisciplinary approach to treat these injuries. Early diagnosis, pinpoint imaging, innovative microsurgery techniques, and specialized rehabilitation unite to restore a patient’s ability to use their shoulders, arms, and hands.

The Center has also developed a new tool to measure outcomes in surgeries used to treat brachial plexus injuries. Until now, there was no standardized method that clinicians used to report outcomes of brachial plexis surgery. With no common tools to compare treatment results, international collaboration and research had been hampered.
To develop the new tool, the HSS team reviewed 660 brachial plexus articles from Medline, the National Library of Medicine’s database, and identified 49 that reported surgical outcomes for repair. The articles were inconsistent. Muscle strength was the most commonly reported element, yet it was reported in only 84% of the articles. Range of motion was mentioned in less than half of the papers. Only 8% recorded assessment of pain.

Most often missing was an integrated reporting scheme that combined restored strength and function. Interconnected elements can be important in brachial plexus outcomes. For example a patient’s nerves could recover beautifully, but if their shoulder is frozen or their hand atrophied, the patient may not have a functional recovery.

Because in brachial plexis repair, unless all elements are assessed, the analysis is incomplete, the new tool simultaneously assesses nerve, muscle and joint recovery.

The key elements of the new tool are measurements of motion, strength and function for seven critical domains of the upper extremity: shoulder elevation, shoulder external rotation, elbow flexion, elbow extension, wrist extension, finger flexion and intrinsics (the distance the fingers can be spread apart). The tool involves assessing tasks such as touching the back of your head, touching your mouth and holding a utensil.

Next, the new tool will be further refined with help from international collaborators, hoping to develop a world-wide system so that outcomes of treating brachial plexus injuries can be reported in standardized measurements that can help advance research everywhere.
In treating patients with brachial plexus nerve injury affecting the isolated upper truck or the main root nerves in the neck, there has been no systematic review of data informing a surgeon which is the better choice to restore shoulder and elbow function: using nerve transfer or nerve grafting for repair.

Now, a new HSS-led systematic analysis and review of existing international data shows outcomes strongly favor traditional nerve grafting for restoration of improved shoulder and elbow function. The study compared outcomes of 299 brachial plexus surgeries using modern intraplexal nerve transfers to 57 performed with autogenous nerve grafting. Nerve transfer produced significantly better outcomes.

The research team searched PubMed, EMBASE, and the Cochrane Central Register of Controlled Trials for studies in which patients had surgery for traumatic upper brachial plexus palsy within one year of injury and with a minimum follow-up of twelve months. 356 surgeries were identified.

Restored strength, as well as regained shoulder and elbow motion were assessed as outcome measure. Analysis showed patients repaired with modern techniques of nerve transfer significantly outperformed patients whose surgeries had been with traditional nerve grafting in all categories and on all standard tests.

This knowledge can help surgeons considering surgical repair options to upper limb and cervical brachial plexus injuries, particularly in cases where the native nerve root at C5 or C6, or branch nerves to the trunk may appear less than optimal, or when long nerve grafts are contemplated.
When assessing acute brachial plexus injuries, imaging and electrodiagnostic studies form an essential part of the evaluation. They can clarify surgical options, help prognostication of outcome, and aid formulation of postoperative management.

The primary objective of imaging is to identify pre-ganglionic injury indicative of nerve root avulsion. The presence of one or more nerve root avulsion injuries is a critical factor in surgical decision-making and the prognosis of surgical reconstruction. CT myelography is the current imaging modality of choice for this purpose.

Initial electrodiagnostic (EDX) testing is ideally performed no sooner than 4 weeks following injury unless otherwise clinically indicated. Follow-up testing can be helpful at approximately 6 week intervals.

The sensory nerve amplitudes are the most important component of nerve conduction testing in distinguishing between pre- and post-ganglionic injuries.

Electromyographic studies will also assist in the determination of a pre- from post-ganglionic injury, the level of plexus involvement and identify potential donor nerves that may be suitable for use as transfers.
Does Posteromedial Chondromalacia Reduce Rate of Return to Play After Ulnar Collateral Ligament Reconstruction?

Taken from two Greek terms meaning essentially "cartilage softness", the medical term for cartilage damage is chondromalacia. Throwing athletes can develop chondromalacia in their elbows from overuse. Different sports and personal throwing styles can lead to chondromalacia in different locations in the elbow. Posteromedial Chondromalacia – or PMC – refers to cartilage damage just behind the middle of the joint.

PMC can develop in throwing athletes who have another overuse condition: ulnohumeral chondral and ligamentous overload – or UCLO. The ulnar collateral ligament, or UCL, is the most important ligament in the elbow. The “overload” in UCLO can create both cartilage damage in the elbow joint and structural insufficiency or tears in the elbow ligament.

Surgical reconstruction of a damaged UCL allows approximately 90% of throwing athletes to return to the game at the same or higher level. Recently, an HSS collaboration investigated what rate of return to competition after UCL reconstruction surgery occurred in baseball players who also had PMC.

Compared to a generally expected 90% return to play rate after UCL reconstruction, just 76% of the baseball players who also had PMC were able to return to prior levels of competition.

The research team reviewed the cases of 61 baseball players who were treated for UCL injury and found 29 players who had also been diagnosed with PMC. The players ranged in age from 16-23 years, with a mean age of 19.6. Most players were college athletes (76%) and pitchers (93%).

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All 29 players in the study had UCL reconstruction surgery performed by a docking technique. Depending on the extent of the cartilage damage, the PMC was addressed by varying treatments. For Grade 2 or 3: no treatment or débridement, a procedure to remove dead or damaged cells. For Grade 4: either débridement or microfracture, a surgical cartilage repair technique using bone marrow cells.

The minimum follow-up was 24 months (mean, 37 months; range, 24-52 months). To assess if the athletes could return to play after surgery, a standard modified four-level scale (by Conway et al) was used. Level 1 – the highest score on the test – means a player could return to preinjury level of competition or performance for at least one season. Higher levels on the test indicate less ability to return to play.

Just 76% of the 29 patients with PMC scored Level 1 and were able to return to prior levels of competition. The other patients with PMC scored Level 2 in four patients (14%), Level 3 in two patients (7%), and Level 4 in one (3%) patient.

The study shows how athletes with PMC who also require UCL reconstruction, should be advised of the potential lower possibilities of return to play at the same level of performance.