MR Imaging of the Postoperative Knee

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Several technical advances in knee surgery have occurred in the areas of anterior cruciate ligament (ACL) reconstruction, meniscal repair and cartilage repair. The number of surgical procedures performed and the number of patients that are now candidates for knee surgery are increasing. MR examinations performed on patients with either persistent or recurrent knee pain in the postoperative setting have also increased and now comprise as many as 3 to 5% of allknee MR examinations in some practices.

Persistent or recurrent pain in the postoperative knee is a fairly common problem and MR imaging plays a definite role in the evaluation of these patients. This paper will discuss some of the more common surgical procedures being performed on the knee, as well as the most common causes of knee pain in the post-operative setting. The normal and abnormal postoperative MR findings will then be described and when appropriate, special imaging techniques to evaluate the postoperative knee will be discussed.

The first and most important question to ask when interpreting any MR examination of the knee is **"has the patient had prior knee surgery"?** This is important because many of the MR findings that represent abnormalities in the virgin knee can represent a normal postoperative finding. Occasionally, the protocol may also change depending on the clinical question and the type of previous surgery. The majority of postoperative knee examinations will begin with our standard knee protocol, which includes T1-weighted sagittal and coronal images, followed by FSE T2-weighted sagittal, coronal and axial images with fat saturation. In the case of prior meniscal repair with a finding equivocal for tear, follow-up MR arthrography following the administration of intra-articular gadolinium will increased accuracy in diagnosing repeat meniscal tear. In the equivocal case of a disrupted ACL graft, high-resolution oblique sagittal images through the ACL graft may be helpful, and to achieve the greatest sensitivity and specificity in evaluating cartilage, a fat-saturated 3D spoiled gradient echo can be performed.

Occasionally when interpreting MR examinations of the knee, the history of prior surgery is not provided. In these cases, the presence of certain MR findings will suggest that the patient has undergone former surgery. The first is the presence of a linear scar of low signal intensity located in Hoffa's fat just inferior to the patella. This is the MR footprint of an arthroscopy cannula portal. The second MR finding occasionally seen in the postoperative knee is ferromagnetic artifact resulting from microscopic pieces of metal or placement of screws during surgery. The routine evaluation of all knee MR examinations should include a search for these clues indicating that prior surgery has been performed and if present, the MR images should be interpreted accordingly.

THE POSTOPERATIVE MENISCUS

Meniscectomy/meniscal repair is currently one of the most common procedures performed on the knee. In the past, the meniscus was freely excised with little understanding of the long-term consequences. More recently, a better understanding of the function and vascularity of the meniscus has lead to the practice of meniscal sparing surgery whenever possible in an attempt to maintain knee function which is closer to normal. Most orthopedic surgeons perform arthroscopically assisted meniscal repair because it provides better visualization of the meniscus and decreases postoperative morbidity. The complication rate following partial meniscectomy ranges in the literature between 3 and 13%. The most common postoperative complications include, laceration of the popliteal artery, peroneal and saphenous nerve palsies, deep infections, instrument breakage, deep vein thrombosis, pulmonary embolism, meniscal cysts, arthrofibrosis, and osteonecrosis of the adjacent femoral condyle or tibial plateau. The majority of these complications can be diagnosed with history and physical examination and MR imaging is only occasionally required.

The most common role of MR imaging in the post-meniscectomy patient is in the evaluation of persistent or recurrent knee pain. Possible etiologies of pain in the post-meniscectomy patient include a residual tear or retear of the meniscus, chondromalacia of the adjacent articular cartilage, osteoarthritis of the involved compartment, loose bodies, and osteonecrosis of the involved femoral condyle or tibial plateau.

Interpreting MR images of the menisci in the patient status-post-partial meniscectomy can at times be difficult. The main dilemma is in distinguishing if signal in the meniscus is a result of prior meniscal repair or if it represents a new or residual tear. The amount of meniscus resected is an important factor in determining which set of criteria is to be used in the evaluation of the remaining meniscus. If less than 25% of the meniscus has been resected, the meniscus can be evaluated using the same MR criteria as a virgin knee. If greater than 25-30% of the meniscus has been resected, it becomes more difficult to determine if retear has occurred, and a different set of criteria must be utilized. In the nonoperated knee, grade III signal extending to the articular surface of the meniscus is unequivocal evidence of a tear. In the post-surgical knee, this may be a normal post-operative finding. Many of the partial meniscectomies are accompanied by repair of the outer third of the meniscus, which is in the vascularized zone. Grade III signal can persist in the repaired portion of the meniscus for years following suturing of the meniscus.

Two reliable signs of repeat meniscal tear include the identification of a displaced meniscal fragment or a tear in a location remote from the prior surgical site. These are highly specific but lack sensitivity. A third MR sign of repeat meniscal tear is grade III signal which extends to an articular surface and contains fluid on T2-weighted images. Using these criteria for retear, the sensitivity is approximately 65% and specificity is in the range of 90%. The sensitivity can be increased to approximately 90% by performing MR imaging following the administration of intra-articular gadolinium. The post-operative meniscus is considered retorn if gadolinium tracks into the meniscus. The increased sensitivity is thought to be primarily a result of distention of the joint by the fluid.

Post operative chondromalacia

Chondromalacia of the articular cartilage adjacent to the meniscectomy site is a common reason for continued knee pain, with a reported incidence of approximately 40% in the post-meniscectomy patients.

Osteoarthritis following meniscectomy is related to the amount of meniscal tissue removed. Osteoarthritis is reported in as many as 60% of patients in long term follow-up following total meniscectomy. This is demonstrated on MR imaging as joint space narrowing, articular cartilage thinning, osteophyte formation, subchondral marrow change and cystic formation.

Loose bodies occasionally occur in the post-meniscectomy patient, and may give rise to the history of locking or decreased range of motion. They can result from fragmentation of articular cartilage at the time of surgery, and may grow over time as they are bathed in synovial fluid, eventually calcifying. Loose bodies can be very subtle on MR imaging, and one must search diligently for them if the appropriate clinical history is given.

Osteonecrosis following partial-meniscectomy is fairly uncommon, and is seen almost exclusively in patients over 55 years of age. However, as surgical techniques improve, more and more elderly patients that were previously considered non-surgical candidates are now undergoing meniscal repair. As a result, we are seeing an increase in the incidence of this complication. Spontaneous osteonecrosis most commonly occurs in the medial femoral condyle, but is occasionally reported in the lateral femoral condyle or the medial tibial plateau. It is thought to represent a cortical insufficiency fracture secondary to redistribution of weight following removal of a portion of the meniscus. It is seen most commonly in the elderly patient with little or no pre-meniscectomy osteoarthritis. Pre-existing osteoarthritis appears to be protective, because the loss of articular cartilage over a prolonged period of time allows for subchondral buttressing of bone, which protects against the insufficiency fracture. Osteonecrosis has also been reported as a complication of laser meniscectomy. Osteonecrosis usually begins as an area of subchondral edema with cortical collapse immediately adjacent to the site of prior meniscectomy. It typically occurs within 2 to 18 months following surgery and is heralded by acute onset of excruciating pain in the patient that was previously recovering normally from the surgery. The area of osteonecrosis can progress to severe osteoarthritis of the involved compartment occasionally requiring total arthroplasty of the joint.

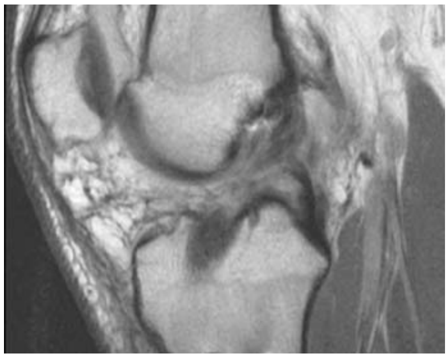
THE ACL GRAFT

The anterior cruciate ligament is an important stabilizer of the knee and is a commonly injured ligament in the athletic individual. Once the ACL has been disrupted, many factors must be considered to determine if a patient is a surgical candidate for ACL reconstruction. The most important factors include the degree of injury, presence of associated injuries including ligamentous, chondral and meniscal injuries, age, activity level, occupation, sports participation, and patient's compliance. Certain career fields such as professional sports or military careers may necessitate repair of an unstable knee. It must also be remembered that most patients with an active lifestyle and an ACL deficient knee will eventually develop osteoarthritis and or a meniscal tear if not repaired.

A preoperative MRI is not necessarily required in all cases of ACL disruption, as an adequate physical examination is very sensitive in detecting rupture of the ACL. The value of the MR imaging is in the evaluation of associated injuries such as meniscal tears or chondral injuries, which allows for improved pre-operative planning.

Once it has been determined that ACL reconstruction is indicated, the type of graft must be chosen. The two most common types of grafts currently utilized are the bone-patella tendon-bone autograft (BTB) and the hamstring (semitendinosus and gracilis) autograft (STG). There is considerable discussion in the orthopedic literature concerning the use of these grafts, although both are considered appropriate. They appear to be similar in restoring long term stability following ACL disruption. The STG graft reportedly results in less subjective anterior knee pain and less quadriceps deficiency, but the BTB graft allows for more rapid rehabilitation in the patient that is returning to cutting sports and high demand sports.

Many complications can occur following ACL repair. Most of these are adequately evaluated with the routine X-ray examination, including patellar fracture, bone plug migration, and hardware failure. MR imaging may be indicated following ACL reconstruction in the lax knee to help differentiate a stretched graft from a disrupted graft. Also, in the postoperative patient who can no longer achieve full extension, MR imaging may help distinguish between loose bodies in the notch, graft impingement, and arthrofibrosis. Following recurrent trauma, MR imaging is useful in evaluating for graft disruption or other internal derangement such as meniscal injury.



Torn ACL Graft

The normal MR imaging appearance of an ACL graft will vary depending on the type of graft used and the time interval since surgery. In the first 3-4 months following surgery, the graft will undergo avascular necrosis. During this time, the BTB graft will appear identical to the patellar tendon on MR images. The STG graft will be dark on pulse sequences but may have fluid tracking between the 4 bundles of tendon used as the graft. During months 4-8, the graft will undergo revascularization. During this time the graft will demonstrate increased signal on short TE sequences and may be difficult to distinguish from surrounding tissues. It should however, remain dark on T2-weighted sequences during this time. Some reports state that there can be mild increase signal even on T2-weighted sequences, but the signal intensity should never reach that of fluid. By 12 months, the ACL graft should have a similar appearance to the native ACL. There is little in the literature concerning the appearance of the STG graft after one year, but it may continue to have fluid tracking between the fibers of the graft. The graft position should be parallel to the roof of the intercondylar notch, running just posterior to the roof, but never touching it. It should enter the tibial tunnel without focal angulation.

Several complications of an ACL graft can be evaluated with MR imaging. If on clinical examination the knee is unstable, the graft may be stretched or disrupted. Disruption is depicted on MR imaging as a complete discontinuity of fibers. The type of graft material and timing of the surgery must be taken into account when determining if a graft is disrupted. Posterior bowing of the graft can be seen in partial tear or stretching of the graft. If a patient presents with loss of normal extension of the knee, impingement and arthrofibrosis should be considered. Impingement of the graft occurs when the tibial tunnel is placed too far anterior and the fibers of the graft rub against the roof of the intercondylar notch. On MR imaging the graft may demonstrate increased signal in the portion abutting the roof of the notch. There may also be kinking of the graft as it passes into the tibial tunnel or courses past the notch. Arthrofibrosis may present as either a cyclops lesion (a focal nodule of fibrous tissue anterior to the graft in the intercondylar notch), or as diffuse fibrous scarring in the anterior fat pad. Decreased range of motion secondary to arthrofibrosis correlates exclusively with the location and amount of intra-articular scar tissue. One last complication that can occur following an ACL graft is the formation of a ganglion cyst. A cyst may result from either degeneration or partial tearing of the graft and they appear to be more prevalent in the STG type of graft. A cyst may be an incidental finding or may result in knee pain or decreased range of motion, and can be a precursor to graft failure. MR images demonstrate a fluid filled cystic structure typically located in or adjacent to the tibial tunnel.

THE PCL GRAFT

The posterior cruciate ligament (PCL) is injured less commonly than the ACL. It is approximately twice as strong as the ACL, and when it is injured it is usually only partially torn and will heal with conservative therapy. Reconstruction may be indicated in a high performance athlete or in an individual who has significant instability following complete disruption of the PCL. When reconstruction is required, it is usually repaired with a patellar BTB graft. Unlike the ACL graft, the PCL BTB graft usually remains dark on all pulse sequences. Disruption of the PCL graft is demonstrated on MR imaging as a complete disruption of the fibers with high signal extending through the entire thickness of the graft on both short TE and T2-weighted sequences.

THE PATELLAR AND HAMSTRING TENDON HARVEST SITE

The BTB graft is harvested from the middle third of the patellar tendon with a small piece of bone taken from the patella and tibia. MR imaging can demonstrate both a defect and signal abnormality in the harvest site of the patellar tendon and adjacent bone for up to one year. Frequently by one year the appearance of the harvest site will appear normal. Complications such as patellar tendon rupture or patellar fractures are occasionally seen on MR imaging. Thickening of the patellar tendon is normal following harvest of the graft. Patellar tendinitis can be diagnosed if the patellar tendon remains greater than 10mm in thickness one year following surgery.

Recent MR studies suggest that the hamstring tendons regenerate following harvest and the harvest site can appear close to normal by 6 to 12 months following surgery. Hamstring strength reportedly returns to 80% of pre-harvest strength within 6 months.

CARTILAGE REPAIR PROCEDURES

Several surgical techniques are currently available to repair cartilage defects in the knee including microfracture techniques, osteochondral allografts, and autologous chondrocyte implantation. MR imaging has been shown to be an accurate non-invasive method for evaluating articular cartilage of the knee, and as cartilage repair becomes more prevalent, MR imaging will play an increasingly prominent role in the post-operative evaluation. Various MR imaging techniques are used to evaluate cartilage. T1-weighted images do an excellent job of characterizing intrasubstance detail of hyaline cartilage but lack sufficient contrast between cartilage and joint fluid and thus do a poor job of evaluating the articular surface. Fast spin-echo T2-weighted imaging with fat-saturation does an excellent job of imaging surface abnormalities of cartilage but lacks the ability to adequately depict the intrasubstance detail. Fat-suppressed 3D spoiled gradient echo imaging has been shown to be the more sensitive than standard MR imaging for depicting cartilage surface abnormalities.

MISCELLANEOUS SURGICAL PROCEDURES

Many other surgical procedures are less frequently performed on the knee. To adequately evaluate the post-operative MR examination of the knee, it is important to have a good history regarding the type of surgical procedure performed as well as a thorough understanding of the clinical question being asked at the time of imaging.

Collateral ligament repair will usually be performed if a complete tear of the ligament occurs in association with other ligamentous injury (such as concurrent ACL or PCL disruption). Grade 1 and 2 sprains are usually treated conservatively. Stapling or suturing can be used to repair a complete disruption (grade 3) of a collateral ligament. Metallic artifact is frequently seen at the surgical site, and persistent thickening of the repaired ligament is common.

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