Radiology

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Index terms:
Athletic injuries
Knee, injuries, 452.4851, 452.4852, 452.4857
Knee, ligaments, menisci, and cartilage
Knee, MR, 452.121411, 452.121412, 452.121413, 452.121415
Shoulder, injuries, 41.4813, 41.4819
Shoulder, MR, 41.121411, 41.121412, 41.121415

Published online before print
10.1148/radiol.2243012180
Radiology 2002; 224:631–635

Abbreviation:
SLAP = superior labrum anterior to posterior

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The Impact of MR Imaging in Sports Medicine[1]

Sports medicine is one of the most rapidly growing subspecialties in orthopedics. Magnetic resonance (MR) imaging in sports medicine includes depiction of normal anatomy and pathologic conditions in almost every joint in the body, but the MR examinations most frequently requested are of the knee and shoulder. The reported high accuracy of MR imaging in the knee has resulted in MR imaging being preferred to diagnostic arthroscopy by most leading orthopedic surgeons. MR imaging is particularly helpful for sports medicine surgeons in evaluating menisci to determine if they are repairable, in posterolateral corner syndrome, and in evaluating the hyaline articular cartilage. In evaluating the shoulder, MR arthrography is becoming the preoperative imaging procedure of choice for many sports medicine surgeons. Shoulder MR imaging is particularly important in helping identify abnormalities that may mimic rotator cuff or labral abnormalities at clinical examination, thus preventing unnecessary surgery in some patients. These abnormalities include Parsonage-Turner syndrome and quadrilateral space syndrome, each of which has a distinctive MR imaging appearance. As the field of sports medicine expands, radiologists will continue to see increased requests for MR imaging, because sports medicine and high-quality imaging are inextricably linked.

Sports medicine is one of the most rapidly growing subspecialties in orthopedics. It has been estimated that 25% of patients seen by primary care physicians complain of musculoskeletal problems (1). In addition, at the oral board examination in orthopedic surgery, the candidates must present the surgical procedures they have performed for the previous 6 months; the most frequently performed procedure reported in the past 2 years was knee arthroscopy (Garrett WE, oral communication, 2000). It is impossible to know the exact causes of disease that led to performance of these procedures, but it is safe to assume that the majority are secondary to a sports- or activity-related cause. Knee arthroscopy is also currently the most frequently performed orthopedic procedure in the United States (2), with over 1.5 million performed each year (see American Academy of Orthopedic Surgery Web site: *www.AAOS.org;* accessed February 2002). Many surgeons use magnetic resonance (MR) imaging to help select which patients are candidates for knee arthroscopy, which represents a huge source of patients for imaging centers.

Sports medicine physicians treat patients of all ages and avocations who have musculoskeletal complaints. However, the elite athlete, whether high school, college, or professional, while comprising only a small percentage of the overall patient population, is the type of high-profile patient that sports medicine–trained orthopedic surgeons attract.

The imaging requirements for sports medicine physicians begin with conventional radiography, but the imaging modality that has most profoundly affected the practice of these surgeons clearly is MR imaging. MR imaging for sports medicine includes high-spatial-resolution multiplanar depiction of anatomy and abnormalities in almost every joint in the body, but the examinations most frequently requested in sports medicine are those of the knee and the shoulder (2). At Duke University, which has a large sports medicine department, we performed just under 20,000 musculoskeletal MR imaging studies in the past 4 years. Knee studies made up 40% of the studies; shoulder studies composed 18%; while hip, ankle, and spine studies accounted for around 10%–15% each. Elbow and wrist studies composed only a few percent per year but seem to be increasingly ordered (Table).

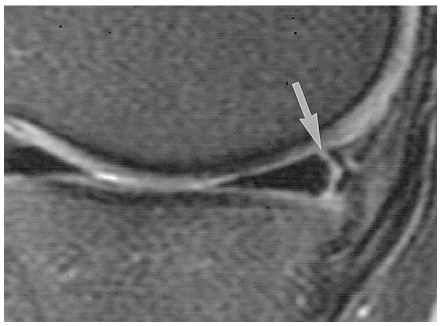


Figure 1. Peripheral meniscal tear. Sagittal spin-echo intermediate-weighted fat-suppressed MR image (repetition time msec/echo time msec, 2,000/20) through the medial meniscus shows a peripheral tear (arrow) with a rim less than 2 mm thick. This is a meniscal tear that should be considered for repair.

Distribution of Musculoskeletal MR Studies at Duke University Medical Center, 1997–2001

Study	Percentage*
Knee	40
Shoulder	18
Hip	15
Ankle	12
Spine	11
Wrist	3
Elbow	2

* Based on $n = 20{,}000$.

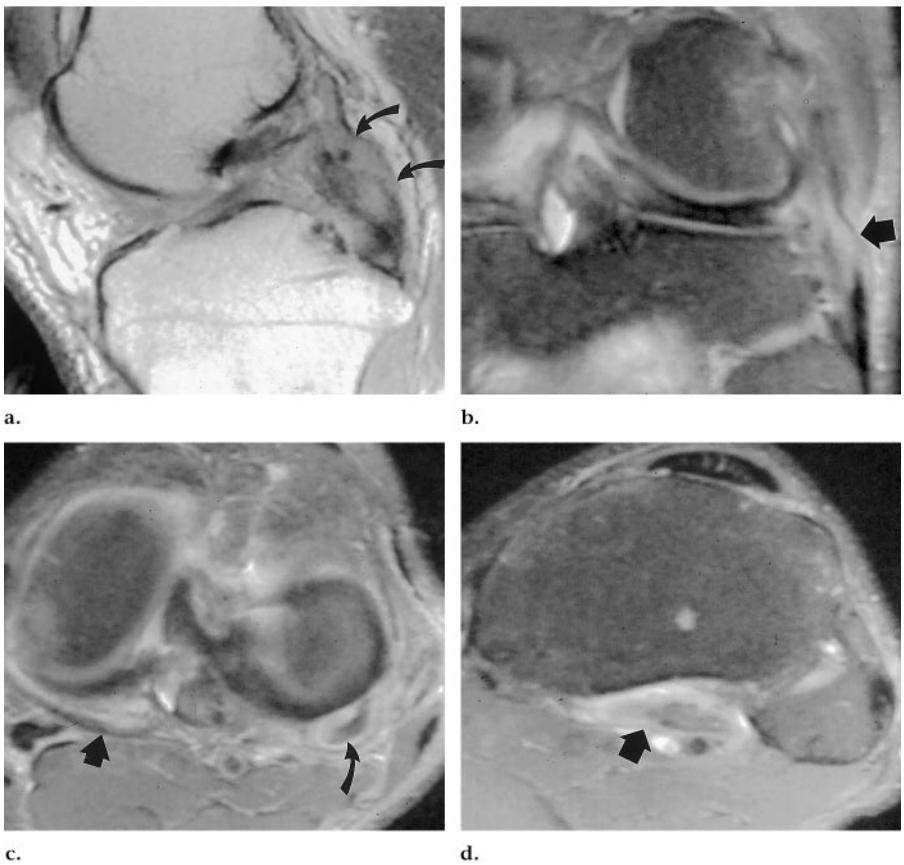


Figure 2. Posterolateral corner injury. **(a)** Sagittal spin-echo intermediate-weighted MR image (2,000/20) through the intercondylar notch shows a thickened posterior cruciate ligament (arrows) with intermediate signal intensity throughout, indicative of a torn posterior cruciate ligament. **(b)** Coronal fast spin-echo T2-weighted fat-suppressed MR image (3,000/70) reveals a torn medial collateral ligament (arrow). **(c)** Transverse fast spin-echo T2-weighted fat-suppressed MR image (3,000/70) at the level of the joint shows the posterior capsule (straight arrow) of the medial side of the joint, which is not evident on the lateral side. This indicates a torn arcuate ligament (which should be seen as a thickening of the lateral capsule at the joint line). In addition, the popliteus tendon (curved arrow) has high signal intensity within and a distended tendon sheath. **(d)** Transverse fast spin-echo T2-weighted MR image (3,000/70) several centimeters distal to the joint shows high signal intensity surrounding the popliteus muscle (arrow), indicative of injury. At surgery, the popliteus muscle was torn at the musculotendinous junction, and the posterior cruciate, medial collateral, and arcuate ligaments were torn.

KNEE INJURIES

Menisci

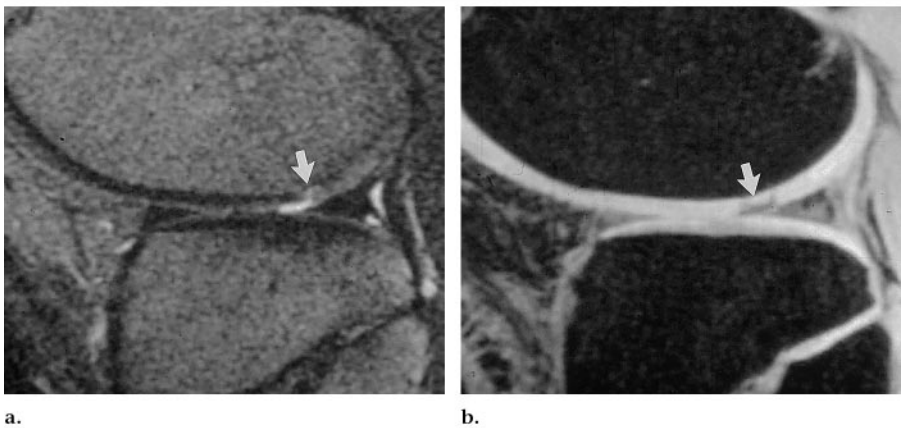
The reported accuracy of MR imaging of the knee for meniscal tears is 90%–95%; for the cruciate ligaments, the accuracy is 95%–100% (3–7). This high accuracy has resulted in MR imaging being preferred to diagnostic arthroscopy by most leading orthopedic surgeons (8). One of the utilities of MR imaging for the menisci is helping the surgeon determine if a meniscus is surgically reparable. The criteria for successful repair include *(a)* the tear is within the peripheral 2–3 mm (Fig 1), *(b)* it is less than 2 cm in length, *(c)* the anterior cruciate ligament is intact, and *(d)* the tear is in the lateral rather than the medial meniscus (9). These criteria are easily identified with MR imaging.

Posterolateral Corner Injury

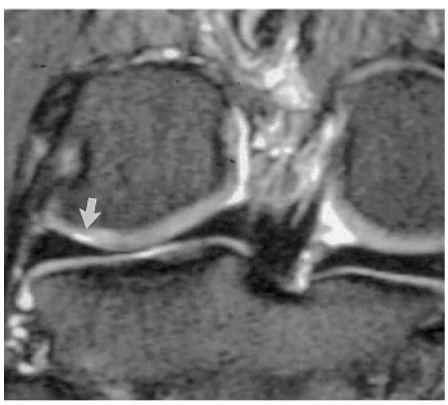
In addition to the ability to aid the surgeon with meniscal pathologic conditions, the MR imaging study can show the findings of a potentially career-ending knee injury for the elite athlete, the posterolateral corner injury. This can be debilitating even for the nonathlete if it is not surgically repaired (10,11). This injury is usually the result of hyperextension. The posterolateral corner is composed of the lateral collateral ligament complex, the arcuate ligament, the popliteus tendon, and multiple smaller ligaments such as the popliteofibular ligament. If two or more of these structures, along with the anterior or posterior cruciate ligament, are torn, the injury is deemed a posterolateral corner injury (Fig 2). Prompt surgical repair (<1-week delay) is recommended for the best outcome in these athletes. MR imaging is crucial in helping establish this diagnosis.

Hyaline Cartilage

Another area in which MR imaging is playing a vital role in athletes is imaging of hyaline articular cartilage in the knee. Newer surgical techniques are evolving that rely heavily on MR imaging for help in identification and classification of cartilage abnormalities (12,13). Imaging techniques are rapidly evolving and improving to aid the surgeon in diagnosing cartilage pathologic conditions. The reported imaging sequences for evaluating hyaline articular cartilage are myriad and seem to have more to do with personal preference than with a quantifiable difference of accuracy. In order of purported accuracy, these MR sequences are *(a)* three-dimensional spoiled gradient echo with fat suppression,

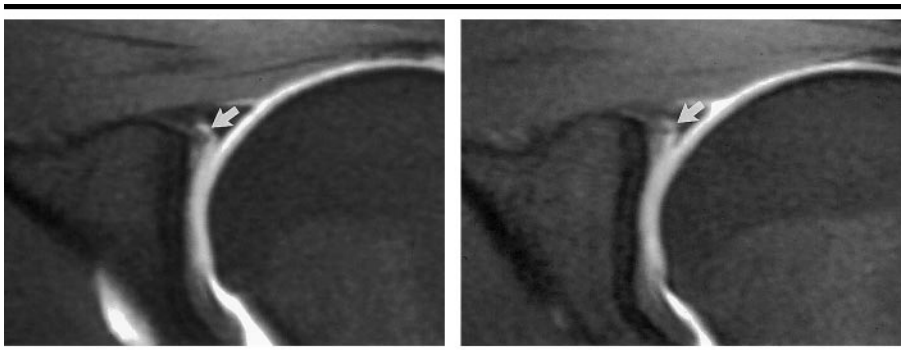


a. b.



c.

Figure 3. Abnormal cartilage demonstrated with different MR imaging sequences. **(a)** Sagittal spin-echo T2-weighted image (2,000/80) shows subtle cartilage abnormality (arrow) in the lateral femoral condyle. **(b)** Sagittal three-dimensional volume spoiled gradient-echo fat-suppressed image (60/5; flip angle, 40°) through the same area as in **a** shows the articular cartilage to have marked high signal intensity with smooth margins, while abnormal cartilage (arrow) has low signal intensity. **(c)** Coronal fast spin-echo T2-weighted image (3,000/70) in the same patient shows the cartilage defect (arrow) in the lateral femoral condyle.



a. b.

Figure 4. SLAP lesion in a professional baseball pitcher. **(a, b)** Consecutive oblique coronal T1-weighted fat-suppressed MR arthrograms (600/20) show gadolinium-based contrast material entering the torn superior labrum (arrow), which was present on multiple images, indicating a SLAP tear. The tear was confirmed at arthroscopy (not shown).

(b) T2-weighted fast spin echo with fat suppression, *(c)* short-inversion-time inversion recovery (STIR), *(d)* gradient echo, and *(e)* conventional spin echo. Most would agree that conventional spin-echo techniques suffer in comparison to fast spin-echo, gradient-echo, STIR, and three-dimensional fat-suppressed spoiled gradient-echo techniques (Fig 3) (14–16).

SHOULDER INJURIES

Rotator Cuff

In evaluating the shoulder, MR arthrography is becoming the preoperative imaging procedure of choice for many sports medicine surgeons (17). Depiction of the rotator cuff and the glenoid labrum is enhanced with MR arthrography, and diagnostic accuracy is improved (18–20). Surgeons are increasingly aware that rotator cuff and labral abnormalities coexist. Combined cuff and labral abnormalities were found in 35% of surgically examined shoulders in a recent report (21). Failure to address both the cuff and the labral conditions during surgical repair can result in failed surgery.

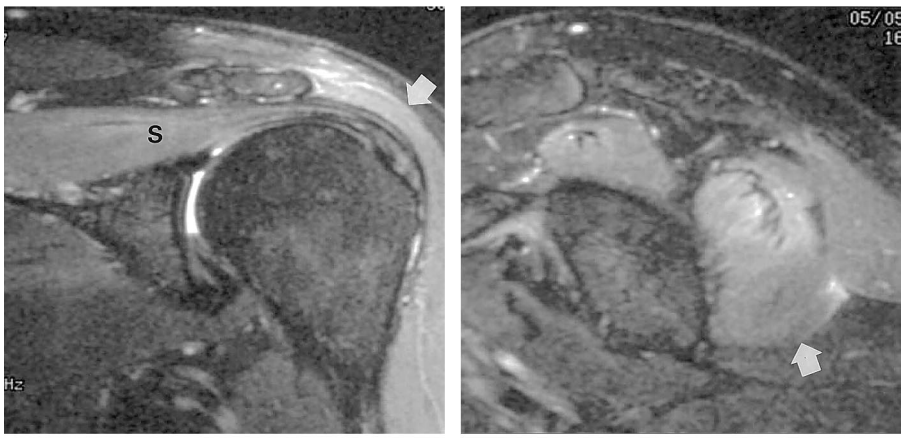
SLAP Tears

Tears or detachment of the superior labrum, called superior labrum anterior to posterior (SLAP) tears, are considered to be caused by the biceps tendon pulling the superior labrum off of the bony glenoid. A SLAP tear can be a debilitating injury for the throwing athlete. These injuries are particularly difficult to diagnose with a clinical examination (22). MR arthrography is considered by many to be the procedure of choice for evaluating the superior labrum, as it is for all of the labrum (Fig 4) (18). There are several types of SLAP lesions described; however, MR imaging is not effective for classification of the type of tear.

Parsonage-Turner Syndrome

MR imaging is particularly important in the shoulder to help identify normal variants (23) and abnormalities that may mimic rotator cuff or labral injuries at clinical examination, thus preventing unnecessary surgery in some patients. These abnormalities include Parsonage-Turner syndrome (acute brachial neuritis), quadrilateral space syndrome, and suprascapular nerve entrapment secondary to a ganglion, each of which has a distinctive MR imaging appearance.

Parsonage-Turner syndrome, also called acute brachial neuritis, is a not infrequent cause of confusion in the diagnosis and treatment of shoulder pain (24). Multiple patients have undergone unnecessary surgery of the shoulder or cervical spine owing to failure to diagnose Parsonage-Turner syndrome. The onset of pain in the shoulder in these patients is dramatically sudden, sometimes waking them from sleep. It is characterized by severe neuritic pain that is accompanied in a few days by profound weakness. Parsonage-Turner syndrome is typically self-limited, with no known treatment other than palliative measures. The cause is unknown. In 20%–30% of patients, the symptoms are bilateral, and about 10%–25% report that they had undergone vaccination or had an infection in the weeks prior to the onset of pain (25,26). MR imaging plays a vital role in the diagnosis



a. b.

Figure 5. Parsonage-Turner syndrome (acute brachial neuritis). **(a)** Oblique coronal fast spin-echo T2-weighted fat-suppressed MR image (3,000/63) shows marked high signal intensity throughout the supraspinatus muscle *(S)* and in the deltoid muscle (arrow). **(b)** Oblique sagittal fast spin-echo T2-weighted fat-suppressed MR image (3,000/70) (anterior to the left) shows that in addition to the high signal intensity in the supraspinatus and deltoid muscles, the infraspinatus and teres minor (arrow) muscles are involved. This diffuse edema pattern is characteristic of a neurogenic deficit involving both suprascapular and axillary nerves.

Figure 6. Quadrilateral space syndrome. Oblique sagittal spin-echo T1-weighted MR image (600/20) (anterior to the left) shows marked fatty atrophy involving the teres minor muscle (arrow), indicative of quadrilateral space syndrome.

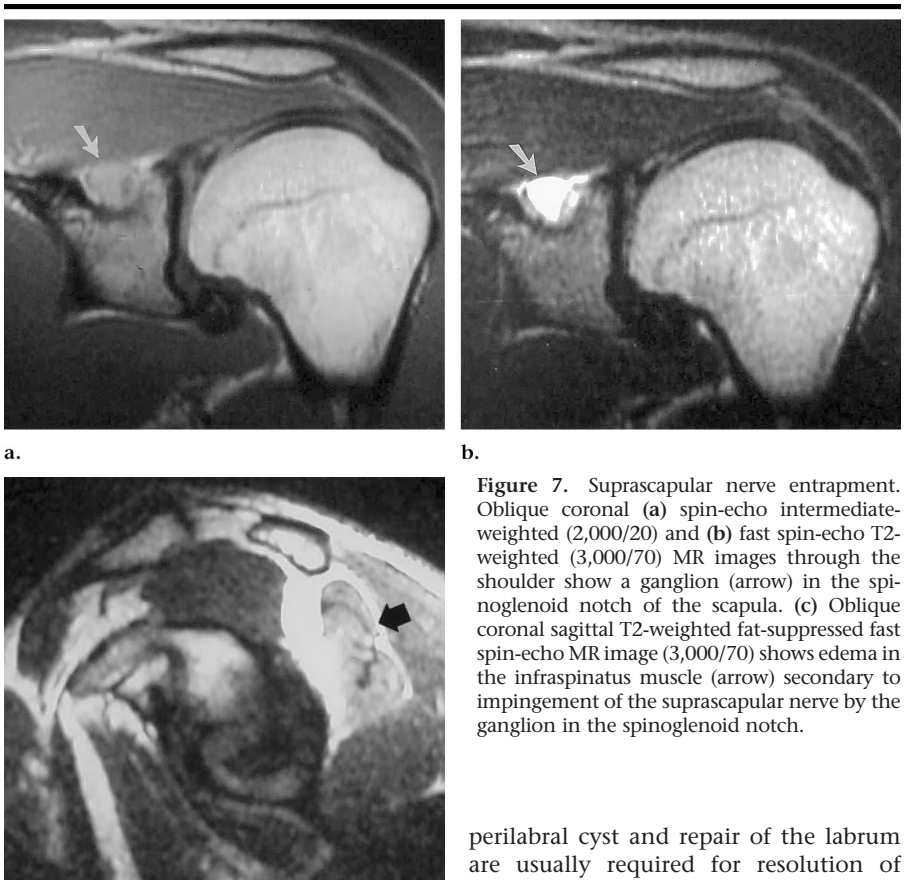
of Parsonage-Turner syndrome and differentiation of it from other causes of shoulder pain (24). The MR imaging appearance is quite characteristic, with marked edema in the affected muscles of the shoulder (Fig 5).

Quadrilateral Space Syndrome

Quadrilateral space syndrome is a painful shoulder disorder that can mimic a rotator cuff tear, resulting in unnecessary shoulder surgery (27). The cause is usually due to fibrous bands in the quadrilateral space causing impingement on the axillary nerve. The fibrous bands are thought to be secondary to prior trauma with resultant scarring. Surgery is usually reserved for patients refractory to aggressive physical therapy. MR imaging will reveal fatty atrophy isolated to the teres minor muscle (Fig 6), which is virtually pathognomonic of quadrilateral space syndrome (28).

Spinoglenoid Notch Cyst or Ganglion

Another cause of a painful shoulder that can mimic a rotator cuff abnormality is suprascapular nerve compression secondary to a cyst or ganglion in the spinoglenoid notch (29). This is almost always associated with a posterior labral tear (30). Diagnosis at MR imaging is established by noting a cyst or ganglion in the spinoglenoid notch (Fig 7). Atrophy or neurogenic edema involving the infraspinatus muscle can be an associated finding. Surgical decompression of the perilabral cyst and repair of the labrum are usually required for resolution of symptoms. The cyst cannot be seen at arthroscopy or open surgery; therefore, MR imaging is critical in establishing the diagnosis and guiding the surgeon to the source of the pain.



a. b.

c.

Figure 7. Suprascapular nerve entrapment. Oblique coronal **(a)** spin-echo intermediate-weighted (2,000/20) and **(b)** fast spin-echo T2-weighted (3,000/70) MR images through the shoulder show a ganglion (arrow) in the spinoglenoid notch of the scapula. **(c)** Oblique coronal sagittal T2-weighted fat-suppressed fast spin-echo MR image (3,000/70) shows edema in the infraspinatus muscle (arrow) secondary to impingement of the suprascapular nerve by the ganglion in the spinoglenoid notch.

These are only a few examples in

which MR imaging plays a critical role for the sports medicine physician. As the field of sports medicine expands, radiologists will continue to see increased requests for MR imaging, because sports medicine and high-quality imaging are inextricably linked.

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