Artifacts and pitfalls of musculoskeletal magnetic resonance imaging

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Learning objectives

The purpose of this article is to describe the normal variants, artifacts and pitfalls that may be encountered when performing magnetic musculoskeletal resonance imaging (MRI).
Background

Magnetic resonance imaging (MRI) has revolutionized the diagnosis of injuries of the musculoskeletal system, becoming the method of choice for its ability to soft tissue contrast and exceptional ease of acquisition in multiple planes. Besides, MRI also does not use ionizing radiation, which is a huge advantage compared to other imaging methods, such as radiography and computed tomography.

Normal variant is a term that is commonly seen since the early days of the residency training. It is extremely common the observation of anatomical variation in the musculoskeletal MR examinations. This is because MRI has an excellent ability to demonstrate tendons, muscles, cartilage, bones, among other structures.

In spite of an enormous advantage for the evaluation of the musculoskeletal system in relation to other methods, sometimes false-positive diagnoses may arise due to imaging pitfalls or anatomic normal variants. These false-positive diagnoses might be harmful to the patient. Besides, radiologists may get distressed as well because of the mistaken diagnosis.

Many of these misdiagnoses may be caused by lacking knowledge of anatomy, with its many variations and particularities. Also, these pitfalls happen due to characteristics of the physical process of image acquisition, patient positioning, and obviously the variation of the anatomy itself. Because of that, it is essential for radiologists to have a solid understanding of the anatomical structures that vary in appearance and differentiate them from the diseases that affect the musculoskeletal system.

In this review we describe the artifacts and pitfalls more relevant in daily routine work. We intend to have a useful, consistent and comprehensive reference for beginner residents and skilled radiologists who work with musculoskeletal MRI, in order to develop more precise reports and help them to avoid making mistakes.
Below we describe the artifacts and pitfalls more relevant in daily routine work.

**Shoulder**

**Long Head of the Biceps Brachii**

The intra-articular portion of the long head of the biceps originates predominantly from the superior labrum (biceps-labral complex or biceps anchor)(1). The attachment of the tendon to the superior labrum also changes according to contributions from both its anterior and posterior aspects, described as follows(2): 1) Posterior labrum only, 2) Predominately from the posterior labrum with small attachment site to the anterior labrum, 3) Identical origins from the anterior and posterior labrum, 4) Predominately from the anterior labrum with small attachment site to the posterior labrum. Rarely, portions of the biceps tendon may also attach to the capsule itself, the rotator cuff, or directly to the osseous supraglenoid tuberosity (3-5).

Besides the location of the biceps attachment to the superior labrum, there is variation in the profile of the biceps-labral complex. In the type 1, biceps-labral complex connects tightly to the superior glenoid. In the type II, complex has a small sublabral sulcus which may communicate with a sublabral hole. In the type III, the biceps-labral complex has a meniscus-shaped labrum with a large sulcus(6).

The long head of the biceps brachii tendon crosses through the glenohumeral joint, travelling into the rotator interval, where it is intracapsular although extrasynovial. Possible imaging pitfalls of the intracapsular long biceps tendon include intermediate signal intensity throughout the normally low-signal tendon. It occurs due to the magic angle artifact. The magic angle artifact refers to the increased signal on sequences with short echo time (TE) (e.g., T1 or PD spin echo sequences) in MR images seen in tissues with well-ordered collagen fibers in one direction (e.g., tendon or articular hyaline cartilage). This artifact occurs when the angle such fibers make with the magnetic field is approximately 54.7 degrees(7).

In addition, since the intra-articular portion of the tendon runs superiorly and posteriorly from the bicipital groove to the biceps-labrum complex, it may appear shifted medially, simulating medial displacement of the tendon.

Inside the bicipital groove, the biceps vincula (synovial bands attaching to the biceps within the tendon sheath) may be seen. Also, blood vessels can be depicted in the bicipital groove.

Some anatomic variations in the origin of the long head of the biceps brachii have been described. The most frequent variation of the biceps brachii is in the number of muscle
bellies, although supernumerary heads are frequent, absence of the long or the short head is rare(8). Supernumerary heads of the biceps brachii have been described as part of a 3-, 4-, or 5-headed biceps brachii(9). Although bifid or duplicated biceps brachii tendon constitutes a normal variation, it may be mistaken for split tendon rupture.

**Rotator Cuff**

Supraspinatus tendon usually inserts on the humerus greater tubercle. However, rarely it may ectopically insert within the bicipital groove.

Magic angle artifact may occur in the supraspinatus tendon on short TE spin echo sequences; likewise seen in the intracapsular long head of the biceps brachii. In these cases, T2-weighted images are very useful to distinguish magic angle artifact from rotator cuff tendinosis or partial tendon tearing. The area of bright signal within the tendon does not persist or is diminished on T2-weighted images with longer TE(10).

Another pitfall involving supraspinatus tendon is the small sulcus of uncovered bone between the osseous insertion of the supraspinatus and the articular cartilage. The presence of this sulcus is important because this small area of exposed bone should not be mistaken for a chondral articular surface injury or even overestimate a known chondral injury(11).

**Glenohumeral ligament and capsular variants**

**Inferior glenohumeral ligament**

The main and the largest stabilizing ligament of the shoulder is the inferior glenohumeral ligament (IGHL). It stabilizes the humerus in external and internal rotation during abduction. The IGHL contains two distinct bands: anterior and posterior bands, which are intervened by the axillary recess of the joint capsule. The IGHL is usually present as a thickening of the joint capsule and may be mistaken for adhesive capsulitis(3).

**Middle glenohumeral ligament**

The middle glenohumeral ligament (MGHL) stabilizes the shoulder in abduction and may have a large spectrum of anatomic variation. The MGHL may attach to the anterosuperior labrum, usually just below the origin of the superior glenohumeral ligament, or attach to the anterior scapular neck itself. In this case, it should not be mistaken for capsular disruption associated with anterior instability.

The MGHL may also have a conjoined insertion with the superior glenohumeral ligament (SGHL), the IGHL or even the long head of the biceps tendon, particularly in cases where the superior glenohumeral ligament is absent.
The size of the MGHL may be thickened (a cord-like pattern) or minimum (12). The association of thickened MGHL and absent anterosuperior labrum is called the Buford complex. Compensatory thickening of the MGHL is due to the absent labrum. The frequency of Buford complex approximates to 1.5% of shoulders (13). The Buford complex should not be mistaken for detachment of the anterior superior labrum (3).

Moreover, the MGHL may be duplicated. In such cases, it should be distinguished from a SLAP lesion (3). The MGHL may be redundant or may unify with the IGHL or anterior capsule before incorporating onto the base of the lesser tuberosity of the humerus. Similar to the IGHL, variations of the MGHL produce modifications in the size and position of the capsular recesses.

**Superior glenohumeral ligament**

The superior glenohumeral ligament (SGHL) may not be found in 3% of shoulders (3). Usually, the SGHL originates on the anterosuperior labrum, just anterior to the biceps-labrum complex, with a conjoined insertion with the MGHL or directly from the proximal biceps tendon (14).

A foramen is typically present between the SGHL and MGHL, which allows the communication between the glenohumeral joint and the subscapularis bursa. In addition, the SGHL is usually thin but may be thickened, particularly in cases where the MGHL is absent.

**Synovial capsule**

The synovial capsule has three variants of the anterior and posterior parts of the glenohumeral joint. The capsule may insert on the glenoid margin (type I), the glenoid neck (type II), or more medially onto the scapula (type III) (15). Types II and III should not be mistaken for posttraumatic capsular laxity. Also, there is no correlation between redundancy of the anterior capsule and anterior instability (3).

**Labral Variants**

Anatomic variations of labral form and contour are common. The greatest shape variation occurs at the half superior of the labrum, close to the inset of many of the supporting capsular structures. These variations may be easily mistaken for labral or capsular pathology, described as follows.

The sublabral foramen is an anatomic variation located at the anterosuperior labrum, where it is detached from the glenoid anteriorly and allows the communication between the glenohumeral joint and the subscapular recess. On MR arthrography, it is an important variation to recognize because it can be misinterpreted as anterior extension of a SLAP tear (3). SLAP tear should be diagnosed whether the medial free edge of the
labrum appears irregular or intra-articular contrast media permeates between the labrum and glenoid.

There is a difference between a sublabral foramen and a sublabral sulcus. The sublabral sulcus or recess is defined as a gap between the biceps-labral complex and the superior glenoid. This occurs in type 2 and type 3 biceps-labral complexes where there is a predominant attachment of the biceps medial to the glenoid rim. In this condition, a latent space between the biceps-labral complex and the osseous glenoid may be seen on MR arthrography. Therefore, careful should be taken to not misdiagnose type II SLAP tear.

A normal sublabral sulcus should have an equal width and depth. Besides, the sulcus posterior to the insertion of the biceps are not usually seen on transverse images. Moreover, on coronal images, the sulcus is parallel to the contour of the glenoid(6). Signal abnormality spreading from this sulcus is suspicious for a labral tear (SLAP) .

In addition, intermediate signal intensity may be observed in the region of an expected sulcus at the interface of the labrum and glenoid. This intermediate signal intensity is consistent with a transitional zone of histology between hyaline cartilage mixed with fibrous or fibrocartilaginous tissue. This should also not be mistaken for a labral tear(3).

Joint recesses and bursae

The subscapular recess is an extension of the glenohumeral joint, located at the posterior and anterosuperior aspect of the subscapularis tendon, typically just below the coracoid process . Therefore, it may be confused for the subcoracoid bursa. The subscapular recess freely communicates with the glenohumeral joint via various possible synovial foramina located between the glenohumeral ligaments . It is important to affirm that there is no communication between the glenohumeral joint and the subcoracoid bursa in healthy shoulders. However, a communication between the subacromial- subdeltoid bursa and subcoracoid bursa may exist(16).

Positional variations

The supraspinatus and infraspinatus tendons are best imaged with a patient's shoulder placed in external rotation. The tendons are taken out of plane on standard coronal and sagittal imaging when the humerus is internally rotated or excessively externally rotated . In this condition, increased overlap of the tendons may preclude the diagnosis of possible injuries, because the supraspinatus tendon may appear discontinuous .

In addition, if there is an exaggerated internal rotation, there may be a false subscapularis tendon thickening or artifactual signal abnormality of the MGHL, and capsular structures . This positioning can also result in abnormal signal intensity between the supraspinatus and infraspinatus, likely due to magic angle artifact .
Also, internal rotation makes imaging of the multipennate aspect of the infraspinatus tendon arduous. Instead, the interposed muscle fibers between the collagen fibers are much better observed in external rotation of the shoulder. This is because positions the rotator cuff tendons parallel to the plane of section on coronal oblique images (17).

**Acromion**

Based on shape, the acromion process has been classified into four types(18): type 1 (straight or flat), type 2 (curved), type 3 (hooked) and type 4 (inverted). This fourth type has been added after and represents a convex or upward pointing undersurface. These acromial morphologic variations may be viewed by using either scapular Y-view radiographs or sagittal oblique and coronal oblique sequences on MRI(19).

It is advocated that a type 3 acromion or prominent enthesophyte can play a primary role in subacromial impingement syndrome(18) and in injury to the anterior leading edge of the supraspinatus. Other acromial shapes, such as a downward projecting keel spur from the acromion or lateral downsloping of the acromion, also likely result in the development of rotator cuff pathology(20).

Embryologically, the acromion may be divided into multiple ossification centers: the basiacromion, meta-acromion, mesoacromion, and preacromion. These ossification centers may be physiologically found during adolescence. After age 25 years, nonfusion of these ossification centers may result in formation of an accessory ossicle, or so called *os acromiale* (3). They are best recognized on axial MR images, where a signal gap is seen between the fat containing marrow of the distal acromion and the nonfused bone.

The *os acromiale* forms a pseudoarticulation with the base of the acromion via fibrous tissue, periosteum, cartilage or synovium. A second "acromioclavicular" joint may be seen on sagittal images, where the *os acromiale* is seen articulating between the remaining acromion and the clavicle. It is important to identify an *os acromiale* because it plays a role in the development of shoulder impingement symptoms due to inferior displacement during deltoid contraction. Degenerative changes of the pseudoarticulation may occur across the synchondrosis or associated with acromioclavicular degeneration, and should be depicted(3).

**Humerus**

A normal groove is often seen at the posterior aspect of the humerus near the junction of the head and proximal diaphysis. This is a potential pitfall on axial MR imaging and should not be mistaken for a Hill-Sachs lesion. This distinction becomes important in patients with a history of glenohumeral instability, because the presence of a Hill-Sachs lesion may warrant further surgical treatment. Usually, Hill-Sachs defects are visible on the uppermost axial sections of the humerus and are positioned within 5 mm of the top of the humeral head superolaterally. The normal anatomic groove of the humerus usually
lies 20 to 30 mm from the superior humeral head and is positioned more medial and posteriorly on axial images. The depth and width of the posterolateral defect are not reliable indicators to its origin(21).

Glenoid

The shallow glenoid cavity provides increased range of motion of the glenohumeral joint at the cost of stability. This stability is achieved through the surrounding structures, in particular the glenohumeral ligaments, labrum, and rotator cuff. Some imaging abnormalities and variations of the glenoid may be present, however, described as follows. At the central area of the glenoid, there is an area of thickened subchondral bone (tubercle of Ossaki) with thinned overlying cartilage. It should not be mistaken for an area of cartilaginous thinning or loss(3).

Likewise, in this equivalent area, a smooth focal fullthickness cartilage defect without thickened underlying bone can be seen as a normal variant. Of course, it should not be confounded with chondromalacia(3).

The glenoid may have different shapes when viewed in the sagittal plane, such as round, ovoid, teardrop-shaped, or pear-shaped. The shape relies on variations in the appearance of the glenoid notch, which can be prominent, diminutive, or absent. The glenoid notch lies at the anterior margin of the glenoid at its upper one-third margin. It designs a pear-shaped appearance of the glenoid on sagittal images.

An oval glenoid on sagittal images is produced by the absence of a glenoid notch. The labrum is not attached to the bony margin of the glenoid at the notch, resulting in the sublabral recess(22).

The glenoid cavity is often more concave inferiorly than superiorly (23). Also, the posterior rim of the glenoid can also vary in shape and configuration. There are 3 predominant shapes of the posterior glenoid rim: 1) pointed (normal), 2) rounded (lazy J), and 3) triangular shaped osseous deficiency (delta)(23). The lazy J and delta shapes are associated with atraumatic posterior shoulder instability(24). On MR imaging, distinguishing between the different shapes of the posterior labrum can be difficult because there is a mixture of low signal intensity between the cortical bone of the glenoid and the glenoid fibrous tissue.

Bone marrow

Bone marrow heterogeneous signal is normally observed within the humeral head and neck. In adult patients, red marrow may be seen physiologically below the physeal scar as mildly hypointense signal on T1-weighted imaging. Red marrow should not be confused for nodule or marrow infiltrative processes, such as tumor. In such cases of infiltrative processes, the marrow signal becomes markedly low, hypointense to muscle.
Elbow

Although is not an articulation often evaluated by MRI, such as shoulder and knee, the elbow can present pitfalls and is essential that radiologists be aware to not make mistakes.

Pseudodefect of the capitellum

Pseudodefect of the capitellum is one of the most frequently pitfalls found in elbow, usually seen in coronal and sagittal images (Figure 1), and should not be confused with osteochondral lesion (25, 26).

Two osteochondral diseases are described in capitellum: osteochondritis dissecans and Panner’s disease.

Panner's disease generally affects younger patients, around 5-10 years, and tends to involve the whole capitellum. Osteochondritis dissecans occurs in patients in adolescence, involvement of the capitellum is often partial and tends to form loose bodies (27).

However, the osteochondral lesion occurs on the anterior aspect of the capitellum while pseudodefeito affects the posterolateral aspect and there is no marrow edema. The presence of synovial fluid or contrast makes easier to recognize this pseudodefect (26, 28).

Trochlear pseudodefect

Trochlear pseudodefect is a bare area devoid of cartilage localized in the trochler notch. It is usually has a small size, measuring up to 7 mm in width (29).

The lesion appears as a slight interruption of cortical bone in sagittal images and like the pseudodefeito the capitellum should not be confused with osteochondral injury. The absence of edema confirms it is a normal find.

It is important to report that trochlear pseudodefect can be a place for loose bodies' deposit.

Transverse trochlear rigde:

Transverse trochlear rigde is detected as central elevation in the trochlear groove on sagital imagens and was detected by Rosenberg and colleagues in 68% of the ulnar bones inspected.
It is usually very small, up to 3 mm high (29), but in a few case can be proeminent and simulate an osteophyte.

**Triceps tendon: striations and insertion**

The triceps tendon is formed by a small surface layer and another layer deeper and thicker, which combine to insert on the posterior aspect of the olecranon (28).

At the triceps tendon insertion high signal can be detected and should not be confused with tear or degeneration. This high signal occurs by the presence of fibro-fatty tissue between the tendon fibers (27, 30).

**Hip**

**Synovial herniation pits**

Femoral fibrocystic changes may occur anteriorly at the junction of the head and neck. Recently, it has been speculated that these fibrocystic changes are related to repetitive impingement of the femoral neck and the anterosuperior acetabulum(31).

**Os acetabuli**

The origin of bone fragments along the acetabular rim, called os acetabuli or os acetabulare. It has been attributed that some acetabula may have secondary ossification centers, and this should not be confused to fractures or ossification of the labrum and/or acetabulum, secondary to the cam type femoroacetabular impingement syndrome(32). Acetabular ossification may also appear after trauma, rickets, osteomyelitis, and osteochondritis dissecans.

**Labrum**

On sectional planes, the labrum is typically triangular and slightly thicker posterosuperiorly than anteriorly(33). The labrum usually has low signal intensity on all routinely used pulse sequences, particularly on T2-weighted sequences. Several variations in the shape and imaging appearance of the acetabular labrum may simulate pathologic conditions and lead to unsuccessful treatment(34).

Labral tears or detachments can be seen on nonarthrographic MR studies with linear fluid signal tracking into the labral substance or undermining the labral attachment to the acetabular rim. Many tears have intrasubstance high signal on T2- weighted or proton density sequences, with surface irregularity and irregularity of the adjacent hyaline cartilage. Tears can be diagnosed on MR arthrography by visualizing injected contrast
material extending into the labrum or through the labrum/acetabulum junction. In more advanced cases, there may be blunting of the labrum, with loss of the normal triangular morphology. Often there is a paralabral cyst with a neck arising either from the labrum itself or from the labro-osseous interface that is commonly seen in association with labral tears.3

Increased signal within the labrum can be a normal finding, mostly on shorter TE pulse sequences, such as T1 or proton density weighted techniques. Intralabral signal can be globular, linear, or curvilinear and may be located in the superior (87%), posterior (21%), and anterior (8%) labrum(35). The intermediate signal may be seen extending to the capsular and/or articular surfaces of the labrum, therefore mimicking labral tears in asymptomatic people. Intermediate signal may persist in 12% of labra on heavily T2-weighted images, even though this is a useful way to resolve these "abnormalities".

The acetabular labrum is typically triangular in cross section, with the lateral part forming the tip and the wider base attached to the bony acetabulum. The labrum is normally thinner anteriorly and thicker superiorly and posteriorly(33). However, there is a variability in labrum shape in asymptomatic subjects, such with a round and flat shape(36).

The anterosuperior labrum may be absent in up to 10% of asymptomatic hips for some authors(36). The finding of absent labral segments may be because of close proximity of the labrum and capsule, impeding depiction of these two separate structures(37). However, other authors opine differently and stress that until more work is done that supports focal absence of the labrum is a normal variant, this finding should be considered abnormal(33).

On some occasions, intermediate signal intensity can be found on MR imaging at the junction of the articular surface of the labrum and the acetabulum. This area of increased signal corresponds to the attachment of the labrum to the acetabular cartilage and should not be mistaken for a tear(33).

A normal sublabral sulcus may be found similar to the shoulder. It is important to accent that sublabral sulci show no abnormal signal in the labrum adjacent to the sulcus, there are no adjacent cartilage lesions or osseous abnormalities, and there are no ganglion cysts(38).

**Transverse acetabular ligament**

The acetabulum closely covers the femoral head, with the exception of its anteroinferior aspect, where there is an absence of bone and cartilage. This anteroinferior aspect of the acetabulum is crossed by the transverse acetabular ligament (TAL). Also, the TAL forms a complete ring around the acetabulum. The transverse ligament attaches to the acetabular rim anteriorly and posteriorly and to the ligamentum teres femoris. The junction between TAL and the acetabular labrum occurs a normal cleft that can be mistaken for an acetabular labral tear.
Perilabral recess

Similar to the shoulder, the hip joint capsule attaches to the osseous rim of the acetabulum, sustained posteriorly by the ischiofemoral ligament and anteriorly by the iliofemoral and pubofemoral ligaments. Between the medial joint capsule and the acetabular labrum may exist a normal sulcus, so called perilabral recess.

Supra-acetabular fossa

The supra-acetabular fossa is small cavity in the superior, weight-bearing region of the acetabulum. It is usually filled with fibrous tissue, covered by cartilage and should be easy distinguishable from an osteochondral lesion.

Tubular acetabular intraosseous contrast tracking

Intraosseous track of contrast material in MR arthrography may be found in hips at approximately 15%(39). These tracks are linear and blind-ending structures that originate from the acetabular fossa at or near its margin with the acetabular cartilage. This finding is thought to be an unlikely source of hip pain(39).

Stellate crease

The stellate crease, also improperly called stellate lesion, is another anatomic variant and represents a uncovered area within the acetabular articular surface above the anterosuperior margin of the acetabulum. On MR imaging, the stellate crease can appear irregular and could be mistaken for an osteochondral lesion.

Iliopsoas bursa

The iliopsoas bursa is located subjacent to the iliopsoas myotendinous junction and a communication either congenital or acquired may occur (15% of people)(40, 41). Obviously, a normal iliopsoas bursa is usually collapsed and not visible on MR imaging, although distention with a small amount of fluid may also be observed in asymptomatic hips. In MR arthrography, intra-articular contrast material may be easily seen.

Accessory iliacus tendon

The accessory iliacus tendon is a common anatomy variation, seen in 66% of MR arthograms, which may simulate iliopsoas tendon abnormality(42). On MR transversal imagens, accessory iliacus tendon is represented by a small tendon paralleling the iliopsoas major tendon, separated by a fat plane. Therefore, visualization of liquid instead
of fat is prone to tendinopathy. Also, tendon pathology is frequently associated with iliopsoas bursitis (43).

**Knee**

The study with magnetic resonance imaging of the knee shows high sensitivity and specificity to detect lesions in meniscus, tendons, cartilage, bones and ligaments (44). The knee is probably the most common joint evaluated by MRI and is essential to know the anatomical variations and different artifacts to do not misinterpreted then as lesion.

**Meniscal tears:**

The sensitivity for meniscal tears appears to be 96% for the medial meniscus and 94% for the lateral meniscus (45).

The posterior horn of the medial meniscus is the most common site of tears. Of the 194 knees examined by Mesgarzadeh and colleagues, 144 had meniscal tears: 45% were limited to the medial meniscus, 22% were limited to the lateral meniscus, and 33% involved both. All cases of medial meniscus tears had injury of the posterior horn; not detected isolated lesion of the body or the anterior horn (46).

However, most of the pitfalls described occur in the lateral meniscus, as described next.

**a. Meniscofemoral ligament**

Meniscofemoral ligaments extends from the posterior horn of lateral meniscus to the lateral aspect of medial femoral condyle. Consists of ligament of Humphrey, anterior to the posterior cruciate ligament (PLC), and ligament of Wrisberg, posterior to the PLC and larger (28).

Vahey and colleagues identified meniscofemoral ligaments in 50% of 109 MR scans. In 39% they causes apareance of pseudotear in sagital imagens(47). The interposition of a thin layer of fat between the posterior horn of the lateral meniscus and ligament meniscofemoral simulates tear. It is necessary to follow these normal structures on subsequent images to do not interpret as meniscal injury (44).

**b. Transverse ligament**

The transverse ligament is identified on MR images of the knee as a hypointense structure that connects the anterior horn of the lateral and medial meniscus (28). It was detected by Sintzoff and colleagues in 78% of cases (48).
The space filled by fat between the ligament and the meniscus can simulate tear in the anterior horn of lateral meniscus, but can also be seen in medial meniscus. Following sequential imagens confirm it is not a tear, but transverse ligament. Furthermore, isolated lesions in the anterior horn of the lateral meniscus are uncommon, detected in 6% of cases (46).

c. Popliteus tendon

The popliteus tendon and its sheath stands between the articular capsule and lateral meniscus to insert in the lateral femoral condyle. The tendon sheath appears as a structure of high signal and can be interpreted as a lesion in the posterior horn of the lateral meniscus, especially in the presence of joint fluid (49, 50) (Herman and Beltran 775-81;Muglia et al. 161-66).

Anatomical knowledge and following of images are essential for correct diagnosis.

d. Speckled anterior horn

Frequently is observed a speckled appearance of the anterior horn of lateral meniscus, possibly occurs by the insertion of the anterior cruciate ligament.

This aspect is found in approximately 56% of cases and should not be confused with injury (51).

e. Fibrillation

The presence of fibrils in free and concave edge of the meniscus is seen as an area of hyperintensity, but that should not be valued if the meniscus has the usual format and other findings are absent (28, 50).

f. Chondrocalcinosis

The presence of meniscal calcification is a form manifestation of calcium pyrophosphate dihydrate of the deposition disease.

This calcification may cause high signal in the meniscus and mimic tear. On the other hand, may obscure a real lesion. It is recommended radiography correlation (44).

g. Meniscal flounce

Meniscal flounce is a normal find present in 0.2% of cases which is associated with ligamentous laxity(52, 53). The meniscus has a folded apperance and it possibly has no clinical signi#cance.

Pseudo jumper knee:
The patellar tendinopathy is associated with sports activities and is also known as jumper's knee. This condition presents with pain, swelling and functional limitation. In studies of MRI appears as strates thickening and increased signal in the tendon (54, 55).

However, often there is a high signal and slightly increased thickness at either or both ends in asymptomatic patients (25).

Schweitzer and colleagues found focal areas of signal in 74% and intratendon signal was also seen commonly in the inferior aspect of the tendon (32%) (56).

Therefore, it is important to always relate to clinical information. Furthermore, increased thickness of tendon tends to be higher in jumper's knee.

Pseudo iliotibial band friction

The iliotibial band friction syndrome is a clinical condition associated with intense physical activity in which occurs friction of the iliotibial tract over the lateral femoral condyle (57).

Joint fluid that accumulates in the lateral recess of the knee can simulate the iliotibial tract syndrome. However, in the syndrome fluid accumulates on both sides of the tract and there are alterations in the iliotibial tract, such as sign changes and thickening. Liquid only on the medial side of the iliotibial tract indicate joint fluid (44).

Anterior cruciate ligament cyst

Anterior cruciate ligament (ACL) is the most common site of cystic lesion inside the knee joint (58). The cysts are most common in males and have an incidence up to 0.44% in MRI studies (59-61). Patients usually complain about painless and restriction of movement. It is important to mention that trauma may cause local changes that lead to cyst formation.

These cysts eventually may simulate rupture of the ACL. Meanwhile, the clinical lesion is different and it presents with a drumstick appearance on sagittal images and cystic on coronal or axial images (27).

Ankle

The evaluation of the ankle MRI revolutionized the diagnosis of lesions in this joint. However, it is essential to have a broad knowledge of the anatomy of the ankle, in view of the various anatomical variations and pitfalls.

There are a wide range of variations, therefore we chose to describe only those that we believe to be the most important.

Pseudodefect of talar dome
Pseudodefect of talar dome is a normal groove in the posterior aspect of the talus for the passage of the posterior talofibular ligament and should not be confused with osteochondral fracture.

This is a very common finding, observed in most MRI studies. In a series involving 40 patients, the pseudodefect was found in 96% of cases. In a few cases that had been examined both ankles, the groove was present in 86%.(62).

It is seen on MRI images as an irregular area of low signal in the posterior aspect of the talus (28). This characteristic location and the absence of other findings make easy to recognize this pitfall and differentiates it from osteochondral injury.

Imaging changes after exercise and normal fluid collection

After physical activities imaging findings can be found on MRI of the ankle and have no pathological significance.

Liquid can be observed in the joint, tendon sheaths and retrocalcaneal bursa. Fluid in the tendon sheath most commonly occurs in the flexor hallucis longus tendon sheath, because it shows communication with the ankle joint. In the lateral compartment, fluid in the peroneal tendons sheath was found in 10% of cases (63).

It is essential to make correlation with clinical findings. Moreover, the liquid tends to surround the tendon in truly pathological conditions (25, 64, 65).

Appearance variations in ligaments and tendons

Tendons and ligaments usually appear as homogeneous and hypointense structures on MRI images. This appearance indicates that there are no injuries and that these structures must be intact. Nevertheless, they may have a different aspect in some cases, usually because of fatty tissue between the ligament and tendon fibers, which does not necessarily indicate injury (5, 64, 66).

The following ligaments are often seen as a striated structure, with heterogeneous signal: posterior talofibular, posterior tibiofibular, talocalcaneal and anterior tibiotalar (deep deltoid). This appearance should not be confused with injury. Normal posterior talofibular ligament with irregular and frayed superior edge was found by Noto and colleagues in 13 of 30 cases (63).

Similarly, the posterior tibial tendon can easily simulate injury, since it has multiple insertions, providing a complex image appearance (64).

Acessory bones and sesamoids
First of all is necessary to differentiate sesamoids from accessories bones, which can be a source of confusion.

Sesamoids are located in the intimacy of the tendon, in places where they change course and over bony prominences. There is a sesamoid bone in the peroneus longus tendon proximal to its entrance into the cuboid sulcus (os peroneum). Another one can be found in the posterior tibial tendon proximal to its insertion into the naviculare tuberosity.

Acessory bones are secondary ossification centers that can be found in various locations of the foot and ankle. They rarely have clinical significance. However, the navicular bone (especially type 2) may eventually present with symptoms, for example. The os trigonum is found in about 10% of population and also may present with pain (os trigonum syndrome).

They are commonly found in imaging studies and should not be confused with fracture. They have regular appearance, rounded shape and typical location. There is no difficulty to to make this differentiation(25, 64, 67, 68).

**Acessory muscles**

It is not uncommon to find accessory muscles in the ankle. In most cases they do not have clinical significance and are often incidentally found. In a few instances may present as a palpable mass, simulating a tumor, or may cause compression of local structures(64, 68).

The peroneus quartus muscle is found in up to 17-22% of the population(69, 70). It originates in the lateral and distal aspect of the fibula, positioned posteriomedial to peroneal tendons, and attachment is variable, including the calcaneus and cuboid bones and the peroneal tendons.

Be careful not to confuse the peroneus quartus muscle with low-lying peroneus brevis muscle belly. The insertion site is different for each one (71).

The peroneus quartus muscle is generally asymptomatic. However, eventually may associate with dislocation and injury in the peroneal tendons (71).

The accessory soleus muscle is rarely found and it is usually asymptomatic. However, there are some cases in the literature that this anomalous muscle presents as soft tissue mass or with local pain(64, 72).

Another muscle described in the ankle is the flexor digitorum longus accessorius, encountered in 6% of asymptomatic individuals, but may be associated with tarsal tunnel syndrome (73).
**Fig. 0:** Rotator cuff magic angle. Increased signal in the supraspinatus tendon on the short TE sequence.

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Fig. 0: Os acromiale. Acromion possible non fused ossification centers.

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Fig. 0: Coronal T1-weighted MR arthrographic image of a normal sulcus of the biceps-labral complex (arrow), which is normally parallel to the glenoid (A). SLAP tear image demonstrates bright signal abnormality (arrow) extending into the substance of the superior labrum (B).

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Fig. 0: Bifid biceps tendon (arrow).

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Fig. 0: Vessels close to the long head biceps tendon (arrows).

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**Fig. 0:** Os acromiale.

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**Fig. 0:** Normal bone marrow striations.

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**Fig. 0:** Hill-Sachs defect. Coronal, sagittal and transversal T1-weighted fat-suppressed image show a bulky superior and posterolateral impaction fracture. The patient has anterior instability condition.

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**Fig. 0:** Rotator cuff magic angle. Coronal PD and T2-weighted images across the supraspinatus insertion. On the left, it is possible to see increased signal on the short TE sequence (arrow), not seen on the longer TE sequence on the right image (arrow).

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Fig. 0: Biceps vincula (mesotendon). The biceps tendon obtains its blood supply from a mesotendon (arrow), also called vincula tendinum, enclosing the terminal branch of the anterior humeral circumflex artery. This mesotendon is attached to the biceps tendon through the visceral layer of the tendon sheath.

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Fig. 0: Superior anterior labrum rupture.

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Fig. 0: Joint recess.

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**Fig. 0:** Joint normal folds.

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**Fig. 0:** Os acetabuli (arrows).

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Fig. 0: Transverse acetabular ligament.

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Fig. 0: Iliopsoas bursa in a patient with sinovitis.

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**Fig. 0:** Stellate "lesion".
Fig. 0: Accessory iliac tendon.

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Fig. 0: Normal striated signal intensity pattern in deep deltoid ligament (arrow).

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Fig. 0: T1-weighted sagittal image: osteochondral fracture. There is a bone defect of talar dome with low sign intensity (arrow).

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**Fig. 0:** T1-weighted sagittal image shows focal low signal intensity irregularity (arrow) and should not be confused with osteochondral fracture.

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**Fig. 0:** Axial T1-weighted MR images shows peroneus quartus muscle belly (white arrow) and its tendon inserting in calcaneal bone (black arrow).

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**Fig. 0:** T1-weighted sagittal image shows an os trigonum (arrow).

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**Fig. 0:** Coronal proton-density fast spin-echo (A) and T1 weight imagens (B) shows inhomogeneity of posterior talofibular ligament (arrowheads).

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**Fig. 0:** Axial T1-weighted MR image shows low position of the peroneus brevis muscle (arrow).

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Fig. 0: Transverse acetabulum ligament.

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Fig. 0: Attachment of the labrum to the acetabular cartilage and should not be mistaken for a tear.

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Fig. 0: Os acetabulli.

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**Fig. 0:** Coronal proton-density fast spin-echo (TR 3580 ms, TE 44 ms): exemple of Wrisberg meniscofemoral ligament (black arrow heads).

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**Fig. 0:** Coronal proton-density fast spin-echo and T1 weight images: normal triceps tendon striations.

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**Fig. 0:** Acromion types.

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**Fig. 0:** Sagittal and coronal proton-density fast spin-echo (TR 2300 ms, TE 35 ms) demonstrate the pseudodefect of the capitellum (white arrows).

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**Fig. 0:** Proton-density fast spin-echo (TR 3580 ms, TE 44 ms) sequential images confirm it is just the transverse ligament.
**Fig. 0:** A and B proton-density fast spin-echo (TR 3580 ms, TE 44 ms). Transverse ligament simulating tear in the anterior horn of lateral meniscus (white arrow in A). Ligament transverse showed in axial imagens (black arrowhead in B).
**Fig. 0:** Sagital proton-density fast spin-echo (A) and T1 weight imagens (B): observe the small areas of increased signal in A and B (arrows).

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Fig. 0: Coronal proton-density fast spin-echo (TR 2620 ms, TE 40 ms) shows a normal iliotibial tract (arrow) and fluid in the lateral recess (arrowheads). It should not be mistaken to iliotibial band friction syndrome.

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Fig. 0: Sagital proton-density fast spin-echo (A) and T1 weight imagens (B): speckled anterior horn of lateral meniscus (arrows).

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**Fig. 0:** Proton-density fast spin-echo (TR 3180 ms, TE 50 ms) sagital image shows the popliteus tendon (short arrow). The direction of the pseudo tear (long arrow) is the same of the tendon.

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Fig. 0: Normal hip joint.

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Fig. 0: Globular labrum.

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Fig. 0: Flat labrum.

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Fig. 0: Stellate "lesion".

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**Fig. 0:** Sagittal proton-density fast spin-echo (TR 2300 ms, TE 35 ms) image of the elbow showing cortical interruption (white arrow): trochlear pseudodefect. There is no marrow edema.

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Conclusion

MRI is one of the most important diagnostic modality of the musculoskeletal system, but awareness and understanding of the pitfalls will minimize errors in diagnosis. Besides, knowledge of the MRI limitations and operator-dependent parameters will permit optimization of the study and improve the overall utility of the technique.
References


