Rotator Cuff

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Eva Llopis, Alexeys Perez, and Luis Cerezal

Learning Objectives

- Review new anatomical concepts of the rotator cuff.
- Review characteristics of the anterior rotator cuff, subscapularis and posterior rotator cuff, and supraspinatus and infraspinatus for partial- and full-thickness and massive tears.
- Describe the more important differential diagnosis when facing a MR request for shoulder pain.
- Learn how to do standardized reports and what information should be included in a report for decision-making.

Key Points

- Knowledge of anatomy and biomechanics of rotator cuff tears is essential for understanding tear patterns.
- Rotator cuff should be divided into anterior and posterior tendon injuries.
- Reports should include location, size, retraction, pattern, and fatty atrophy.

Its anatomy allows abduction, adduction, flexion, extension, and medial and lateral rotation but sacrifices stability. Rotator cuff tendons and muscles are the dynamic stabilizers of the shoulder helping the bone discrepancy between the glenoid and the humeral head to avoid shoulder dislocation. The origin of the rotator cuff is the scapula, and they insert into the humeral head forming parallel structures (Fig. 2.1). Although the rotator cuff is separate at the origin, the rotator cuff is organized in a five-layer structure where they approach each other near the insertion. This layered structure explains the appearance of delaminating tears. In the lower level, there are some perpendicular lineal fibers that represent an extension of the coracohumeral ligament and extend from the rotator interval through the supraspinatus and the infraspinatus. It is called the rotator cable and has biomechanical implications

Fig. 2.1 Anatomy of the shoulder, sagittal PD FSE fat sat WI, 1 subscapularis; 2 long head of the biceps tendon; 3 supraspinatus; 4 infraspinatus; 5 teres minus; 6 coracoid process; 7 acromioclavicular joint

2.1 Anatomy

The shoulder is the most flexible and movable synovial joint allowing a huge ROM.

The original version of this chapter was revised. The cross-referenced chapter incorrect Surname and Given name in reference 18 has been corrected. The correction to this chapter is available at https://doi.org/10.1007/978-3-030-71281-5_21

E. Llopis (✉)
Hospital de la Ribera, Hospital IMSKE, Valencia, Spain

A. Perez
CST, Consorsis Sanitari de Terrassa, Terrassa, Spain

L. Cerezal
DMC, Diagnostico mÉdico Cantabria, Santander, Spain

Fig. 2.2 Anatomy of the shoulder, sagittal PD FSE fat sat WI, rotator cable is shown as an extension of the coracohumeral ligament crossing the underlying fibers of the supraspinatus and infraspinatus

in stress shielding, acting like a suspension bridge. It can be depicted on US and MR, especially in ABER position where the fibers of the supraspinatus relax [1–7] (Fig. 2.2).

The posterior rotator cuff tendons include the supraspinatus and infraspinatus that have a bursal and an articular site. The teres minus is rarely injured, and its function on the biomechanics of the shoulder is still to be determined. The supraspinatus inserts onto the anterior part of the greater tuberosity. It is important to realize that it has some anterior extensions to the lesser tuberosity reinforcing the rotator interval and merging with the subscapularis. The infraspinatus origins in the infraspinatus fossa at the inferior part of the scapula and inserts into the greater trochanter with a trapezoidal shape appearance. It has a wide insertion covering part of the supraspinatus insertion [8, 9].

The subscapularis has the largest tendon, with many fascicles. Its superior fascicles have a tendinous insertion, many of which insert into the lesser tuberosity, while some cross toward the greater tuberosity, whereas its inferior fascicles have a muscular insertion onto the humerus. Its function is anterior stabilization of the shoulder and of the long head of the biceps tendon [10].

2.2 Posterior Rotator Cuff, Supraspinatus and Infraspinatus

1. Tendinopathy.

Secondary to repetitive contact of the tendons with movements between the acromioclavicular arch and the

Fig. 2.3 Coronal PD fat sat WI, demonstrates high signal intensity within the insertion of the supraspinatus without disruption

humeral head and between the joint capsule and the glenoid rim, the tendons experience structural changes. These changes represent histologically a continuum model of different progressive changes that start in reactive tendinopathy and continue into tendon disrepair and degenerative tendinopathy and end in tendon rupture. Initially those changes are reversible but shift to degeneration and rupture when the capacity of the tissue to repair is not enough. Our role would be to be sensitive enough to depict changes that are reversible. Initially the reaction of the tendon to load, friction, and activity results in small changes with disorganized extracellular matrix and subtle inflammatory reaction around the tendon that can be seen on imaging as peritendinitis and focal thickness of the tendon on high-resolution MR or US. In an attempt to heal matrix breakdown with collagen, separation and proliferation of abnormal tenocytes and increase of vascularization occur, which on imaging can be seen as low echogenicity areas on US and focal areas of high signal intensity on fluid-sensitive MRI. Progressively histological changes evolve to cellular and matrix changes with mucoid degeneration, chondral metaplasia, and amyloid deposition together with reparative changes and inflammation such as an increase of fibroblastic cells and neovascularization. These changes represent degenerative tendinopathy, and they are precursors of tendon tears. On imaging an increase in tendon thickness and changes of intrasubstance echogenicity on US and signal intensity on MR can be depicted [11, 12] (Fig. 2.3).

2. Partial Tears.

The incapacity to heal and restore the native structure of the tendon leads to partial tear with scar formation with disorganized tissue that decreases mechanical properties. On imaging this is seen as focal areas of fluid echogenicity or high signal intensity on fluid-sensitive sequences, particularly PD fat saturation or T2 fat saturation sequences. They can be divided depending on the location, in articular, intrasubstance, or bursal partial tears (Fig. 2.4). Tears that are bigger than 50% have

Fig. 2.4 Two different cases on coronal PD fat sat FSE WI. (a) Articular side partial (arrows) rupture of more than 50% of tendon thickness; (b) bursal side partial rupture (arrows) affecting less than 50% of the tendon thickness

higher probability to progression to a full-thickness tear than those that are smaller than 50% of the thickness. Tears that are smaller than 50% are usually treated conservatively; surgical treatment is only recommended when conservative measures fail [13, 14].

Bursal-side tears are associated with subacromial and coracohumeral arch degenerative changes. The presence of fluid in the subacromial bursa facilitates the radiological diagnosis. These tears are occult to arthroscopy. Because of their adequate blood supply, they have a tendency to heal [13, 14].

Partial articular surface tears are the more frequent; they have been named as PASTA (partial articular supraspinatus tendon avulsion) lesions or rim rent tears. They don't heal properly and have a tendency to progress to full-thickness tears. Insertional tears occur in younger population and are related to traumatic events, whereas more proximal tears in the critical zone are associated with degenerative changes. Partial tears have a vertical component that should be measured in mm and is easy to be seen in conventional projections; its horizontal component is more difficult, and ABER position helps to depict its full extension. Partial articular surface tears occurring within the 2nd and 3rd layer may extend horizontally and might involve the supraspinatus and the infraspinatus in a delaminating type of injury without retraction [15–18] (Fig. 2.5).

Fig. 2.5 Coronal PD fat sat WI, showing delaminating partial rupture with fluid between the different layers without disruption of its articular side insertion

Intrasubstance tears occur within the tendon and usually are associated with intense pain.

3. Full-Thickness Tears.

Full-thickness tears are those tears that extend from the articular side to the bursal side; they don't have to involve the entire tendon in other planes. It is important to describe the size of the tear, the number of tendons affected, the retraction, and the shape of the tear. The size of the tear is categorized as smaller than 2 cm, between 3

and 4 cm, or greater than 5 cm. The retraction is defined as no retraction, small retraction if it doesn't reach the level of the acromioclavicular joint, and large when it passes the AC joint. Arthroscopically the pattern of the tear is described as crescent, U-, or L-shaped [15–18] (Figs. 2.6 and 2.7).

Fat atrophy has implication on the therapeutic approach and patient prognosis. If the atrophy is greater than 50% of the muscle, there is a high rate of recurrence after

Fig. 2.6 Full-thickness tear of the supraspinatus, coronal (a) and sagittal (b) PD fat sat WI

Fig. 2.7 MRI arthrography of the shoulder coronal (a) and sagittal (b) T1 FSE fat sat WI demonstrating full-thickness complete rupture of the supraspinatus

Table 2.1 Lafosse classification

Grade I	Partial lesion of the superior one third
Grade II	Complete lesion of the superior one third
Grade III	Complete lesion of the superior two thirds
Grade IV	Complete lesion with head centered and fatty degeneration < stage 3
Grade V	Complete lesion with eccentric head and fatty degeneration > stage 3

Fig. 2.8 Sagittal FSE T1WI showing moderate atrophy of the supraspinatus [1] and severe atrophy of the infraspinatus

repair. There have been different classifications for fat atrophy. The Goutallier system is based on the percentage of fat within the muscle on CT axial planes; Zanetti and Thomazeau analyzed the supraspinatus fossa on T1-weighted sagittal MR images, and recently ISAKOS defined four different grades [13, 19–21] (Table 2.1) (Fig. 2.8).

4. Massive Rotator Cuff Tears, Rotator Cuff Arthropathy.

A massive rotator cuff tear is characterized by the involvement of two or more tendons or a retraction greater than 5 cm. As the rotator cuff centralizes the humeral head into the glenoid and serves as the fulcrum when the deltoid abducts and elevates the arm, its deficiency changes the biomechanics. There is progressive migration of the humeral head superiorly causing adaptive changes on the coracoacromial arch with acetabulization.

Fig. 2.9 Coronal PD FSE WI of a massive rupture of the rotator cuff showing superior migration of the humeral head (black arrow), remodeling of the acromioclavicular arch (black arrow head), glenohumeral degenerative changes, and fatty atrophy of the supraspinatus (*)

Glenohumeral arthrosis can be seen as loss of the joint space and presence of inferior humeral osteophytes. In the last stages and on imaging, we can depict subchondral cyst formation, secondary areas of avascular necrosis and bone marrow edema, and ultimately collapse of the humeral head [13, 21–23].

For treatment purposes it is important to describe the morphology and bone stock of the glenoid, the deltoid, and the alignment [21–23] (Fig. 2.9).

2.3 Subscapularis Tendon Tears

Subscapularis tendon tears are more frequent than previously thought. They have been found in cadavers in more than 30%. They are underestimated in all imaging techniques. The sagittal plane is the best for its MR evaluation. On MR arthrography we strongly recommend external forced rotation for better depiction of partial articular side tears. Most missed are partial- and full-thickness tears of the posterior fibers of the subscapularis. They are closely related to the rotator interval and the anterior crossing fibers of the supraspinatus. Lafosse classification is the most accepted one; it is divided into five grades (Table 2.2). Subscapularis tears are associated with anterosuperior impingement. Anterosuperior impingement was described by Gerber arthroscopically revealing impingement of the undersurface of the subscapularis tendon against the anterosuperior glenoid rim in the position of flexion and internal rotation. It is less common than posterosuperior impingement. There are

Table 2.2 Fatty atrophy

Grade 0	Normal muscle
Grade 1	Some fatty streaks
Grade 2	Less than 50% of fatty infiltration
Grade 3	50% equal fat to muscle
Grade 4	More than 50% fatty infiltration

ISAKOS adopted Goutallier and Fuchs classification of the fatty atrophy valid for CT and MRI

Fig. 2.10 Axial arthro-MRI FSE T1 fat sat WI demonstrates partial articular side tear of the subscapularis

associated rotator interval lesions, long head of the biceps tendon lesions and dislocation, and SLAP lesions [24–26] (Fig. 2.10).

2.4 Differential Diagnosis

It is important to know some entities that clinically can mimic rotator cuff lesions.

1. Calcified Tendinopathy.

Crystal deposition, especially CPPD deposits on the tendon, causes inflammation and is an important cause of shoulder pain in young adults. Its cause is still unknown although microtrauma, ischemia, and metaplasia have been proposed as causes. It is usually a self-limited disease with spontaneous resolution in a high percentage of cases. Different clinical stages have been described: a precalcification phase which is clinically silent; the calcification phase in which crystal deposition occurs, subsequently the start of a resorptive phase with inflammatory reaction that causes severe pain; and the end a post-calcification phase (Fig. 2.11). The deposits of CPPD might migrate to the subacromial bursa causing bursitis or less frequent into the bone at the lesser or greater tuberosity. It is important to know this potential involvement of the humeral head to avoid confusion with a tumor. MRI shows a sclerotic or lytic lesion surrounded by peripheral bone marrow edema. The key for the diagnosis is the association with calcifications within the proximal tendon [27, 28] (Fig. 2.12).

Fig. 2.11 Rotator cuff hydroxyapatite deposition disease. (a) AP radiograph shows periarticular calcifications; (b) axial GET2; (c) coronal PD FSE fat sat WI shows coarse ovoid calcification in the subacromial subdeltoid bursa surrounded by fluid indicating inflammation

Fig. 2.11 (continued)

2. Adhesive Capsulitis.

Adhesive capsulitis is a clinical diagnosis characterized by pain and marked decrease of the range of motion, especially to external rotation. MRI findings are usually not specific but can correlate with the clinical stages. In the acute inflammatory phase, MRI can show axillary capsular thickening and capsular edema and rotator interval synovitis. Progressively hypervascularization and fibrosis occur, which may be reflected on MRI images by thickening of the coracohumeral ligament, subcoracoid fibrosis, and capsular thickening. On MR arthrography classic findings are low volume injection, often less than 8 ml, and thickening of the structures [29, 30] (Fig. 2.13).

3. Nerve Denervation Syndromes.

There are two main nerve denervation syndromes around the shoulder secondary to the suprascapular nerve and to the axillary nerve. Suprascapular neuropathy can be related to compression of an associated paralabral cyst in a superior labrum injury. When there is no compression, there are two main origins: a viral inflammation and or overuse in athletes with overhead activities. On imaging in the acute phase, supraspinatus and infraspinatus muscle edema is seen, whereas in chronic phases fatty atrophy and volume loss of the muscle are shown [31] (Fig. 2.14).

The causes of axillary nerve denervation can be secondary to injury of the axillary nerve in anterior inferior shoulder dislocation especially in patients older than 40 years of age; can be secondary to compression due to a lesion in the quadrilateral space; or can be idiopathic. The role of MRI is to rule out compression causes and

Fig. 2.12 Intrabone migration of hydroxyapatite deposition, (a) AP radiographs demonstrate calcifications in the greater tuberosity surrounded by a radiolucency area (*). Calcifications within the rotator cuff space help for the diagnosis of hydroxyapatite deposition disease. (b) Coronal FSE PD fat sat WI shows the same features of calcifications within the greater tuberosity (*) surrounded by a hyperintense halo (arrow)

associated injuries in shoulder dislocation. MRI will demonstrate secondary to the lesion of the axillary nerve edema of the teres minus or fatty atrophy on chronic stages [31] (Fig. 2.15).

Fig. 2.13 Patient with decreased external rotation, sagittal FSE PD fat sat WI shows thickening of the coracohumeral ligament with soft tissue edema

4. Isolated Greater Tuberosity Fractures.

Isolated fractures of the greater tuberosity can be secondary to shoulder direct or indirect trauma or in older population to minor trauma in osteoporotic patients. When there is little or no displacement (<5 mm), they might be difficult to see on plain films especially if only one projection is seen. They can be seen on US as a discontinuity of cortical bone line and are easy to be diagnosed on MRI [32] (Fig. 2.16).

2.5 Conclusions

Our radiological report in rotator cuff injuries plays a critical role in the decision-making process for the surgeon and the patient outcome. Spend time recognizing the pattern. The report should be simple and standardized. The radiologist must be aware of the treatment implications of the different types of tear and understand the parameters used to evaluate rotator cuff tears on MRI.

Diagnosis of concomitant lesions and knowing the differential diagnosis are very important.

Fig. 2.14 (a) axial GE T2 WI and (b) sagittal FSE T2 WI of a paralabral cyst (*) in the supraglenoid notch causing entrapment of the suprascapularis nerve and secondary edema in the infraspinatus (arrow)

Fig. 2.15 A 48-year-old patient with anterior and inferior dislocation of the shoulder and associated complications like partial tear of the supraspinatus, greater tuberosity fracture, and axillary nerve injury with soft tissue edema of the teres minor. **(a)** Sagittal FSE PD fat sat WI shows anteroinferior glenoid-labral complex lesion (white arrow) soft tissue edema and effusion in the axillary recess [1] and edema in the

teres minor [2]; **(b)** coronal FSE PD fat sat WI demonstrates small partial tear of the supraspinatus (*), non-displaced fracture of the greater tuberosity (white arrows), and soft tissue edema of the axillary recess (black arrow); **(c)** posterior plane on coronal FSE PD fat sat WI demonstrates edema of the teres minor secondary to axillary nerve lesion

Fig. 2.16 A 45-year-old male with a request of US to rule out rotator cuff lesion after indirect trauma; **(a)** US of the shoulder shows discontinuity of the cortical bone of the greater tuberosity (arrow); **(b)** AP radiograph performed later demonstrates the small non-displaced fracture (arrows)

Key Points

- Anterior rotator cuff, subscapularis and posterior rotator cuff, and supraspinatus and infraspinatus are slightly different.
- Superior fibers of the subscapularis and anterior fibers of the supraspinatus weaved together are closely related to biceps tendon and rotator interval tears.
- New patterns of injuries such as delamination tears can be depicted with high-resolution MRI.
- Reports should include pattern, size, retraction, shape, and fatty atrophy.

Take Home Messages

- Reports of rotator cuff tears should follow a structured form including size of the lesion, retraction, shape, and atrophy.
- It is important to remember that despite the rotator cuff muscles origin are separate when they insert, they weave together being these areas the more difficult to depict on MRI.
- Differential diagnosis should include other causes of shoulder pain that might be clinically mimickers.

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