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MRI of Rotator Cuff Tendon Tears – An Introduction

Part 1: Imaging Protocols and Relevant Anatomy

ABSTRACT

Rotator cuff tendon tears are a common reason to refer a patient for shoulder MR imaging.

The role of the radiologist, in addition to diagnosing the presence or otherwise of an actual tear and assessing the surrounding soft tissue and skeletal structures, is to convey diagnostically and prognostically useful information that helps referring clinicians devise optimal management plans for their patients.

Part 1 discusses how MR imaging of the shoulder is performed, in addition to relevant MR rotator cuff tendon anatomy, whereas part 2 (to be published in the next issue) will describe rotator cuff tendon tears in detail.

KEYWORDS

Shoulder, Magnetic resonance imaging (MRI), Radiology, Rotator cuff, Tendon

INTRODUCTION[1]

Shoulder pain and discomfort is a musculoskeletal complaint that doctors and other allied health professionals encounter on a regular basis, only lagging behind lower back and neck pain.

Rotator cuff tears (RCTs) are amongst the commonest causes of shoulder pain in patients over 40 years of age.

A significant proportion (20-50%) of individuals aged 50 years or older have a known RCT, getting more frequent with increasing age, with at least 50% of individuals older than 70 years having an underlying, asymptomatic RCT.[2]

An intact rotator cuff is an important dynamic stabilizer of the glenohumeral joint, compressing the humeral head against the glenoid cavity, thereby increasing joint stability, as well as providing a stable fulcrum for the deltoid to elevate the arm.

Magnetic resonance imaging (MRI) is very useful in diagnosing shoulder pathology, furthermore, it has played an increasingly important role as a noninvasive test for determining which patients may benefit from surgery.[3-6]

Whilst MRI and ultrasound (US) have demonstrated similar sensitivity and specificity for evaluation of the native rotator cuff musculotendinous complex, MRI offers the advantage of allowing optimal structural evaluation of the bone marrow, tendons, muscles, ligaments, capsules, bursae, and labrum, and in any plane desirable.

Most indications for shoulder MRI, including rotator cuff integrity, do not require the administration of intravenous or intra-articular contrast medium.

MRI TECHNIQUE AND PROTOCOLS[7,8]

The patient is placed in the supine position, with their affected arm by the side, with the shoulder slightly externally rotated. Internal rotation should be avoided as much as possible, in order to optimally evaluate the supraspinatus and subscapularis tendons, as well as the middle glenohumeral ligament.

Excessive external rotation is also undesirable given that this may give rise to false positive diagnoses of small supraspinatus insertional tendon tears anteriorly.

Multiplanar imaging is then acquired in the axial, coronal oblique and sagittal oblique planes.

Coronal oblique imaging is planned parallel to the scapular body or to the supraspinatus tendon, and is to include the entire humeral head.

Sagittal oblique sequences should extend from the lateral aspect of the deltoid muscle, all the way medially to the scapular body.

Axial sequences should extend from above the acromioclavicular joint to below the level of the axillary pouch.

Angled oblique sagittal sequences have also been described in the radiology literature to provide additional diagnostic value, especially in relation to small supraspinatus insertional tendon tears.[9]

Slice thickness should not be more than 3 mm. The sequences utilized usually include a combination of intermediate-weighted (fat-suppressed, fluid-sensitive), T1-weighted and T2-weighted sequences.

IMPORTANT ANATOMY[7,10]

The rotator cuff is a composite of a capsule, ligaments and tendons, histologically consisting of five different layers that fuse together (Fig. 1, a-d), the latter feature contributing to the lamellated appearance appreciated on MR imaging.

The most important of these layers are II and III; layer II is formed by tightly packed tendon fibers arranged in large bundles, whereas layer III consists of thinner, smaller, more disorganized collagen bundles. Layer II fibers are elastic, more resistant to rupture and are well vascularized, whereas layer III fibers are more prone to injury, being inelastic and poorly vascularized.

The histological differences between layers 2 and 3 can potentially explain the origin of partial and delaminating tear patterns.

The histology of the rotator cuff contributes to one of the difficulties of rotator cuff MRI interpretation - the magic-angle effect, or angular anisotropy.[11,12]

This MRI artifact occurs when normally low-signal structures that are made of organized collagen fibers appear with higher signal intensity on images obtained with a short echo time (TE). This occurs when the long axes of collagen fibers are oriented at 55° to the main magnetic field, and this tends to affect the rotator cuff tendons at the commonest sites of tears and tendinopathy. It is for this reason that radiologists opt to assess the rotator cuff tendons on long TE sequences (intermediate/T2-weighted).

The *rotator cable*[13,14] (fig. 2) is a deeper, capsular reinforcement noted along the inferior aspect of the supraspinatus and infraspinatus tendons, coursing perpendicular to the long axis of the corresponding tendons. Histologically, it forms the fourth layer of the rotator cuff complex. The area lateral to it is known as the *rotator crescent*, and is the area at greatest risk of injury.

The rotator cable functionally behaves as a suspension bridge, offloading the rotator crescent fibers, also limiting retraction of any torn supraspinatus or infraspinatus fibers.

It is best appreciated on high-resolution MRI, with some researchers concluding that this yields a better visualization in MR arthrography.

The tendons of subscapularis, supraspinatus, infraspinatus and teres minor are the main components of the rotator cuff complex, along with reinforcing superficial and deep-seated capsular ligaments.[15-17]

The *supraspinatus* (fig. 3) is supplied by the suprascapular nerve, inserting predominantly onto the greater tuberosity, with a small proportion of fibers inserting into the lesser tuberosity.

Figure 1. Normal supraspinatus and infraspinatus ultrastructure.[10]
a - Drawing shows the different layers of the rotator cuff.
b - Rotator cuff histology.
c,d (medial to lateral) - Oblique-sagittal T1-weighted MR arthrography images.

- Layer 1 - superficial fibers of the coracohumeral ligament;
- Layer 2 - dense parallel collagen fibers from supraspinatus and infraspinatus tendons;
- Layer 3 - smaller collagen fibers of less uniform orientation;
- Layer 4 - rotator cable;
- Layer 5 - superior capsule.

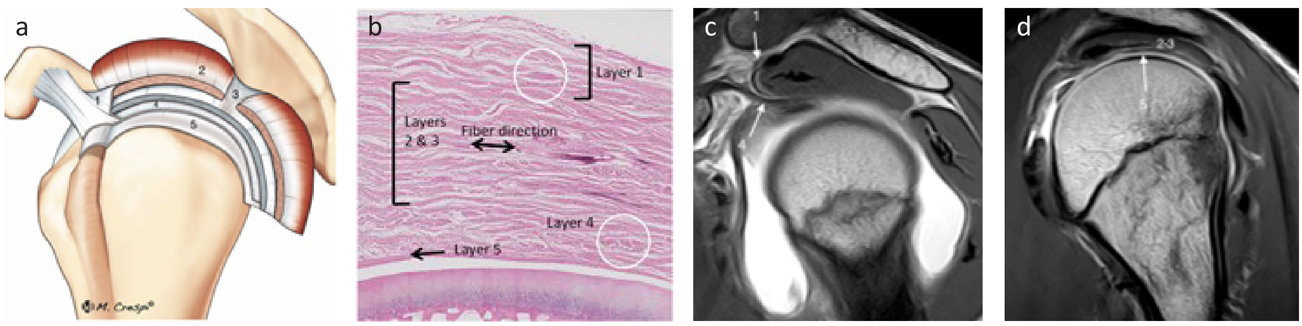


Figure 2. Rotator cable (arrows) demonstrated in the axial (a), coronal (b) and sagittal (c) planes.

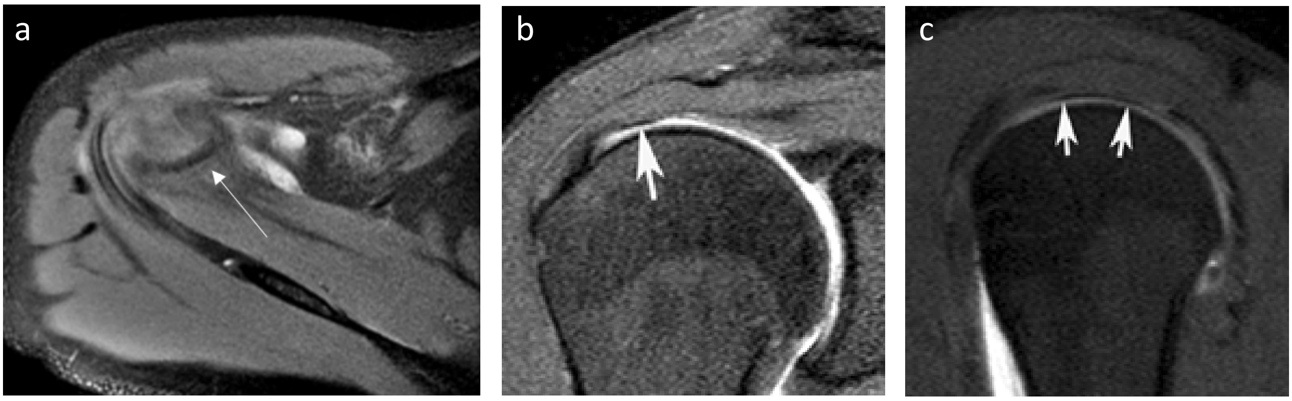
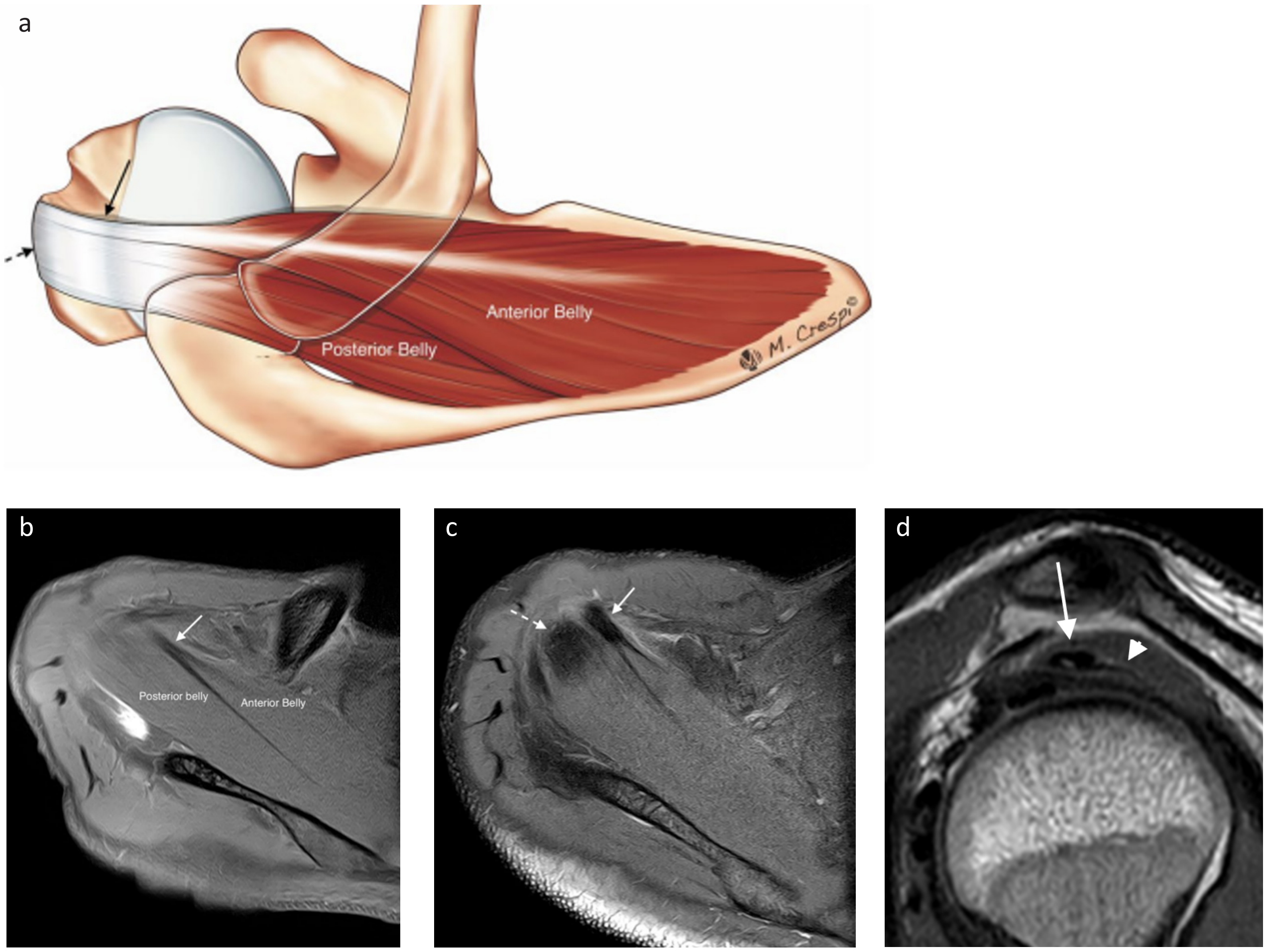


Figure 3. The supraspinatus components.[10,11]
a - Drawing showing the bellies and tendons of supraspinatus.
b,c - Axial fat-suppressed proton density-weighted MRI showing the anterior belly with its long tendon and insertion (arrows) and the posterior belly with a broader tendon (dashed arrows).
d - Sagittal oblique proton density-weighted MRI showing the narrow anterior tendon (white arrow) and thinner but broader posterior tendon (arrowhead).



A SIGNIFICANT PROPORTION (20-50%) OF INDIVIDUALS AGED 50 YEARS OR OLDER HAVE A KNOWN RCT, GETTING MORE FREQUENT WITH INCREASING AGE, WITH AT LEAST 50% OF INDIVIDUALS OLDER THAN 70 YEARS HAVING AN UNDERLYING, ASYMPTOMATIC RCT

Figure 4. Coronal oblique (a) and axial (b) Fat-suppressed proton density fast spin-echo weighted MR images showing the broad insertion of the infraspinatus tendon (arrows) onto the superior and middle facets of the greater tuberosity.

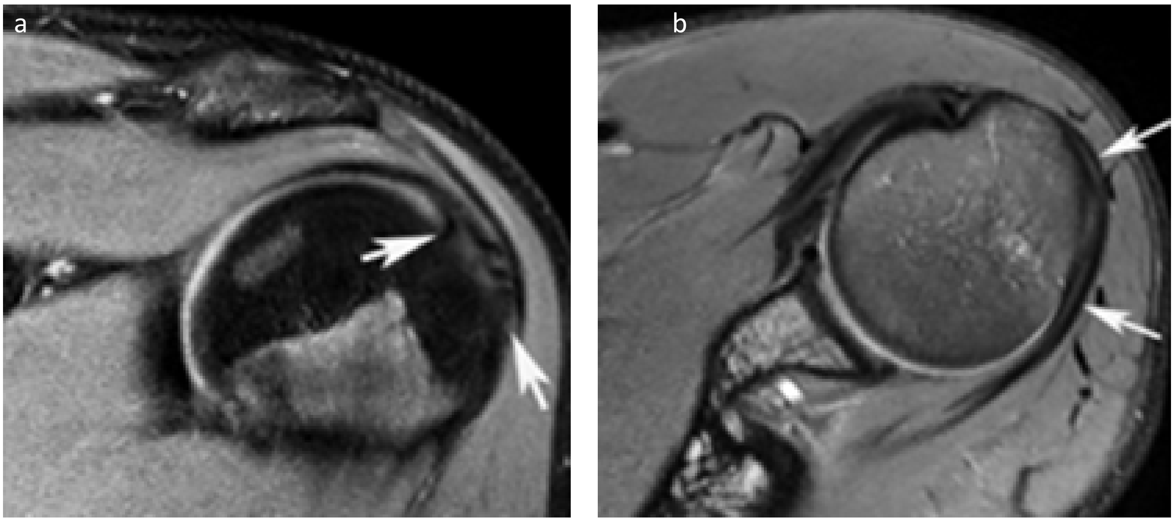


Figure 5. Subscapularis anatomy.
a - Four distinct facets of the subscapularis insertion, displayed on an anatomical specimen;[17]
b - Multipennate nature of subscapularis (arrow) as shown on a sagittal oblique T1 weighted image;[11]
c - Axial fat-suppressed, proton density, fast spin weighted image showing the subscapularis (SSC) attaching onto the lesser tuberosity (arrow), with contributory fibres overlying the proximal humeral intertubercular groove and to the greater tuberosity.[11]

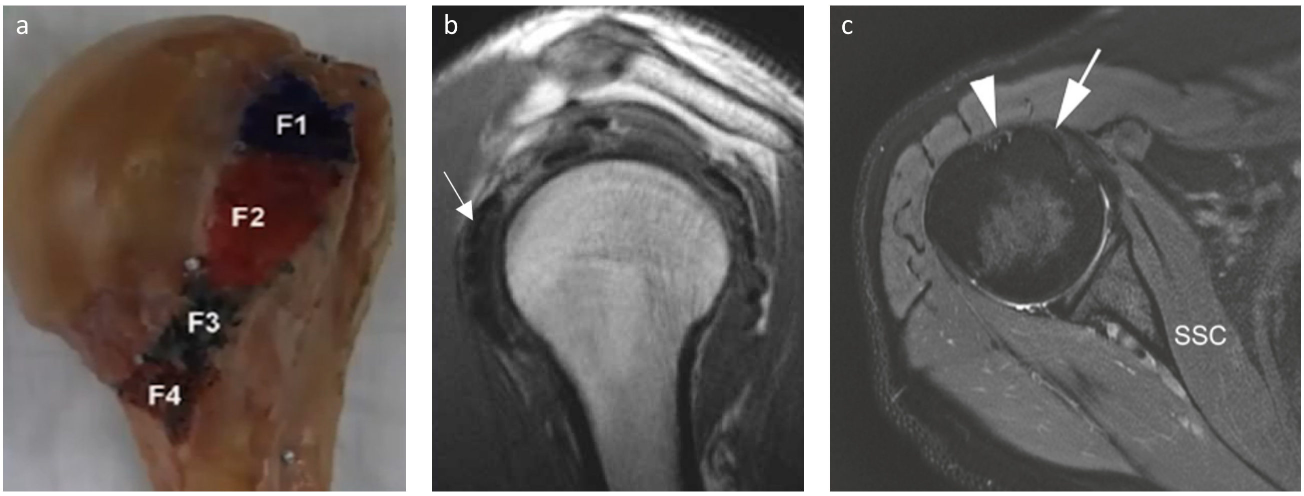
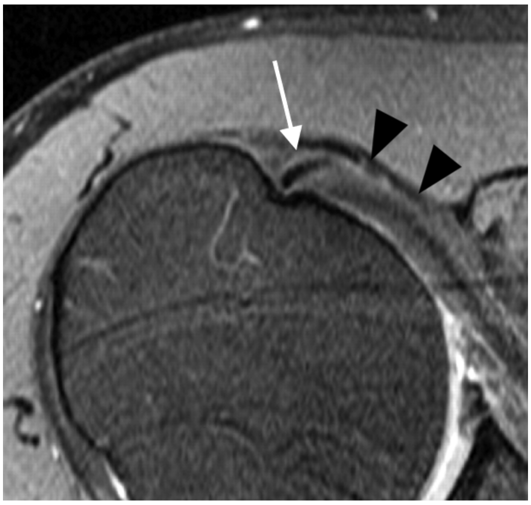


Figure 6. LHBT anatomy.
Axial proton density, fast spin image showing the uniformly hypointense proximal extra-articular LHBT (white arrow) as it lies within the upper proximal intertubercular groove. Note the close association with the subscapularis tendon (black arrowheads).



It consists of two muscle bellies (anterior and posterior), with the larger anterior belly continuing laterally into a thinner central tendon, and the strap-like posterior belly showing an associated broader terminal tendon.

This anatomical arrangement may well explain the predominance of anterior tendon failure, in view of the greater contractile forces being generated by the anterior belly.

The *infraspinatus* (fig. 4) is the primary external rotator, also innervated by the suprascapular nerve. It mainly inserts onto the middle facet of the greater tuberosity, with a smaller portion attaching onto the superior facet.

It consists of two muscle bellies (transverse and oblique), and demonstrates a larger footprint with respect to supraspinatus.

The *subscapularis* (fig. 5) is the largest and strongest rotator cuff component, consisting of multiple (between four and nine) muscle-tendon units that converge laterally. It is innervated by the upper and lower subscapular nerves, and demonstrates a very long, four-faceted insertion onto the humerus, extending downwards from the lesser tuberosity.

Its upper humeral insertion is tendinous in nature, with its lower third being muscular.

The upper fibres of the subscapularis interdigitate with the anterior fibers of the supraspinatus tendon and the rotator interval. This may explain why the subscapularis tendon tears are frequently associated with massive RCTs or rotator interval injuries.

The *teres minor* is the smallest and least injured of the rotator cuff components, classically involved in cases of posterior glenohumeral dislocation. It is innervated by a branch of the axillary nerve, and inserts onto the lowermost facet of the greater tuberosity.

The *long head of biceps* tendon (LHBT - Fig.6) is technically not part of the rotator cuff complex - nevertheless, given its close association by virtue of its origin and course, it is not uncommonly affected whenever there is an underlying RCT.[18]

Characteristic LHBT abnormalities associated with RCTs include intra-articular disruption as well as medialisation, which may be intra- or extra-articular.

CONCLUSION

MRI nowadays is a crucial tool in the assessment of RCT tears, helping surgeons and patients make important decisions regarding management. It is therefore imperative that the clinician reviewing the study is familiar with study planning and potential pitfalls, as well as with the underlying multiplanar anatomy.

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