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Review Article

Comparative imaging modalities for diagnosing rotator cuff injuries

Abdullah Fuad Aborukbah[1]*, Mohammed Muwaffaq Ashoor[2], Hisham Abdalla Elbashir[3], Saif Tawfig Namri[4], Ebtisam Ali Hamdi[5], Ziad Mohamed Khayat[6], Rami Moraya Sharahili[7], Nawwarah Abdulrahman Alharbi[8], Ahmed Sulaiman Fallatah[9], Hisham Mohammed Balqurun[10]

[1]Department of Orthopedics, Al Thager Hospital, Jeddah, Saudi Arabia
[2]Department of Pediatrics, Al Aziziya Children Hospital, Jeddah, Saudi Arabia
[3]Department of Orthopaedic, Nottingham University Hospital, Nottingham, UK
[4] College of Medicine, King Khalid University, Abha, Saudi Arabia
[5]Department of Radiology, Mohammed Abdo Hassan Hakami Health Services Company, Jazan, Saudi Arabia
[6]College of Medicine, Cairo University, Cairo, Egypt
[7]Department of Radiology, Muhayil General Hospital-Ministry of Health, Muhayil, Saudi Arabia
[8]Almatar Alqadim Primary Healthcare Center, Qassim Health Cluster, Arass, Saudi Arabia
[9]Hera General Hospital, Mecca, Saudi Arabia
[10]Department of Emergency Medicine, King Salman Medical City, Medina, Saudi Arabia

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***Correspondence:**
Dr. Abdullah Fuad Aborukbah,
E-mail: AABO-RUKBAH@moh.gov.sa

ABSTRACT

Rotator cuff injuries are a significant cause of shoulder pain and dysfunction, with their prevalence increasing with age. Diagnosing these injuries accurately is crucial for determining appropriate treatment strategies. Various imaging modalities, such as high-resolution ultrasonography (HRUS), magnetic resonance imaging (MRI), and magnetic resonance arthrography (MRA), play a pivotal role in identifying rotator cuff injuries. MRI, considered the gold standard, offers detailed insights into tendon degeneration, partial tears, and full-thickness tears. Meanwhile, HRUS is favored for its cost-effectiveness, non-invasive nature, and real-time dynamic assessments. This review compares these imaging techniques, highlighting their diagnostic accuracy, strengths, and limitations in the context of rotator cuff injuries. Although MRI provides comprehensive information on tendon pathology and associated conditions like muscle atrophy, HRUS remains a valuable tool due to its accessibility and accuracy in diagnosing both partial and full-thickness tears. Understanding the comparative efficacy of these imaging modalities is essential for clinicians to make informed decisions about patient management.

Keywords: Rotator cuff injuries, HRUS, MRI, Tendon tears, Imaging techniques

INTRODUCTION

Shoulder pain is a common complaint with various underlying causes, such as rotator cuff tears, adhesive capsulitis, bursitis, arthritis, tendinitis, and fractures. Symptoms may arise gradually or suddenly after activities like heavy lifting or trauma.[1] Rotator cuff tears are considered a leading cause of shoulder pain, with a prevalence of 22.1% in the general population, and this rate increases with age.[2,3] They are among the most common conditions affecting the shoulder. Rotator cuff tears can be classified as either acute due to injury or chronic due to cumulative degeneration. In acute cases, significant stress is required to tear a healthy tendon, whereas in tendons with preexisting degeneration, a much smaller amount of stress can lead to a tear.[4] Diagnosis of rotator cuff tears is based on physical assessment and history, including details of prior activities and whether symptoms are acute or chronic, along with a thorough shoulder examination.[5]

In 2013, Richard et al found that the surgeries for rotator cuff injuries accounted for over $3 billion in direct surgical costs, excluding other expenses such as diagnostic tests, office visits, and non-surgical treatments like physical therapy, medications, and injections.[6] Fatty infiltration or myosteatosis in rotator cuff muscles worsens with age, affecting tendon healing and clinical outcomes.[7] Myosteatosis is a key prognostic factor in managing rotator cuff tears, with irreparability ranging from 6.5% to 30%, primarily due to tear size and muscle infiltration. However, clinical assessments still rely on outdated qualitative methods.[8]

Proper diagnosis of these injuries is essential to ensure appropriate treatment.[9] Rotator cuff strains, impingement syndromes, and tears are the three primary conditions responsible for shoulder pain and dysfunction. Diagnostic modalities like HRUS and MRI are necessary to differentiate rotator cuff injuries from other conditions such as glenohumeral joint instability. HRUS and MRI are both effective tools for diagnosing these injuries.[10]

MRI is regarded as the gold standard for diagnosing internal shoulder derangements due to its ability to detect other conditions like tendinosis, calcific tendinitis, muscle atrophy, and issues with the long head of the biceps brachii tendon, all of which are important for determining rotator cuff treatment and prognosis. MRA is another technique used to diagnose and manage joint instabilities.[11] Although arthrography is more effective in detecting rotator cuff tears, its invasive nature causes discomfort, which is a key drawback.

In terms of cost, non-ionizing properties, and the ability to provide rapid, real-time diagnosis of rotator cuff tears, HRUS is often preferred over MRI. HRUS has been reported to have nearly 90% accuracy, sensitivity, and specificity in detecting rotator cuff tears, including partial and full-thickness tears, as well as periarticular conditions. HRUS can also identify other conditions often mistaken for rotator cuff tears, such as tendinitis, tendinosis, calcific tendinitis, and subacromial-subdeltoid bursitis.[10] HRUS is considered a low-cost alternative to MRI for detecting rotator cuff tears, with the added advantage of dynamic, real-time assessment.[12]

LITERATURE SEARCH

This study is based on a comprehensive literature search conducted on 8 October, 2024, in the Medline and Cochrane databases, utilizing the medical subjects heading (MeSH) and a combination of all available related terms, according to the database. To prevent missing any possible research, a manual search for publications was conducted through Google Scholar, using the reference lists of the previously listed papers as a starting point. We looked for valuable information in papers that discussed imaging modalities for diagnosing rotator cuff injuries. There were no restrictions on date, language, participant age, or type of publication.

DISCUSSION

Impingement syndrome is a clinical diagnosis caused by repetitive compression of the supraspinatus tendon beneath the coracoacromial arch. In 1991, Fu and colleagues proposed a unifying theory, building on the work of others, that connects rotator cuff disease to impingement and glenohumeral instability.[13] Impingement syndrome frequently leads to shoulder dysfunction, occurring when the space for the bursa and tendon becomes reduced, resulting in recurrent injury to the rotator cuff tendon, which may provoke subdeltoid bursitis.[14] Rotator cuff disease and impingement syndrome result from a complex interplay of intrinsic and extrinsic factors that lead to tendon degeneration and mechanical compression within the shoulder joint. Intrinsic factors, including relative ischemia, critical zones, and trauma, contribute to degenerative changes within the rotator cuff, resulting in tendon tears and vascular differences that predispose the rotator cuff to further injury. Conversely, extrinsic factors, such as mechanical compression from the coracoacromial arch and variations in acromion morphology, play a significant role in exacerbating these conditions. Primary and secondary impingement, OS acromiale, and posterosuperior impingement further illustrate the diverse mechanisms underlying rotator cuff disease.[15]

Pathogenesis of rotator cuff injuries

The pathogenesis of rotator cuff tears can be attributed to both impingement and tendon degeneration. Tears typically begin at the point of maximum load, such as the articular side of the supraspinatus tendon insertion. When the load exceeds the tendon's strength, fibers fail and retract under tension, leading to rupture.[16] Chronic rotator cuff disease is often accompanied by tenosynovitis of the biceps tendon. In cases of chronic supraspinatus tears, the long head of the biceps brachii tendon may become impinged between the humeral head and the acromion, resulting in tendinopathy or tearing of the intracapsular portion of the tendon.[17]

Shoulder radiography serves as the primary imaging modality for the initial assessment of both traumatic and atraumatic shoulder pain, as recommended by the American college of radiology appropriateness criteria.[18] While direct visualization of the rotator cuff is not possible through radiographs, these images effectively highlight bony abnormalities associated with rotator cuff impingement and other potential pain sources, such as glenohumeral and acromioclavicular osteoarthritis. The anteroposterior view aids in evaluating acromion morphology and joint space narrowing, while the outlet view provides critical insights into the coracoacromial arch and acromial characteristics. Additionally, the axillary view enhances the understanding of glenohumeral alignment and related anatomical structures. Together, these radiographic evaluations establish a foundation for further diagnostic exploration and management of shoulder conditions.[18]

Imaging appearances of rotator cuff disorders

HRUS

The effectiveness of HRUS assessment for the rotator cuff relies on a qualified sonographer trained in musculoskeletal ultrasound and a knowledgeable radiologist. Mastering the skills needed for performing and interpreting musculoskeletal ultrasounds involves a significant learning curve. Research indicates that to achieve proficiency in shoulder HRUS examinations, it is necessary to complete around 300 scans under the supervision of an experienced musculoskeletal sonographer.[18]

Tendinosis is characterized by degenerative or tendinopathic changes, appearing as hypoechoic thickening of the tendon, with severe tendinitis showing diffuse thickening and reduced echogenicity, but no disruption of tendon fibers.[15] Partial-thickness rotator cuff tears can involve the articular or bursal surfaces, or be intrasubstance, presenting as localized hypoechogenicity or focal hyperechogenicity within the tendon. To avoid anisotropic artifact misinterpretation, careful transducer adjustment is required, as artifacts disappear with transducer movement, while tears remain visible. Partial-thickness tears are less commonly detected than full-thickness tears and typically do not greatly affect treatment.[15]

Full-thickness rotator cuff tears are identified by disrupted tendon fibers extending from the articular to the bursal surface, loss of the normal convexity of the superior tendon surface, and possibly flattening or concavity (Figure 1).[19] The tear may be filled with joint fluid or mildly echogenic granulation tissue, masking the tear, but gentle transducer pressure can help delineate it. Tear dimensions are measured, and large tears may result in the complete absence of the tendon.[15] Additional findings supporting the diagnosis of rotator cuff tears include fluid in the subacromial-subdeltoid bursa, joint space, or around the long head of the biceps tendon in the bicipital groove, significantly raising the likelihood of full-thickness tears. Fluid in both the bursa and the joint has a 95% predictive value for a tear. Fluid surrounding the biceps tendon sheath, seen as a hypoechoic halo in a transverse view, may indicate biceps tendon pathology, although small amounts of fluid around the sheath are normal.[20]

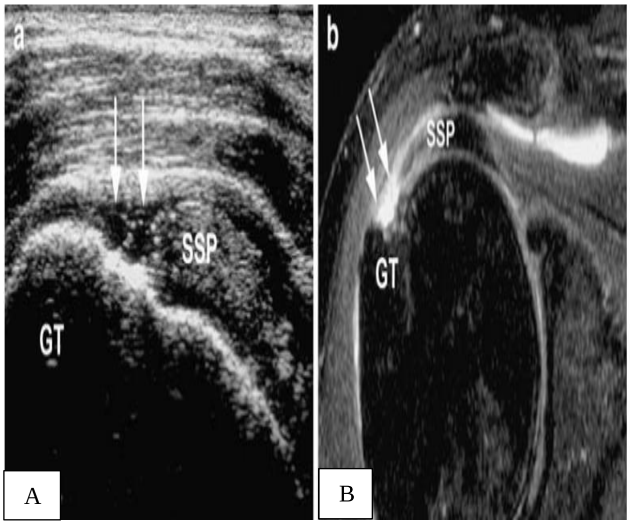

Figure 1 (A and B): Full-thickness rotator cuff tear. Ultrasound appearance of a full-thickness tear (arrows) at the insertion of the supraspinatus tendon (SSP).

GT=greater tuberosity. The corresponding oblique coronal gradient T1-weighted MR arthrography image, showing the same configuration of the full-thickness tear (arrows) of the supraspinatus tendon (SSP). GT=greater tuberosity.[19]

MRI

MRI illustrates the spectrum from rotator cuff degeneration or tendinopathy to partial or full-thickness rotator cuff tears. Partial or complete rotator cuff tears manifest as increased signal intensity on proton density and T2-weighted images, with higher intensity seen on T2-weighted images.[15]

Tendinosis is marked by tendinopathic changes appearing as high signal intensity on short echo time (TE) sequences, such as proton density-weighted images, which persist in long TE sequences, like T2-weighted images, without intensifying on the latter. Increased signal intensity on short TE sequences may also occur in normal tendon morphology due to the 'magic angle phenomenon,' an artifact that arises when tendon fibers are at a 55-degree angle to the magnetic field. This artifact does not appear in T2-weighted sequences, helping differentiate it from tendinopathy.[21]

Partial-thickness tears are characterized by localized fiber discontinuity filled with fluid, shown as focal areas of increased signal intensity on short TE images, with a relative increase in signal intensity on long TE images, though less intense than joint fluid. Fat-suppressed sequences better highlight fluid-filled defects. The abnormal signal is confined to one of three regions of distal tendon fibers: the articular surface, bursal surface, or intrasubstance, with articular surface tears being the most common.[22] Additional findings include increased fluid in the glenohumeral joint or subacromial-subdeltoid bursa, tendon surface fraying, or thickening. MRI findings of tendinopathy and minor partial tears may overlap, as both often coexist, necessitating attention to the morphology of bursal and articular surfaces and the distribution of abnormal signal intensity on proton-density or T2-weighted sequences. Partial cuff fiber retraction is indicative of a partial-thickness tear. Intrasubstance tears show intratendinous high signal intensity on T2-weighted images without extension to the bursal or articular surfaces, while bursal surface tears cause discontinuity along the tendon's superior surface. T2-weighted images are also useful for assessing periarticular fluid collections and cysts not visible on T1-weighted imaging.[15]

Snyder's classification system for partial-thickness rotator cuff tears provides a framework for assessing the severity of tendon damage. The classification ranges from normal tendon integrity to severe tears involving multiple tendons. Table 1 outlines the different stages of tendon fraying and fiber failure, offering valuable insights into the extent of injury and guiding treatment decision.[23]

Table 1: Classification of the severed-thickness rotator cuff tears by Snyder.[23]

Classification	Description
0	Normal.
I	Minimal bursal or synovial irritation or minimal capsular fraying in a localized area (<1 cm).
II	Fraying and failure of rotator cuff fibers with synovial bursal or capsular injury (<2 cm).
III	Fraying and fragmentation of tendon fibers involving the entire surface of a cuff tendon, typically the supraspinatus (<3 cm).
IV	Severe tear with tendon fraying, fragmentation, and a sizable flap tear affecting more than one tendon.

Another grading system for partial tears is based on tendon fiber involvement depth in (Table 2).

Table 2: Grading system for partial rotator cuff tears.[15]

Grade	Description
1	Involves less than 3 mm of tendon thickness.
2	Involves 3 to 6 mm and less than 50% of the cuff thickness.
3	Involves more than 6 mm and over 50% of the rotator cuff thickness.

Surgical decisions for rotator cuff repair are based on the tear's severity, tendon quality, and the patient's activity level.

Full-thickness tears, extending from the articular to the bursal surface, are identified by increased signal intensity on T2-weighted images, spanning from the superior to inferior tendon on at least one image (Figure 2).[4] On T1-weighted images, these tears display moderate hyperintensity within the tendon, with hyperintense fluid visible at the tear site on T2-weighted images. They are categorized by tear size in the anteroposterior dimension: small (less than 1 cm), medium (1-3 cm), large (3-5 cm), and massive (greater than 5 cm), with massive tears often involving both the supraspinatus and infraspinatus tendons, accompanied by tendon retraction. Supraspinatus tears over 2.5 cm frequently extend into the infraspinatus or subscapularis, and a tear does not need to span the full anteroposterior dimension to be considered full-thickness.[15] Additional indicators of full-thickness tears include muscle retraction, with the musculotendinous junction pulled back onto the humeral head, fluid in the subacromial-subdeltoid bursa, and the disappearance of the peribursal fat plane.[24] Full-thickness rotator cuff tears crecation between the subacromial bursa and the glenohumeral joint cavity, which can lead to hemorrhage or fluid accumulation in the bursa.[25] While subacromial-subdeltoid bursal fluid is not full-thickness tears, it is considered a sensitive sign and is commonly associated with such tears, though it can also occur in cases of bursitis. The most specific sign of a full-thickness rotator cuff tear is tendon discontinuity.[26] Additional findings include superior translation of the h and remodelling of the acromion's undersurface, resulting in acromiohumeral articulation. Muscle atrophy from chronic tears is best visualized on sagittal oblique T1-weighted images.

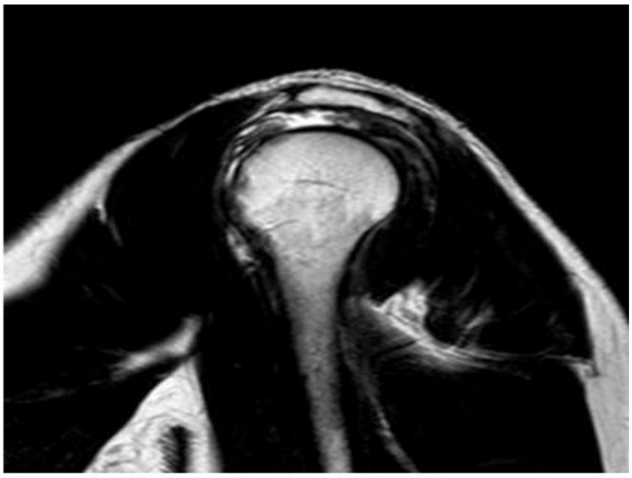

Figure 2: MRI, T2WI, sagittal view showing full thickness tear of supraspinatus.[4]

Bicipital tendon and its synovial sheath are well-assessed by MRI. Increased fluid in the biceps tendon synovial sheath suggests tenosynovitis but may also be noted in cases of nonspecific joint effusion. Minimal fluid is sometimes normal. This is considered nonspecific and often unreliable. A hyperintense focus on T2-weighted images within the biceps tendon itself is an accurate indicator of bicipital tendinitis. Progressive bicipital tendinitis often precedes complete rupture of the biceps tendon.[27] Extension of anterior rotator cuff tears into the rotator interval ularis can cause biceps tendon dislocation out of the bicipital groove.[28]

In traumatic cases, subscapularis tears typically involve the superior fibers, while non-traumatic cases usually affect the inferior fibers, with isolated inferior tears being rare.

The rotator interval, located between the anterior fibers of the supraspinatus and the superior fibers of the subscapularis, resists posteroinferior translation of the humeral head. Tears often spread from the supraspinatus to the infraspinatus or subscapularis, involving the rotator interval capsule. Isolated rotator interval tears are rare and often occur due to anterior dislocation, making them difficult to identify on routine MRI without intra-articular contrast medium.[15]

Computed tomography

Computed tomography (CT) is an excellent imaging modality for assessing bone detail and detecting gas and calcium deposits; however, conventional CT is less effective at identifying bone marrow edema and soft tissue details in the shoulder (Figure 3).[18] When CT arthrography is performed with the intra-articular injection of 12 mL of diluted iodinated contrast, the evaluation of articular-sided partial and full-thickness tears is improved, making it a useful alternative to MRI and ultrasound.[29,30] The diagnostic accuracy of CT arthrography for detecting articular-sided partial and full-thickness tears is comparable to that of 1.5 T MR arthrography when compared to arthroscopy, the gold standard.[31] While CT arthrography cannot detect intrasubstance or bursal-sided partial-thickness tears, it can effectively assess intra-articular structures, such as the labrum and chondral surfaces.

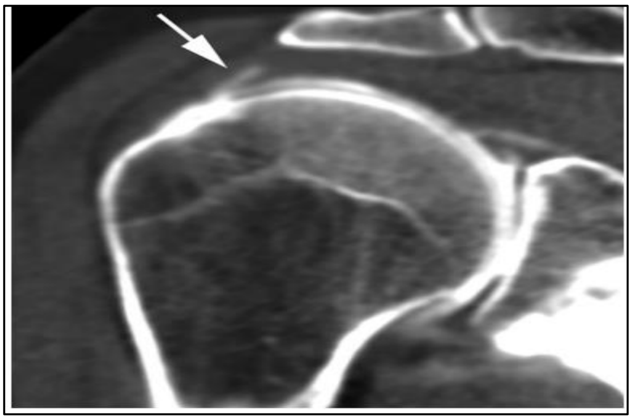

Figure 3: CT arthrography. Coronal reconstruction from CT arthrogram reveals a small partial thickness undersurface tear (arrow).[18]

CONCLUSION

Both HRUS and MRI are the most effective imaging modalities for diagnosing rotator cuff injuries. While MRI remains the gold standard due to its comprehensive detail, HRUS offers advantages in accessibility and cost-effectiveness, making it a valuable option for clinicians in evaluating shoulder conditions.

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