Shoulder ultrasound: What you need to know

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Abstract
Shoulder ultrasound is consistently used in the assessment of rotator cuff and is as accurate as magnetic resonance imaging in the detection of rotator cuff tear. It can be used as a focused examination providing rapid, real-time diagnosis, and treatment in desired clinical situations. This article presents a simplified approach to scanning and image-guided intervention, and discusses common sonographically apparent shoulder pathologies.

Key words: Shoulder; ultrasound; technique; pathology

Introduction
Shoulder ultrasound has been in use for quite some time is considered operator-dependent, and has a proven accuracy in rotator cuff assessment. Scanning the shoulder can be challenging and time-consuming in the beginning. The use of a protocol-driven examination, understanding of pertinent anatomy, tendon orientation, and familiarity with imaging pitfalls, can improve individual performance. This essay presents a simplified approach to scanning the shoulder, and also illustrates the pathological findings.

Technique
There are various techniques for scanning the shoulder, some operators prefer to face the patient, and others prefer to stand behind, scanning over the patient’s shoulder. The author prefers to scan standing behind the patient and recommends following a protocol that the user is comfortable with. The probe should be held at its end with the edge of the hand resting on the patient’s shoulder, in order to reduce stress and allow fine motor control. Obtaining a brief history at the beginning of the examination can provide clues to the underlying pathology. Good-quality ultrasound equipment and a high-frequency (12-15 MHz) linear-array (with a flat surface) probe is required. The more the transducer frequency, which improves the resolution, the less is the depth penetration. Probe frequency selection depends on the patients build. Lower for obese patient and higher for thin patient. Tissue harmonic imaging can increase the conspicuity of tears, although, no difference in the diagnostic accuracy has been found. How much you adjust the machine controls and settings as you scan is very much a matter of taste. Some familiarity and understanding of the controls is an essential especially, if you are not the only one who uses the scanner. The author recommends following a systematic approach for scanning the shoulder [Table 1].

Shoulder Evaluation-Technique and Abnormalities

Biceps tendon
The tendon can be readily identified in the intertubercular groove on the anterolateral aspect of the humerus with the arm in a neutral position and is examined in both transverse and longitudinal planes [Figure 1A and B]. It is important not to confuse anisotropy due to probe angulation [Figure 1C-F] with tendinopathy [Figure 1G]. Small amounts of fluid can normally be seen surrounding the tendon. This can easily be differentiated from tenosynovitis...
where there are internal echoes within the fluid with areas of increased Doppler flow.

Biceps tendon can rupture in either an acute or chronic setting. Acute rupture results in non-visualization of the tendon within the bicipital groove [Figure 2A] and biceps muscle contraction with bulbous appearance/popeye sign [Figure 2B]. In chronic rupture there is partial non-visualization of the upper portion of the tendon. An empty bicipital groove becomes filled with echogenic scar tissue that simulates a normal Long head of biceps tendon [Figure 3], although the characteristic fibrillar pattern of the tendon is not seen. The patient then externally rotates the arm [Figure 4A] and the long head of the biceps is again examined for subluxation from its position in the groove.

Subscapularis tendon

While the arm is passively externally rotated the subscapularis can be examined in orthogonal planes from its insertion into
the lesser tuberosity to the point at which it becomes hidden to ultrasound by the coracoid process medially. Diagnosing subscapularis injury is clinically difficult and assessment of subscapularis integrity may be limited during arthroscopy or open surgery. It is important to assess the superior portion of the tendon, close to the biceps tendon, on the transverse view [Figure 5] for any tears.

Supraspinatus tendon (SST)
In order to visualize the SST the patients are asked to place their hand on their back pocket [Figure 6A and B]. In the longitudinal plane [Figure 6C] the tendon has a beak-shaped configuration. It is important to be able to see the anterior border of the supraspinatus, a common site for tear, in the short axis/transverse plane and this may sometimes require scanning with the elbow drawn backward [Figure 6D]. This makes the arm a less internally rotated (than with the hand on the back pocket) and brings the rotator interval [Figure 6E] out. At the insertion of the supraspinatus into the humerus the tendon fibrils turn to insert perpendicular to the bone cortex. This means that an area of low reflectivity due to anisotropy may be seen within the tendon at its insertion [Figure 7] and the probe will need to be angled to avoid confusing this for a tear. Various patterns of supraspinatus tears occur [Table 2].

Full-thickness tear
A full-thickness rotator cuff tear is a defect in the tendon that reaches from the bursal to the articular margin. Typically, these tears occur at the footprint of the greater tuberosity where the tendon fibers insert, and then propagate proximally. Full-thickness rotator cuff tears are quantified as small (<1 cm), medium (1-3 cm), large (3-5 cm) and massive (>5 cm) according to DeOrio and Cofield classification, measured in its longest dimension. The normal tendon echogenicity is replaced by a hypoechoic or anechoic defect and the length or degree of retraction of a full-thickness tear (measured on longitudinal views oriented parallel to the long axis of the cuff) and width (measured on transverse views oriented perpendicular to the long axis of the cuff) is assessed, since this information is needed by orthopedic surgeon for deciding management and to prognosticale outcome of therapy. Secondary or indirect signs are reliable criteria for the detection of rotator cuff tears. Various patterns of supraspinatus tears occur [Table 2].
When fluid is present in the subacromial/subdeltoid bursa and in the glenohumeral joint, the probability of a rotator cuff tear is 95%. Other indirect signs of partial or full-thickness rotator cuff tears are the sagging of bursa [Figure 8A] and a bright aspect of the humeral cartilage (cartilage interface sign or uncovered cartilage sign), which is caused by enhancement of the ultrasound signal due to fluid and loss of cuff tissue above the cartilage [Figure 8B].

Table 2: Various patterns of supraspinatus tear

| Full-thickness tear                  | Partial-thickness tear         |
|-------------------------------------|-------------------------------|
| Anterior free edge                  | Articular surface             |
| Mid-substance                       | Bursal surface                |
| Complete                            | De-laminating                 |
| Massive                             | Rim-rent                      |
| Laminar intrasubstance              | Uncovered cartilage sign      |

Figure 6 (A-E): Supraspinatus tendon (SST). Transducer placement for supraspinatus tendon in long-axis (A) and short-axis (B) with the hand on the back pocket. Longitudinal view of the SST (C) with overlying thin hypoechoic line (black arrow) representing subacromial subdeltoid bursa and the overlying subdeltoid fat (white arrows). Elbow backward position (F) to see the anterior border of supraspinatus tendon in transverse plane (E) with the echogenic component of biceps tendon sling, coracohumeral ligament (arrow). GT: Greater tuberosity, HH: humeral head, D: Deltoid muscle

Figure 7: Longitudinal view of the supraspinatus tendon with an area of reduced echogenicity due to anisotropy, at the site of tendon insertion over the greater tuberosity, which is not to be confused with a tear. HH: Humeral head
A complete tear of the tendon involves the whole width of the tendon. A full-thickness tear may be complete or may only involve the anterior free edge [Figure 9A] or mid substance [Figure 9B]. A massive cuff tear [Figure 10] occurs when the entire attachment of SST to the greater tuberosity is disrupted, allowing the tendon to retract proximally beneath the acromion. These tears may extend to involve the infraspinatus (IST), subscapularis and the long head of the biceps.

Partial-thickness cuff tear
Partial-thickness tear is a focal discontinuation, which is limited to tears affecting either the articular surface [Figure 11A] (common) or the bursal surface [Figure 11B] (uncommon) of the tendon, but without communication of the tear to the opposing tendon surface. Partial-thickness tears have been classified by Ellman\textsuperscript{[17]} by the depth of the tear, as Grade 1 for tears less than 3 mm; grade 2 for tears 3-6 mm; and grade 3 for those greater than 6 mm. These can also be divided into “high-grade” (greater than 50% thickness) or “low-grade” (less than 50% thickness). A cortical bone irregularity of the greater tuberosity is a sensitive sign of an articular-side partial-thickness tear.\textsuperscript{[16]} Occasionally, a partial tear may propagate proximally within the tendon substance [Figure 11C] causing a “de-laminating tear.” A rim rent tear [Figure 11D] is an articular surface tear near the footplate of the tendon.

The deltoid tendinous intersections cause an acoustic shadow (i.e., a refractile shadow) when they are relatively thick or scanned tangentially. This causes a hypoechoic area within the tendon [Figure 12A], which can simulate a rotator cuff tear.\textsuperscript{[19]} This needs to be distinguished from a true tear [Figure 12B] through the tendon substance, which does not extend into the echogenic superficial layer of the subacromial-subdeltoid (SASD) bursa.

Tendon inhomogeneity
Inhomogeneities of the tendon are frequently encountered with degenerative changes of the tendon (i.e., tendinosis).\textsuperscript{[19]} In tendinosis, a tendon can appear hypoechoic [Figure 13A] due to an increased amount of fluid and/or amyloid deposits in and between the tendon fibers.\textsuperscript{[20]} Tendinosis is often coexistent with partial-thickness rotator cuff tears. These may be difficult to detect when they are

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**Figure 8 (A, B):** (A) Longitudinal view of supraspinatus tendon (SSP). Full-thickness tear of the tendon (long arrow) that reaches from the bursal to the articular margin with sagging of the overlying bursa (short arrow). (B) Long-axis view of the right SSP. Partial thickness articular surface tear (black arrow) and a bright anterior aspect of humeral cartilage (white arrow) – Cartilage interface sign

**Figure 9 (A, B):** (A) Full-thickness tear (arrow) in anterior free edge of supraspinatus tendon. Tiny echogenic shadows due to blood particles (thin arrow) are seen to move on dynamic compression. Note irregularity over the greater tuberosity (arrowhead). (B) Short-axis view of left supraspinatus tendon. There is a full-thickness tear in the mid-portion of the tendon (between the markers) with sagging of the overlying bursa (arrow). BT: Biceps tendon

**Figure 10:** Short-axis view of supraspinatus tendon. There is a massive tear of the tendon with the deltoid muscle lying directly on the humeral head cartilage (arrows)

**Figure 11 (A-D):** Partial-thickness tear of supraspinatus tendon. (A) Short-axis view. There is a partial-thickness articular surface tear in the mid-substance of the tendon (between markers) with a few intact fibers overlying (arrow). (B) Partial-thickness bursal surface tear (arrow) of the supraspinatus tendon. (C) Partial-thickness intrasubstance tear (arrow). (D) Partial tear (rim rent) of supraspinatus tendon at greater tuberosity (arrow). BT: Biceps tendon, HH: Humeral head
located in an area of tendinosis. With long-standing impingement (i.e., chronic tendinosis), calcium may be deposited in the rotator cuff tendons and/or the SASD bursa. Because of its structure (e.g., milk of calcium) or size, calcification may have a fluffy appearance, with echogenic foci without posterior shadowing [Figure 13B], or may appear as typical discrete, well-circumscribed calcifications with posterior shadowing [Figure 13C]. Correlation with plain radiographs [Figure 13D] is necessary. It is believed that the calcifications become symptomatic when the calcium undergoes resorption.\textsuperscript{[21]}

Ultrasound guided fine-needle puncture [Figure 13E], and lavage has been proposed as an effective treatment prior to possible surgery.\textsuperscript{[22,23]} The technique involves successive propulsion and aspiration of the calcium, which can be readily identified in the syringe as a white cloud-like substance mixing with the lidocaine that would then deposit in the dependent portion of the syringe [Figure 13F] and then 40 mg of triamcinolone is injected into the bursa.

**Infraspinatus (IST) and teres minor tendons**

The IST and teres minor tendons lies more posteriorly and can be well visualized with the arm in a flexed and adducted position. This can be done by asking the patient to place their arm across the front of their body [Figure 14A]. The IST is demonstrated in longitudinal section as a beak-shaped soft-tissue structure [Figure 14B].
In this position, the scan depth can be increased to visualize the posterior aspect of the gleno-humeral joint [Figure 14C]. This presents a further opportunity to look for joint effusion. Isolated IST tears are uncommon but may be encountered in association with internal (postero-superior) impingement in individuals involved with over-arm throwing activities. The teres minor tendon may be visualized as a trapezoid structure and can be differentiated from the IST by its oblique internal echoes. Teres minor is found to be normal in most rotator cuff tears and may not be scanned routinely. Isolated Teres minor atrophy, caused by compression of the posterior humeral circumflex artery and axillary nerve in the quadrilateral space, may be identified on ultrasound.

**Accuracy**

Ultrasound and magnetic resonance imaging (MRI) are comparable in both sensitivity and specificity. Ultrasound has 92.3% sensitivity and 94.4% specificity for full-thickness and 66.7% sensitivity and 93.5% specificity for partial-thickness tear. MR arthrography is the most sensitive and specific technique for diagnosing both full-and partial-thickness rotator cuff tears.

**Non-rotator cuff abnormalities**

There is a spectrum of non-rotator cuff abnormalities that are amenable to US examination. Once adequate radiographs have been obtained to exclude apparent bone disorders, high-resolution US should be the first-line imaging modality in the assessment of non–rotator cuff disorders of the shoulder, assuming the study is performed with high-end equipment by an experienced examiner. Subacromial...
impingement syndrome\textsuperscript{[27]} is the result of chronic irritation of the SST against the undersurface of the anterior one-third of the acromion, the coracoacromial ligament, and the acromioclavicular joint. This process leads to tendinopathy and tears of the rotator cuff as well as SASD bursitis. While shoulder impingement is a clinical diagnosis, ultrasound is routinely used to help evaluate the condition by demonstrating supportive findings, discovering alternative causes of shoulder pain, and directing therapeutic injections [Figure 15A-C]. The SASD bursitis is demonstrated by the presence of increased fluid in the bursa and/or thickening of the wall of the bursa [Figure 15D]. Gathering of the SASD bursa [Figure 15E] demonstrated during dynamic ultrasound, which has been reported as a useful feature in diagnosing impingement by some authors\textsuperscript{[28-30]} does not necessarily indicate painful impingement of the bursa as it is found to a similar degree in patients with a clinical diagnosis of impingement, and healthy volunteers.\textsuperscript{[31]}

Fatty atrophy of the rotator cuff muscles is an important consideration in assessing the prognosis in-patients being considered for rotator cuff surgery. Sonographic assessment of fatty atrophy is by calculating the occupation ratio, measured by dividing the cross-sectional area of the supraspinatus muscle by that of its fossa.\textsuperscript{[32]}

The ultrasound features and grading of fatty atrophy are relatively subjective but they correlate well with MRI findings.\textsuperscript{[33,34]}

Fatty infiltration causes loss of normal muscle parenchymal pattern, loss of conspicuity of the central tendon and increased echogenicity of the muscle and is measured by comparing it echogenicity with that of trapezius muscle. US has been found to be moderately accurate in the diagnosis of substantial fatty atrophy of the supraspinatus or IST muscle.\textsuperscript{[35]} It has been documented that extended field of view sonography results in greater interrater reliability than conventional sonography for the detection of rotator cuff muscle atrophy.\textsuperscript{[36]} In our practice we use MRI for the assessment of fatty infiltration and rotator cuff muscle atrophy inpatients being considered for cuff repair.

US is helpful in evaluating the superior aspect of the acromio-clavicular joint. Bone erosion, fluid, cysts, and hypertrophic changes represent degeneration. An acromio-clavicular joint cysts may present as a tumor mass. They are associated with extensive rotator cuff tears and there is usually communication of the cyst with the joint space.\textsuperscript{[35-37]}

**Conclusion**

The ultrasound image quality has substantially improved with technological advancement, producing spatial resolution exceeding that obtained with MRI. Ultrasound gives the ability to provide direct correlation of the imaging findings with the symptoms of the patient, and helps with guided interventional procedures.

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