Dynamic ultrasonography of the shoulder

Jina Park, Jee Won Chai, Dong Hyun Kim, Seung Woo Cha

Department of Radiology, SMG-SNU Boramae Medical Center, Seoul National University College of Medicine, Seoul, Korea

Ultrasonography (US) is a useful diagnostic method that can be easily applied to identify the cause of shoulder pain. Its low cost, excellent diagnostic accuracy, and capability for dynamic evaluation are also advantages. To assess all possible causes of shoulder pain, it is better to follow a standardized protocol and to perform a comprehensive evaluation of the shoulder than to conduct a focused examination. Moreover, a proper dynamic study can enhance the diagnostic quality of US, especially when the pathology is not revealed by a static evaluation. The purpose of this article is to review the common indications for dynamic US of the shoulder, and to present the basic techniques and characteristic US findings.

Keywords: Shoulder; Ultrasonography; Movement

Introduction

Ultrasonography (US) is a commonly performed examination for shoulder pain, recommended by experts as the first-choice technique to evaluate various rotator cuff diseases and nonrotator cuff diseases [1–4]. When US is performed by an experienced radiologist, its diagnostic sensitivity and specificity for detecting rotator cuff tears are comparable to those of magnetic resonance imaging (MRI) [5].

The advantages of US include not only excellent diagnostic accuracy but also high resolution and the capability of dynamic evaluation [6]. To assess all possible causes of shoulder pain, it is better to follow a standardized protocol and to perform a comprehensive evaluation of the shoulder than to conduct a focused examination. Moreover, a proper dynamic study can enhance the diagnostic quality of US, especially when the pathology is not revealed by a static evaluation. The purpose of this article is to review the common indications for dynamic US of the shoulder, and to present the basic techniques and characteristic US findings.

Long Head of the Biceps Tendon Subluxation

The long head of the biceps tendon (LHBT) can be assessed with the patient in the neutral position, with his or her elbow flexed and the dorsum of the hand placed on the ipsilateral thigh. The LHBT is visible as a cord-like hyperechoic structure that lies within the bicipital groove between the greater and lesser tubercle of the proximal humerus and is covered by the transverse humeral ligament. In normal shoulders, the LHBT is secured by the tendon sheath and pulley, as well as the transverse humeral ligament, so that it is not subluxated or dislocated during internal or external rotation of the shoulder [2,6–8].
Dynamic evaluation for subluxation or dislocation of the LHBT was first introduced in 1995, by Farin et al. [9]. They found that maximal external rotation of the shoulder was helpful for diagnosing transient subluxation of the LHBT, and the sensitivity of the dynamic assessment was 86%. The authors suggested that a dynamic study for LHBT subluxation should be included in routine shoulder US. LHBT subluxation and dislocation are frequently reported with a shallow bicipital groove and rotator cuff tears, especially subscapularis tendon tears [9,10]. A bicipital groove less than 3 mm deep is regarded as shallow [9]. The diagnosis of subluxation or dislocation can be made when the LHBT overlies the wall of the bicipital groove or moves out of the groove in the short-axis view, either in the neutral or external rotation position [9–11] (Fig. 1). Skendzel et al. [12] reported LHBT subluxations accompanied by partial tears of the LHBT, and postulated that LHBT subluxation associated with surface irregularities should raise suspicion of a partial-thickness tear of the LHBT.

**Intra-articular Entrapment of the LHBT**

Intra-articular entrapment of the LHBT, known as “hourglass biceps,” was first described by Boileau et al. [13]. This is a novel mechanical impairment of biceps tendon movement that presents as pain and locking of the shoulder. The sliding motion of the LHBT in the limited space of the bicipital groove is blocked by severe swelling of the intra-articular LHBT during shoulder abduction, subsequently causing buckling of the intra-articular LHBT and leading to pain in the anterior shoulder. US criteria for intra-articular entrapment of the LHBT were suggested by Pujol et al. [14], and include a 10% increase in the diameter of the intra-articular LHBT or tendon buckling that is visible during shoulder abduction (Fig. 2). The sensitivity of the dynamic evaluation (50%) was not satisfactory, but the specificity was 100%.

**Subcoracoid Impingement**

Subcoracoid impingement or coracoid impingement is a rarely diagnosed, but well-known cause of anterior shoulder pain [15,16]. The known etiologies of subcoracoid impingement are anatomic variations of the scapulae (coracoid process), ossifications of the subscapularis tendon (Fig. 3, Video clip 1), ganglion cysts, and other osseous deformities caused by surgery or trauma [17] that produce excessive pressure on the LHBT or subscapularis tendon.

The main diagnostic criterion for subcoracoid impingement in imaging studies is coracohumeral distance, although discordant opinions about its diagnostic value have been reported in the literature [18,19]. The coracohumeral distance is known to be smaller in symptomatic patients than in asymptomatic volunteers [18]. Because the coracohumeral distance on MRI is known to be smaller in women than in men, a sex-adjusted criterion (11.5 mm in men) was proposed by Girolori et al. [19], but it showed poor predictive value. Recently, subcoracoid bursitis and impingement were observed with dynamic US during internal/external rotation of the shoulder [20], which is one of the well-known appearances of subacromial impingement. Because anatomical or biomechanical properties are different in each patient, real-time observation of the mechanical blockage (Fig. 4, Video clip 2) might have the potential to be able to diagnose this mechanical condition, although further...
Fig. 2. A 71-year-old woman with anterior shoulder pain.
A, B. The long-axis view and the short-axis view of the long head of the biceps tendon (LHBT) in the neutral position of the shoulder are shown. The LHBT is thickened, with a hypoechoic appearance suggesting tendinopathy. A small amount of effusion (arrowheads) is noted in the biceps tendon sheath. The diameter of the intra-articular tendon was 2.8 mm. C, D. The long-axis view and the short-axis view of the LHBT in the abduction position of the shoulder are shown. The intra-articular LHBT has a more curved appearance (arrows) and is elevated from the humeral head (H). The diameter of the intra-articular tendon was 3.5 mm, with an increase of 25% compared to the neutral position. A, acromion.

Fig. 3. A 19-year-old man with subscapularis tendon ossification and subcoracoid impingement.
A. The long-axis view of the subscapularis tendon shows slightly thickened subcoracoid bursa (arrows), superficially located above the subscapularis tendon (arrows). There are two ossifications in the subscapularis tendon (asterisks). B. During internal rotation of the shoulder, the subscapularis tendon does not fully glide under the coracoid process due to ossifications (asterisks), and subcoracoid impingement occurs. Note the bulging contour of the hypoechoic soft tissue by the subcoracoid bursa and the subscapularis tendon (arrowheads). C, coracoid process; LT, lesser tubercle of the humerus.
including anywhere between flexion and abduction of the shoulder (Fig. 6). The coracoacromial ligament is the central part of the coracoacromial arch, which can be the main causative structure for subacromial impingement and has recently received attention as part of ultrasonographic evaluations [22,24,25]. The coracoacromial ligament can be visualized by placing one end of the probe at the acromion and the other end at the coracoid process (Figs. 6, 7A). Subacromial impingement beneath the coracoacromial ligament can also be visualized by turning the probe 90° from the long-axis view of the coracoacromial ligament, which is slightly anterior from the acromion, and along the direction of the supraspinatus tendon (Fig. 7B) [22]. The thickness and length of the coracoacromial ligament is not different between normal subjects and those who have subacromial impingement syndrome, but superior displacement of the coracoacromial ligament is significantly increased during shoulder abduction-internal rotation (throwing motion) [24-26].

Adhesive Capsulitis

Adhesive capsulitis or frozen shoulder is a frequently encountered disease in the shoulder, causing pain and a limited range of motion. It is more common in individuals with diabetes and perimenopausal women [22]. The ultrasonographic findings of adhesive capsulitis are hypoechoic changes and hypervascularity in the rotator interval [27], and thickening of the coracohumeral ligament (mean thickness of 3.0 mm, compared to 1.4 mm in asymptomatic patients) [28] and the inferior glenohumeral ligament (mean thickness of 4.0 mm compared to 1.3 mm in the asymptomatic contralateral shoulder) [29]. However, the diagnosis of adhesive capsulitis still substantially relies on the radiologist’s observation of limited external rotation or abduction during routine shoulder US.

The dynamic US findings of adhesive capsulitis were reported in 1993 by Ryu et al. [30]. They found that continuous limitation of supraspinatus movement beneath the acromion and continuous visualization of the supraspinatus tendon during shoulder abduction were useful criteria that could diagnose adhesive capsulitis validation is needed.
with 92% accuracy. When the axillary pouch is stiff and cannot be stretched to let the shoulder abduct, the patient will try to compensate by scapulothoracic rotation to raise the arm. However, the glenohumeral joint relationship is fixed, and the supraspinatus tendon is persistently visible at the lateral aspect of the acromion (Fig. 8, Video clip 6). If there is no visible tendon pathology or soft tissue impingement, we can more confidently make the diagnosis of adhesive capsulitis using this dynamic evaluation.

**Acromioclavicular Joint Instability**

Acromioclavicular (AC) joint instability is another indication for dynamic US. For traumatic injuries of the AC joint, the classification mainly relies on the AC joint space and the extent of the ligament injury [31]. Because a normal AC joint can show variable obliqueness and step-offs, AC joint space measurement on US can be problematic, and the criterion for widening (6 mm) established on radiographs [32] cannot be directly used on US [33]. Therefore, a
comparison with the contralateral side is recommended to diagnose abnormal widening of the AC joint [34], and a relative measurement (AC index = AC joint space on the uninjured side/AC joint space on the injured side) is suggested [35]. The normal AC index is 1, and the AC index is lower in more widened and severely injured AC joints.

A dynamic evaluation procedure for AC joint injuries was introduced by Peetrons and Bedard in 2007 [34]. By placing the palm at the contralateral shoulder, in the so-called cross-arm maneuver, the AC distance is decreased in the injured AC joint (Fig. 9), and becomes widened again with the change of position to neutral (hands on the ipsilateral thigh). An uninjured AC joint shows minimal change (less than 1 mm) in the cross-arm maneuver [34].

Osteoarthritis is another cause of AC joint instability, and the joint space can be severely decreased, with the cross-arm maneuver showing a “kissing” appearance. However, we can easily differentiate osteoarthritis with chronic instability from acute AC joint injury by joint space narrowing, subchondral bone changes, and the presence of osteophytes in the neutral position.

**Joint Effusion and Synovial Hypertrophy**

It is important to identify joint effusion for the diagnosis of septic arthritis or inflammatory arthritis in the glenohumeral joint. Joint effusion is commonly detected in the posterior recess of the glenohumeral joint and tendon sheath of LHBT by communication with the glenohumeral joint [36]. However, joint effusion can be invisible in the posterior recess in neutral position, even if the joint is distended with 8–12 mL of fluid [37]. Most likely, the fluid is pooled in the axillary pouch because of gravity when the patient is in sitting position. External rotation of the shoulder increased the sensitivity from 17% to 100% for detecting fluid in the glenohumeral joint in the posterior recess (Fig. 10).

**Differential Diagnosis of Cystic Lesions at the Spinoglenoid Notch**

The spinoglenoid notch is the groove between the glenoid and the base of the scapular spine, where the suprascapular nerve and suprascapular vessels run. This region should be evaluated during routine shoulder US for a possible paralabral cyst [2, 6, 22, 36], because a paralabral cyst at this location can entrap the suprascapular...
nerve and cause pain or weakness of the shoulder. Occasionally, we can see the suprascapular vessels and nerves as tiny hypoechoic structures in the spinoglenoid notch [36]. Sometimes the vessels are engorged or distended with blood, especially in the external rotation position of the shoulder, and can be confused with a paralabral cyst or ganglion cyst [38]. Usually, the internal rotation position of the shoulder (cross-arm maneuver) decreases suprascapular varicosity (Fig. 11), whereas a true paralabral cyst or ganglion cyst does not change with internal rotation of the shoulder [6,22].

However, familiarity with these dynamic maneuvers and indications, and their proper application, will significantly improve the diagnostic value of shoulder US.

**Conflict of Interest**
No potential conflict of interest relevant to this article was reported.

**Supplementary Material**
Video clip 1. A 19-year-old man with subscapularis tendon ossification and subcoracoid impingement. Long axis view of the subscapularis tendon shows slightly thickened subcoracoid bursa,
superficially located to the tendon. There are two ossifications in the subscapularis tendon. During internal rotation of the shoulder, the subscapularis tendon does not fully glide under the coracoid process due to the ossifications and subcoracoid impingement occurs. Note the hypoechoic soft tissue bulging contour by the subcoracoid bursa and the subscapularis tendon (https://doi.org/10.14366/usg.17055.v001).

Video clip 2. A 69-year-old woman with subcoracoid impingement with soft tissue involvement. On the long axis view of the subscapularis tendon, the thickened subcoracoid bursa is located superficial to the subscapularis tendon. During internal rotation of the shoulder, pooling of the fluid in the subcoracoid bursa is noted at the lateral aspect of the coracoid process. There is a smooth gliding of the subscapularis tendon underneath the coracoid process and the bursa, without significant impingement of the tendon (https://doi.org/10.14366/usg.17055.v002).

Video clip 3. A 31-year-old man without subacromial impingement. During the dynamic evaluation of subacromial impingement, there is no significant soft tissue or osseous impingement. The supraspinatus tendon and the greater tubercle show smooth passage underneath the acromion (https://doi.org/10.14366/usg.17055.v003).

Video clip 4. A 45-year-old woman with grade 2 subacromial impingement. Long axis view of the supraspinatus tendon between acromion and greater tubercle shows subacromial-subdeltoid bursal thickening above supraspinatus tendon surface. During shoulder abduction, subacromial-subdeltoid bursal fluid pooling at the lateral aspect of acromion is seen. The humeral head normally moves inferiorly (https://doi.org/10.14366/usg.17055.v004).

Video clip 5. A 50-year-old woman with grade 3 subacromial impingement. Long axis view of supraspinatus tendon between acromion and greater tubercle shows severe tendinosis of supraspinatus tendon and adjacent thickened subacromial-subdeltoid bursa. During the dynamic examination, the osseous impingement occurs. The humeral head does not sufficiently move inferiorly and the supraspinatus tendon and subacromial-subdeltoid bursa cannot be passed underneath the acromion (https://doi.org/10.14366/usg.17055.v005).

Video clip 6. A 54-year-old man with adhesive capsulitis. Long axis view of the supraspinatus tendon during shoulder abduction
shows limitation of supraspinatus movement beneath the acromion and continuous visualization of the supraspinatus tendon. There is no significant subacromial soft tissue impingement (https://doi.org/10.14366/usg.17055.v006).

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