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EURO-MUSCULUS/USPRM Dynamic Ultrasound Protocols for Shoulder

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EURO-MUSCULUS

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ABSTRACT

In this dynamic protocol, ultrasound examination of the shoulder using different manuevers is described for several/relevant shoulder problems. Scanning videos are coupled with real-time patient examination videos for better understanding. The authors believe that this practical guide prepared by an international consensus of several experts will help musculoskeletal physicians perform a better and uniform/standard approach.

KEY WORDS

Shoulder, ultrasonography, dynamic imaging, maneuver, Physical and Rehabilitation Medicine

Among physiatrists, the utility of musculoskeletal ultrasound imaging/examination has already skyrocketed in daily clinical practice. In addition to the basic scanning, dynamic assessment is perhaps one of the most important superiorities of this imaging technique when compared with other modalities. Herewith, protocols as regards how to implement this method in various shoulder pathologies does not exist in the relevant literature. As such, and similar to the former/basic shoulder scanning protocols in physical and rehabilitation medicine;[1] an international group of experts also prepared this protocol for dynamic assessment of shoulder disorders.

ANTERIOR ASPECT

1. Coracoid/Subcoracoid Window

Technique

With the arm adducted to the trunk, the forearm supinated and the elbow flexed to 90 degrees, the glenohumeral joint is slowly (internally/externally) rotated **(Figures 1A, B, C)**. The dynamic assessment is performed in the long-axis view, at the level of the coracoid process or just caudally to visualize the coracoid muscle/tendon complex. During dynamic scanning, it is possible to visualize the gliding of the subscapularis muscle-tendon unit under the coracoid process and coracoid muscles (e.g., the short head of the biceps brachii muscle and coracobrachialis muscle) **(Video 1, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=92)**. [2,3]

Clinical Indications

Anterior shoulder impingement: Mechanical conflict may develop among different anterior components of the shoulder i.e., subscapularis muscle-tendon unit, coracoid bone/coracoid muscles and the humeral head. The clinical spectrum might encompass several conditions like tendinosis/tears **(Video 2, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=91)** [4] or calcific tendinopathy of the subscapularis, hypertrophy or mass lesions of the subscapularis muscle, anterior glenohumeral instability, calcific tendinopathy of the coracoid muscles and congenital/traumatic coracoid process abnormalities.[5]

Anterior synovitis: During active rotations of the glenohumeral joint, hypertrophic synovial tissue - interposed between the subscapularis muscle-tendon unit and the coracoid space - can be identified as a potential pain generator **(Video 3, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=90)**. Of note, in this anatomical region, the pathological synovial tissue may stem from the subcoracoid bursa,[6] the subacromial/subdeltoid bursa (with an abundant medial portion located in the subcoracoid space) or from the subscapularis recess i.e. an extension of the glenohumeral synovium **(Video 4, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=89)**.[7]

Restriction of the glenohumeral joint motion: Stiffness and/or thickening of the anterior portion of the shoulder capsule (e.g., in adhesive capsulitis) can reduce the excursion of the subscapularis muscle-tendon unit during active rotations of the glenohumeral joint.[2,3] Of note, this dynamic sonographic finding would particularly be evident in comparison with the asymptomatic shoulder.

Abnormal gliding of the muscular and fascial planes: Several pathological conditions related with the rotator cuff tendons and synovial structures may influence the physiological gliding and tension of the connective layers of the shoulder at different levels i.e. muscular epimysium, intermuscular septum, intramuscular aponeurosis and subdeltoid fascia.[8] In this sense, dynamic assessment can indisputably be considered as a valuable tool to promptly visualize these peculiar conditions **(Video 5, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=88)**.

2. Humeral Groove Window

Technique

With the arm adducted to the trunk, the forearm supinated and the elbow flexed to 90 degrees, the glenohumeral joint is slowly (internally/externally) rotated while visualizing real-time the bicipital groove and the long head of the biceps tendon (LHBT) in its short-axis **(Figures 1A, B, C)**.[2,3] During the dynamic assessment, it is possible to evaluate the relationship among the LHBT, the bony groove, and the surrounding stabilizing soft tissues e.g. the transverse humeral ligament **(Video 6, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=87)**.[9]

Clinical Indications

Instability of the LHBT: During dynamic assessment, the LHBT may shift medially over the lesser tuberosity of the humeral head - with total/partial dislocation.[2,3,9] Feeling of a click may (or may not) be associated with this shift. Of note, the effusion in the synovial sheath of the LHBT may be an indirect sign of instability; therefore, the authors suggest to perform this dynamic assessment when it is present **(Video 7, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=86)**. Interestingly, in some patients - with mild instability of the LHBT - gas bubbles can also/often be detected inside this effusion **(Video 8, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=85)**.[10]

3. Coracoacromial Window

Technique

With the arm in slight abduction, the patient is asked to slowly flex the shoulder in order to exactly reproduce the pain and/or the click sensation. Of note, each and every patient may describe different movements/positions provocating the symptoms. Herewith, the same coracoacromial acoustic window - i.e. long-axis view of the coracoacromial ligament - is used for the dynamic examination **(Figures 1D, E)** [11] during which gliding of the subacromial tissues (e.g. synovial bursa, rotator cuff/interval) can be visualized under the coracoacromial arch **(Video 9, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=84)**.[12]

Clinical Indications

Bursal conflict: During active movements of the shoulder, focal thickening of the synovial layers of the subacromial/subdeltoid bursa (e.g. chronic nodular bursopathy) can be entrapped under the coracoacromial arch with pathological/painful displacement of the ligament - sometimes accompanied by sensation of a click **(Video 10, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=83)**.[13] In some patients, active shoulder motions can push the bursal effusion medially, tensioning the coracoacromial ligament and exacerbating the pain **(Figure 1D, E)**.

Anterolateral shoulder impingement: Mechanical conflict between the rotator cuff and the coracoacromial arch can be related with several pathological conditions e.g. tendinosis/tear [14] or calcific tendinopathy of the rotator cuff and muscle imbalance **(Video 11, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=82)**. In addition, disorders of the rotator interval e.g. tendinosis of the proximal segment of the LHBT ('hourglass biceps') **(Figure 1F)** and/or thickening of the stabilizing pulley may result in anterolateral impingement under the coracoacromial arch **(Video 12, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=81)**.[15-17] Lastly, especially in young patients, short coracoacromial ligament (assessed by comparison with the symptomatic side) may prevent physiological, anterior translation of the humeral head during active shoulder movements. In this sense, abnormal contact between humerus and the ligament may be visualized during dynamic scanning.

SUPERIOR ASPECT

1. Acromiohumeral Window

Technique

With the forearm in pronation and the elbow in extension, the patient elevates the arm halfway between flexion and abduction. The acromiohumeral acoustic window is used in coronal plane **(Figure 2A, B, C)**. During dynamic scanning, it is possible to visualize the gliding of the superior portion of the rotator cuff and the subacromial/subdeltoid bursa under the acromion **(Video 13, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=80)**.[2,3,9]

Clinical Indications

Superior shoulder impingement: A transient snapping or mechanical conflict between the superior portion of the rotator cuff and the acromion can be identified during the elevation of the upper limb.[18,19] Several pathological conditions may be related to the superior shoulder impingement - e.g. rotator cuff tendinosis/tear, calcific tendinopathy of the rotator cuff and imbalance of the stabilizing muscles of the glenohumeral joint with abnormal superior shift of the humeral head during the elevation phase of the upper limb.

Bursal conflict: During dynamic assessment of the acromiohumeral space, focal thickening of the synovial layers of the subacromial/subdeltoid bursa - i.e. chronic nodular bursopathy - can intermittently be entrapped between the superior portion of the rotator cuff and the acromion, with pain and feeling of 'click' complained by the patient **(Video 14, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=79)**.[20]

2. Acromioclavicular Window

Technique

With the arm flexed forward to 90 degrees, the patient adducts the upper limb in the horizontal plane to cross the chest at the maximal effort. The acromioclavicular acoustic window is used in the long-axis view of the acromioclavicular joint **(Figure 2D)**. During dynamic scanning, it is possible to visualize - in real-time - the reciprocal relationships between the acromion and the lateral portion of the clavicle. This maneuver is also known as the "US-guided cross-body adduction test".[2]

Clinical Indications

Instability of the acromioclavicular joint: Malalignment of the articular surfaces during horizontal adduction and/or protrusion of the fibrocartilaginous meniscal disk (with bulging of the superior joint capsule) is considered to be the ultrasonographic features that potentially correlate with the joint instability **(Video 15, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=78)**.[2] Of note, in young patients, recurrent and minor subluxation of the joint (due to congenital laxity of the stabilizing ligaments) may be identified during dynamic assessment. A painful click sensation can also accompany during active movements.

3. Rotator Interval Window

Technique

Starting from a "simplified" Crass position (with the upper limb adducted to the trunk, the forearm supinated, the elbow flexed to 90 degrees, and the shoulder extended), the patient performs flexion and extension movements of the glenohumeral joint. The probe is kept in an oblique transverse plane to promptly evaluate how the proximal segment of the LHBT shifts inside the rotator interval **(Figure 2E)**.[21] Normally, the tendon is dynamically stabilized inside the rotator interval by a multilayer pulley - that is composed of coracohumeral and superior glenohumeral ligaments, glenohumeral capsule and some fibers crisscrossing between the supraspinatus and subscapularis tendons - and glides over the hyaline cartilage of the humeral head **(Video 16, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=77)**.[22]

In addition, with the arm adducted to the trunk, elbow flexed to 90 degrees, and forearm fully supinated, the patient performs complete external rotation of the glenohumeral joint to apply tension on the proximal intra-capsular segment of the LHBT, reducing its curvature inside the rotator interval. Likewise, positioning the probe in an oblique coronal plane (long-axis view of the rotator interval), the intra-articular portion of the LHBT can be visualized until its attachment to the superior labrum **(Figure 2F)**.[23-26] In some patients, the shape and size of the acromion may hinder optimal visualization of the tendon's insertion - referred as "covering acromion". Of note, due to the curved course of the tendon over the humeral head and the deep proximal insertional site, the anisotropy artifact must be considered and promptly managed with the 'heel-toe' maneuver.[23-26] After identifying the biceps-labral complex **(Figure 2F)**, a dynamic stress test (inferior distraction of the arm) can be performed to evaluate the integrity/continuity of the aforementioned anatomical structures.[27]

Clinical Indications

Anatomical integrity of the biceps-labral complex: Using the long-axis view of the rotator interval and applying an inferior distraction force to the arm, an anechoic gap can be visualized between the tip of the superior labrum and the proximal portion of the LHBT in case of injury. In the presence of a consistent clinical scenario, the aforementioned US finding could be suggestive of injury to the biceps-labral complex. Magnetic resonance imaging might be required to confirm the diagnosis though.[23-26]

Instability of the intracapsular segment of the LHBT: Injuries of the anterior edge of the supraspinatus tendon and/or the superior portion of the subscapularis tendon - involving the soft tissues of the rotator interval (pulley) - can lead to instability of the proximal segment of the LHBT. Focal enlargement due to degenerative tendinosis, coupled with abnormal shifting of the tendon over the hyaline cartilage of the humeral head (‘windshield wiper effect’), is the most common US finding.[28] Short-axis view of the rotator interval can be used for the dynamic assessment.

Other disorders of the intracapsular segment of the LHBT: Thickening and tendinosis of the proximal segment of the tendon - hourglass biceps - may result in intraarticular or intracapsular impingement leading to a condition mimicking the adhesive capsulitis.[15-17] Indeed, in patients with frozen shoulder, the restriction of active and passive movements is also related to the entrapment of the LHBT inside the rotator interval, due to capsular fibrosis and/or focal synovitis around the tendon sheath.[22] In this sense, dynamic assessment of the rotator interval - observing the real-time interactions between the tendon and the stabilizing pulley - could be considered as a useful tool to better define the diagnosis and treatment.

4. Supraspinatus Fossa Window

Technique

With the same position of the patient described for the rotator interval window, it is possible to put the proximal intra-capsular segment of the LHBT under tension. Positioning the probe in an oblique coronal plane over the supraspinatus fossa - long-axis view of the supraspinatus muscle-tendon unit - and using a low-frequency curvilinear probe (extended view and deep penetration), the biceps-labral complex can be visualized **(Figure 3A)**. As previously mentioned, the shape and size of the acromion may prevent optimal visualization. During abduction/adduction of the shoulder, the reciprocal relations between the humeral head, glenoid and the biceps-labral complex can be promptly evaluated **(Video 17, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=76)**.[23-26]

Clinical Indications

Anatomical integrity of the biceps-labral complex: During dynamic assessment, the presence of synovial fluid and/or gas microbubbles slipping between the glenoid and the biceps-labral complex could be suggestive of injury. Again, the diagnosis of a biceps-labral complex tear can be confirmed with magnetic resonance imaging.[23-26]

Glenohumeral joint instability: During dynamic assessment, excessive cranial or caudal shift of the humeral head with respect to the glenoid may be suggestive of superior/inferior glenohumeral joint instability - especially if coupled with consistent clinical findings. Herein, especially in young patients with physiological laxity of the capsuloligamentous structures, the authors suggest to perform a comparative dynamic examination before diagnosing shoulder instability.

POSTERIOR ASPECT

1. Retroacromial Window

Technique

With the arm adducted to the trunk, the forearm supinated and the elbow flexed to 90 degrees, the glenohumeral joint is internally/externally rotated slowly. A retroacromial posterior window -

i.e. long-axis view of the infraspinatus muscle-tendon unit **(Figure 3B, C)** - is used. During dynamic scanning, it is possible to visualize the physiological contraction of the infraspinatus muscle, the gliding of the posterior portion of the rotator cuff and the normal retroflection of the posterior capsule-synovial recess at the end of external rotation **(Video 18, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=75)**.[2,3,9,27]

Clinical Indications

Restriction of the glenohumeral joint motion: Stiffness/thickening of the anterior portion of the shoulder capsule (e.g. adhesive capsulitis) counteracts the end phase of external rotation - reducing or preventing the visualization of the physiological retroflection of the posterior capsule-synovial recess.[29] In young patients, a similar scenario may be related with different etiologies such as congenital shortening of the subscapularis muscle-tendon unit secondary to local denervation.

Dynamic quantification of joint effusion: The dynamic maneuver reduces the tension of the posterior capsule and, at the same time, generates a squeeze-effect on the anterior portion of the glenohumeral cavity. Therefore, if a small amount of intra-articular effusion is present, it flows into the posterior recess and becomes clearly visible in the posterior window **(Video 19, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=74)**.[2,3,30]

Dynamic evaluation of the humeral shape: A "panoramic" view of the humeral head is well depicted during movements.[2,3,9,30] In young patients, congenital dysmorphic humeral head might appear in an aspherical (e.g. elliptical) shape and can lead to mechanical impingement or joint instability. Of note, aberrant orientation of the glenoid (i.e., retroverted glenoid) can be associated with dysmorphic humeral head in young patients. For this reason, the physician should pay attention to both articular surfaces during the dynamic maneuver. In adult patients, a similar condition may be related to a posttraumatic (Hill-Sachs defect) or degenerative deformation of the humeral head, impinging with the posterior edge of the glenoid during rotations (bony block) **(Video 20, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=73)**.[31]

Dynamic evaluation of the posterior capsule-tendon complex: Dynamic assessment can help better define a partial or complete injury of the posterior rotator cuff and the glenohumeral capsule.[2,3,30] Indeed, dynamically tensioning the aforementioned tissue layers, precise localization of the "gap" can be promptly identified **(Video 21, 22, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=72, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=71)**. Lastly, calcific depositions in the posterior rotator cuff can sometimes cause mechanical friction with the surrounding fasciae or synovia during specific movements **(Video 23, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=70)**.[2,3,27]

Dynamic evaluation of the posterior labrum: In case of posterior labral pathologies (e.g., labral cyst, fissuration, detachment), dynamic US assessment can promptly show the relationship between the pathological fibrocartilage and the surrounding soft tissues, unmasking the possible cause of pain **(Video 24, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=69)**.[2,3,27] Of note, pushing the synovial fluid from the glenohumeral cavity through the labral defect, shoulder movements can be contributory/confirmatory for the precise diagnosis. In other words, the intraarticular effusion can serve as a natural contrast material which can be directed to a specific compartment.

2. Retroacromial Window (ABER Maneuver)

Technique

Starting with the shoulder in 90 degrees of forward flexion, the patient slowly and horizontally extends the shoulder, with the elbow flexed to 90 degrees reproducing the ABER (abduction and external rotation) maneuver. During active movements, the posterior retroacromial acoustic window is used to identify the infraspinatus muscle-tendon unit in the long-axis view **(Figure 3D, E)**.[2,3,30] During dynamic assessment, the posterior capsule-synovial complex of the glenohumeral joint - gliding through different tissue planes - can be observed until the final location between the deep surface of the infraspinatus muscle-tendon unit and the posterior labrum **(Figure 3F)**. Of note, during the ABER maneuver, the infraspinatus tendon diverges from the posterior capsule of the shoulder which "rolls up" over the posterior labrum and glenoid **(Video 25, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=68)**.[30] Lastly, this technique allows the physician to promptly observe the "dynamic centering" of the humeral head inside the joint. As such, it represents an indirect ultrasonographic sign of functional neuromotor control of the shoulder i.e. the balance between internal and external rotator muscles.[32-35]

Clinical Indications

Loss of joint congruence: During the ABER maneuver, the humeral head can develop a remarkable anterior shift compared to the glenoid ("dive sign") - causing pain, capsular stretching and pinching of the posterior synovial recess between the articular surfaces. This sonographic finding, coupled with the relevant clinical scenario, may be suggestive of an anterior glenohumeral instability due to muscular imbalance, laxity of the anterior capsule or abnormal articular surfaces. Of note, the loss of a concentric position of the humeral head over the glenoid during the dynamic assessment can also be associated with posterior shoulder instability. In that case, horizontal adduction of the upper limb and, abrupt protrusion of the humeral head toward the posterior deltoid can clearly be observed during the dynamic assessment **(Video 26, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=67)**.[36,37]

Posterior intracapsular impingement: At the end phase of the ABER maneuver, compression of the posterior soft tissues (i.e. labrum, capsule-synovial complex, rotator cuff) between the humeral head and the glenoid may be suggestive of a posterior intraarticular impingement **(Video 27, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=66)**.[31] If clinically indicated, magnetic resonance imaging may be performed to better define the injury of the labrum/glenoid.

ADDITIONAL ASPECTS

1. US-Guided Rotator Cuff Stress Test

Technique

Initially, a specific tendon of the rotator cuff is visualized in short- and long-axis views.[1,2] Then, the physician can apply resistance to a specific movement of the shoulder e.g. blocking the external rotation of the glenohumeral joint to evaluate the infraspinatus muscle-tendon unit. Naturally, isometric contraction of the imaged muscle will be performed by the patient. Likewise, visualization of a focal gap at any level (e.g. tendon, myotendinous junction, muscle) may be contributory for a specific diagnosis **(Video 28, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=65)**.[2,3,27]

Clinical Indications

Differential diagnosis of tendinosis vs. tear: Real-time dynamic US imaging with stress application can help visualize the retraction (loss of anatomical continuity) in the tendon fibers in case of tears.[2,3]

Atypical injuries of the rotator cuff: Using the same dynamic technique, it is possible to better identify peculiar lesions of the rotator cuff i.e. at the myotendinous junction or directly inside the muscle belly (e.g. posttraumatic shoulder).[2,3]

2. Bursal sono-palpation

Technique

In certain situations, it may be necessary to gently push the probe over the skin to better observe how the subacromial/subdeltoid bursa reacts to the pressure changes. Different from chronic adhesive bursopathy with a nodular pattern,[38] in case of acute exudative bursitis (bursal effusion), sono-palpation can uncover the communication between the bursal cavity and the glenohumeral joint. Moreover, gentle vibratory movements of the probe can also help the physician to better characterize the bursal content.

Clinical Indications

Dynamic evaluation for intra-bursal pathologies: Minor movements of the shoulder together with gentle sono-palpation can help differentiate an intrabursal loose body from hypertrophic synovial villi.[3,27] While the former is expected to move randomly/freely inside the bursa, the latter would rather float inside the effusion with its peduncle on the bursal wall **(Video 29, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=64)**.

Atypical pathologies of the bursa: With the aforementioned technique, a subdeltoid mass - originating from the subacromial/subdeltoid bursa - can be better characterized in order to plan a conservative or surgical approach **(Video 30, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=63)**. For instance, the typical villous pattern of lipoma arborescens can be differentiated from the compact pattern of synovial lipoma.[39]

Post-operative bursopathy: After surgical repair of the rotator cuff tendons, several abnormalities of the subacromial/subdeltoid bursa may be identified during US imaging.[40] Due to the variable combinations of bursal effusion, synovial hypertrophy and local proliferation of fibrotic tissues;

post-operative bursopathy is also called “the complex bursa” **(Video 31, https://journals.lww.com/ajpmr/Pages/videogallery.aspx?autoPlay=false&videoId=62)**.

REFERENCES

1. Özçakar L, Kara M, Chang KV, et al. EURO-MUSCULUS/USPRM basic scanning protocols for shoulder. Eur J Phys Rehabil Med. 2015; 51: 491-6.
2. Chang KV, Wu WT, Hsu PC, et al. Clinical tests of the shoulder: accuracy and extension using dynamic ultrasound. Am J Phys Med Rehabil. 2020; 99: 161-9.
3. Corazza A, Orlandi D, Fabbro E, et al. Dynamic high-resolution ultrasound of the shoulder: how we do it. Eur J Radiol. 2015; 84: 266-77.
4. Oh JH, Song BW, Choi JA, et al. Measurement of coracohumeral distance in 3 shoulder positions using dynamic ultrasonography: correlation with subscapularis tear. Arthroscopy 2016; 32: 1502-8.
5. Lappin M, Gallo A, Krzyzek M, et al. Sonographic findings in subcoracoid impingement syndrome: a case report and literature review. PMR 2017; 9: 204-9.
6. Drakes S, Thomas S, Kim S, et al. Ultrasonography of subcoracoid bursal impingement syndrome. PMR 2015; 7: 329-33.
7. Bianchi S, Jacob D, Lambert A, et al. Sonography of the coracoid process region. J Ultrasound Med. 2017; 36: 375-88.
8. Pirri C, Stecco C, Fede C, et al. Ultrasound imaging of the fascial layers: you see (only) what you know. J Ultrasound Med. 2020; 39: 827-8.
9. Park J, Chai JW, Kim DH, et al. Dynamic ultrasonography of the shoulder. Ultrasonography 2018; 37: 190-9.
10. Malghem J, Omoumi P, Lecouvet FE, et al. Presumed intraarticular gas microbubbles resulting from a vacuum phenomenon: visualization with ultrasonography as hyperechoic

microfoci. Skeletal Radiol. 2011; 40: 1287-93.

11. Wang YC, Wang HK, Chen WS, et al. Dynamic visualization of the coracoacromial ligament by ultrasound. Ultrasound Med Biol 2009; 35: 1242-8.
12. Wu CH, Wang YC, Wang HK, et al. Evaluating displacement of the coracoacromial ligament in painful shoulders of overhead athletes through dynamic ultrasonographic examination. Arch Phys Med Rehabil 2010; 91: 278-82.
13. Boudier-Revéret M, Chang KV, Wu WT, et al. Dynamic ultrasound imaging for anterior snapping shoulder: coracoacromial ligament is in play. PM R. 2020; 12: 842-44.
14. Wu CH, Chang KV, Su PH, et al. Dynamic ultrasonography to evaluate coracoacromial ligament displacement during motion in shoulders with supraspinatus tendon tears. J Orthop Res 2012; 30: 1430-4.
15. Pujol N, Hargunani R, Gadikoppula S, et al. Dynamic ultrasound assessment in the diagnosis of intra-articular entrapment of the biceps tendon (hourglass biceps): a preliminary investigation. Int J Shoulder Surg 2009; 3: 80-4.
16. Hsiao MY, Hung CY, Chang KV, et al. Dynamic ultrasonography of the intra-articular long head biceps tendon and superior labrum. Am J Phys Med Rehabil 2016; 95: e183-e184.
17. Ricci V, Becciolini M, Özçakar L. "Hourglass" biceps tendon: an ultrasound "mime" of frozen shoulder? J Ultrasound Med. 2020; 39: 1021-2.
18. Chang KV, Wu WT, Özçakar L. Association of bicipital peritendinous effusion with subacromial impingement: a dynamic ultrasonographic study of 337 shoulders. Sci Rep 2016; 6: 38943.
19. Chang KV, Wu WT, Han DS, et al. Static and dynamic shoulder ultrasound imaging to

predict initial effectiveness and recurrence after ultrasound-guided subacromial corticosteroid injections. Arch Phys Med Rehabil 2017; 98: 1984-94.

20. Daghir AA, Sookur PA, Shah S, et al. Dynamic ultrasound of the subacromial-subdeltoid bursa in patients with shoulder impingement: a comparison with normal volunteers. Skeletal Radiol 2012; 41: 1047-53.
21. Thaker S, O'Connor P, Gupta H. Ultrasound evaluation of the rotator interval and adjoining tendons in shoulders with restricted movements: a technical note describing a simplified shoulder position. J Ultrasound. 2021 Jan 27. doi: 10.1007/s40477-020-00541-z.
22. Tamborrini G, Möller I, Bong D, et al. The rotator interval - a link between anatomy and ultrasound. Ultrasound Int Open. 2017; 3: E107-16.
23. Wu WT, Chang KV, Özçakar L. Dynamic ultrasound imaging for the diagnosis of superior labrum anterior to posterior lesion. Am J Phys Med Rehabil. 2019; 98: e130-e131.
24. Lee BJ, Park D. Glenoid labral detachment during dynamic ultrasonography in a patient with posterosuperior labral tear. Am J Phys Med Rehabil. 2020; 99: e105-e106.
25. Lee BJ, Han J, Lee H, et al. Dynamic ultrasonography of a patient with posterosuperior labral tear. Am J Phys Med Rehabil. 2020; 99: e19-e20.
26. Hsiao MY, Hung CY, Chang KV, Özçakar L. Dynamic ultrasonography of the intra-articular long head biceps tendon and superior labrum. Am J Phys Med Rehabil. 2016; 95: e183-e184.
27. Ricci V, Özçakar L. From "ultrasound imaging" to "ultrasound examination": a needful upgrade in musculoskeletal medicine. Pain Med. 2020; 21: 1304-6.

28. Ricci V, Özçakar L. Windshield wiper in the shoulder: Ultrasound imaging for the proximal rotator cuff interval. Am J Phys Med Rehabil. 2019; 98: e27.

29. Ricci V, Özçakar L. Looking into the joint when it is frozen: A report on dynamic shoulder ultrasound. J Back Musculoskelet Rehabil. 2019; 32: 663-5.

30. Vincenzo R, Levent Ö. Dynamic ultrasound imaging of the posterior capsule in the shoulder: tips and tricks. Kaohsiung J Med Sci. 2020; 36: 471-2.

31. Do HK, Lim JY. Ultrasonographic evaluation and feasibility of posterosuperior internal impingement syndrome: a case series. PMR 2017; 9: 88-94.

32. Desroches G, Desmeules F, Gagnon DH. Characterization of humeral head displacements during dynamic glenohumeral neuromuscular control exercises using quantitative ultrasound imaging: a feasibility study. Musculoskelet Sci Pract 2017; 29: 150-4.

33. Rathi S, Taylor NF, Green RA. The effect of in vivo rotator cuff muscle contraction on glenohumeral joint translation: An ultrasonographic and electromyographic study. J Biomech. 2016; 49: 3840–7.

34. Sikdar S, Wei Q, Cortes N. Dynamic ultrasound imaging applications to quantify musculoskeletal function. Exerc Sport Sci Rev. 2014; 42: 126-35.

35. Michael JW, Kuhn S, Yildirim B, et al. Dynamic ultrasound for the golfer shoulder. Int J Sports Med 2008; 29: 77-80.

36. Yuen CK, Chung TS, Mok KL, et al. Dynamic ultrasonographic sign for posterior shoulder dislocation. Emerg Radiol 2011; 18: 47-51.

37. Sanchez TR, Chang J, Bauer A, et al. Dynamic sonographic evaluation of posterior shoulder dislocation secondary to brachial plexus birth palsy injury. J Ultrasound Med. 2013; 32: 1531-4.

38. Ricci V, Galletti S, Chang KV, et al. Ultrasound imaging and guidance in the management of adhesive bursopathy of the shoulder: a video demonstration. J Ultrasound Med. 2020; 39: 633-5.

39. Dawson JS, Dowling F, Preston BJ, et al. Case report: lipoma arborescens of the sub-deltoid bursa. Br J Radiol. 1995; 68: 197-9.

40. Yoo HJ, Choi JY, Hong SH, et al. Assessment of the postoperative appearance of the rotator cuff tendon using serial sonography after arthroscopic repair of a rotator cuff tear. J Ultrasound Med. 2015; 34: 1183-90.

FIGURE LEGENDS

Figure 1

Schematic drawings show the dynamic assessment of the coracoid/subcoracoid space and the humeral groove during rotations of the glenohumeral joint **(A, B, C)**. Bursal effusion *(blue asterisk)* can be displaced medially - under the coracoid *(Cor)* and the coracoacromial ligament *(white arrowhead)* **(D)** - during abduction and/or flexion **(E)**. Of note, the pain may be related to the tension of the ligament and/or to the increase of the pressure inside the bursal cavity. Tendinosis of the proximal segment of the LHBT *(yellow arrowheads)* - hourglass biceps - should be considered among the causes of anterolateral shoulder impingement under the coracoacromial arch **(F)**.

SSP: supraspinatus tendon, red: rotator cuff, yellow: long head of the biceps tendon, white: coracoacromial ligament, blue: synovial bursa

Figure 2

Schematic drawings show the dynamic assessment of the acromiohumeral space during abduction **(A, B, C)**; of the acromioclavicular joint *(green)* during horizontal adduction **(D)** and, of the proximal segment of the LHBT *(yellow)* during specific shoulder movements **(E)**. In this patient, the effusion *(white asterisk)* around the intracapsular portion of the LHBT *(void arrowhead)* may be related to the mechanical impingement between the osteophyte *(yellow arrowhead)* of the superior pole of the humeral head and the biceps-labral complex **(F)**.

red: rotator cuff, white: coracoacromial ligament, blue: labrum, Gl: glenoid, black: transverse humeral ligament, black dotted lines: movements of the LHBT

Figure 3

Schematic drawings show the dynamic assessment of the supraspinatus fossa during abduction **(A)**, real-time evaluation of the posterior rotator cuff and glenohumeral joint during rotations **(B, C)** and during the ABER maneuver **(D, E)**. From the anatomical point of view, at the end phase of the ABER maneuver, the posterior glenohumeral recess *(yellow)* presents a C-shape extending from the humeral head *(HH)* to the base of the labrum *(blue)* passing deep to the infraspinatus *(ISP)* muscle-tendon unit **(F)**.

red: rotator cuff, blue: labrum, yellow: long head of the biceps tendon

VIDEO LEGENDS

Video 1

In physiological conditions, regular gliding of the subscapularis muscle-tendon unit can be observed at the level of the coracoid/subcoracoid space. No snapping phenomena or fluid collection is visible during dynamic assessment. Note that the subscapularis muscle belly - visible at the end of external rotation - should not be misinterpreted as an anechoic pathology.

Video 2

Complete injury of the subscapularis muscle-tendon unit (medially retracted) is associated with an anterior translation of the humeral head. During active rotations of the glenohumeral joint, it is possible to visualize the rolling of the naked humerus just below the fibers of the deltoid muscle with a mechanical conflict in the proximity of the coracoid bone.

Video 3

During dynamic scanning, the synovial fluid is pushed from the glenohumeral joint to the anterior compartment of the subacromial/subdeltoid bursa, confirming the full-thickness rotator cuff tear. Note that the peculiar pathway of fluid is related to the dynamic pressure gradient i.e. greater inside the joint and lower in the bursal cavity.

Video 4

In a patient with no ultrasonographic findings of subacromial-subdeltoid bursitis or rotator cuff tear, articular effusion is pushed from the glenohumeral cavity to a large superior subscapular recess during active shoulder external rotation. This phenomenon is related to the presence of Weitbrecht foramina at the level of the anterior glenohumeral capsule.

Video 5

The dynamic evaluation clearly shows friction between the (enlarged) proximal segment of the LHBT and the anterior deltoid muscle fibers. Herein, the - highly innervated - subdeltoid fascia should also be considered among the potential pain generators.

Video 6

The shape of the bicipital groove and the surrounding stabilizing structures (soft tissues) ensure a correct function of the LHBT during active shoulder movements. Note the anatomical continuity of the transverse humeral ligament with the subscapularis tendon fibers.

Video 7

The LHBT floats inside the effusion of the synovial sheath but does not shift out of the bicipital groove during dynamic scanning, confirming its mechanical stability.

Video 8

Widely diffuse gas microbubbles inside the sheath's effusion in a patient with intermittent snapping of the LHBT during sports activities.

Video 9

Regular gliding of the rotator cuff and synovial bursa (under the coracoacromial arch) during dynamic assessment. No snapping phenomena or fluid collection is visible.

Video 10

During dynamic assessment, transient snapping of the bursal nodule is clearly visualized under the coracoacromial ligament. Note that the mechanical conflict between the soft tissues can be painful and related to a feeling of click complained by the patient.

Video 11

A partially fragmented calcific deposition (located inside the rotator cuff tendons) impinges with the coracoacromial ligament during the dynamic evaluation - also reproducing the patient's complaint.

Video 12

In a patient with massive full-thickness tear of the superior portion of the rotator cuff, the thickened proximal segment of the LHBT, snapping under the coracoacromial ligament is clearly visible during the dynamic assessment.

Video 13

Regular gliding of the superior portion of the rotator cuff and subacromial/subdeltoid bursa (under the acromion) during active shoulder abduction. No mechanical impingement or fluid displacement is visible.

Video 14

Dynamic US imaging of the acromiohumeral space during abduction and adduction shows snapping of a bursal nodule under the inferior edge of the acromion.

Video 15

Dynamic assessment of the acromioclavicular joint (during horizontal adduction) shows misalignment of the articular surfaces with capsular bulging, confirming the posttraumatic joint instability.

Video 16

Dynamic assessment of the rotator interval (using the simplified Crass maneuver) shows the normal stabilization of the intraarticular portion of the LHBT by the soft tissues (the pulley). However, small amount of effusion is pushed from the glenohumeral joint into a delaminated rotator cuff tear, passing through a focal defect of the anterolateral capsule.

Video 17

During dynamic assessment, physiological rolling of the humeral head inside the glenoid is visualized. There is no synovial fluid or gas microbubbles slipping between the glenoid and the biceps-labral complex, confirming the anatomical integrity. The acoustic shadow on the left side of the screen is related to the acromion.

Video 18

Regular gliding of the posterior rotator cuff and the glenohumeral capsule - at the level of the posterior retroacromial space - during active shoulder internal rotation.

Video 19

Intraarticular effusion can be squeezed from the anterior to the posterior compartment of the glenohumeral capsule using active shoulder rotations. External rotation of the shoulder puts tension on the anterior capsule, pushing the fluid in the posterior capsule-synovial compartment i.e. between the infraspinatus muscle-tendon unit and the posterior labrum.

Video 20

Dynamic assessment clearly shows an advanced/degenerative deformity of the humeral head (associated with complete injury of the posterior rotator cuff and/or joint capsule) and severe subdeltoid effusion, impinging posteriorly with the glenoid bone. During active shoulder rotations, the fluid is pushed from the glenohumeral cavity to the subdeltoid collection, increasing the local pressure and exacerbating the pain.

Video 21

Dynamic evaluation better defines the partial and articular sided tear of the infraspinatus tendon, tensioning the fibers during active contraction of the muscle. Note the clearly visible posterior joint capsule between the tendon injury and the joint cavity.

Video 22

During passive rotations of the shoulder, it is possible to promptly confirm the complete injury of the infraspinatus tendon with partial preservation of the posterior glenohumeral capsule. Note that the anechoic effusion inside the synovial bursa and the glenohumeral joint clearly define the edges of the posterior capsule.

Video 23

During active rotations of the glenohumeral joint, hard calcific deposition located at the level of the infraspinatus tendon, impinges with the posterior deltoid muscle fibers, irritating the highly innervated subdeltoid fascia and provoking the pain ("fascial impingement").

Video 24

Dynamic US assessment - using the posterior retroacromial acoustic window - clearly shows regular gliding of the infraspinatus muscle over the ganglion of the posterior labrum. Any shift of synovial fluid from the glenohumeral joint to the labral cyst is not observed during the dynamic maneuver.

Video 25

Dynamic US imaging - of the posterior shoulder during ABER maneuver - clearly shows the physiological gliding and rolling of the posterior capsule-synovial complex over the glenoid bone and the posterior labrum.

Video 26

US-guided ABER maneuver promptly shows the posterior subluxation of the humeral head during the end phase of horizontal adduction.

Video 27

During US-guided ABER maneuver, intraarticular impingement (between the labral cyst and the posterior glenohumeral recess) is visualized, confirming the clinical hypothesis. Note that the mechanical conflict occurs only at the end phase of horizontal abduction due to the peculiar gliding/rolling movements of the posterior capsule-synovial complex.

Video 28

Asking the patient to actively contract the subscapularis muscle against resistance, the tendon fibers can be stretched and its full-thickness, incomplete tear can be confirmed. During the US-guided rotator cuff stress test, dynamic protrusion of the peribursal fat tissue inside the injury can be considered an additional ultrasonographic sign supporting the diagnosis.

Video 29

Minor movements of the shoulder - coupled with gentle sono-palpation - are necessary to visualize dynamic floating of the hypertrophic villi inside the bursal effusion. Note its connection with the bursal wall i.e. the stabilizing peduncle.

Video 30

Dynamic assessment of the hyperechoic subdeltoid mass promptly confirms the presence of a solitary oval nodule (originating from the subdeltoid bursa) which is suggestive for synovial lipoma.

Video 31

Combining sono-palpation and small movements of the shoulder; the "complex pattern" of the subacromial/subdeltoid bursa with several gas microbubbles moving inside the effusion, synovial fringes and thickened fibrotic septum partially compartmentalizing the bursal cavity are clearly visible. Note that the small gas bubbles might often be related to the presence of microcracks from the post-operative tendon, generating persistent flowing of the synovial fluid between the bursal cavity and the glenohumeral joint. Needless to say, such bubbles can otherwise/possibly represent infection with anaerobic bacteria as well.

Figure 1

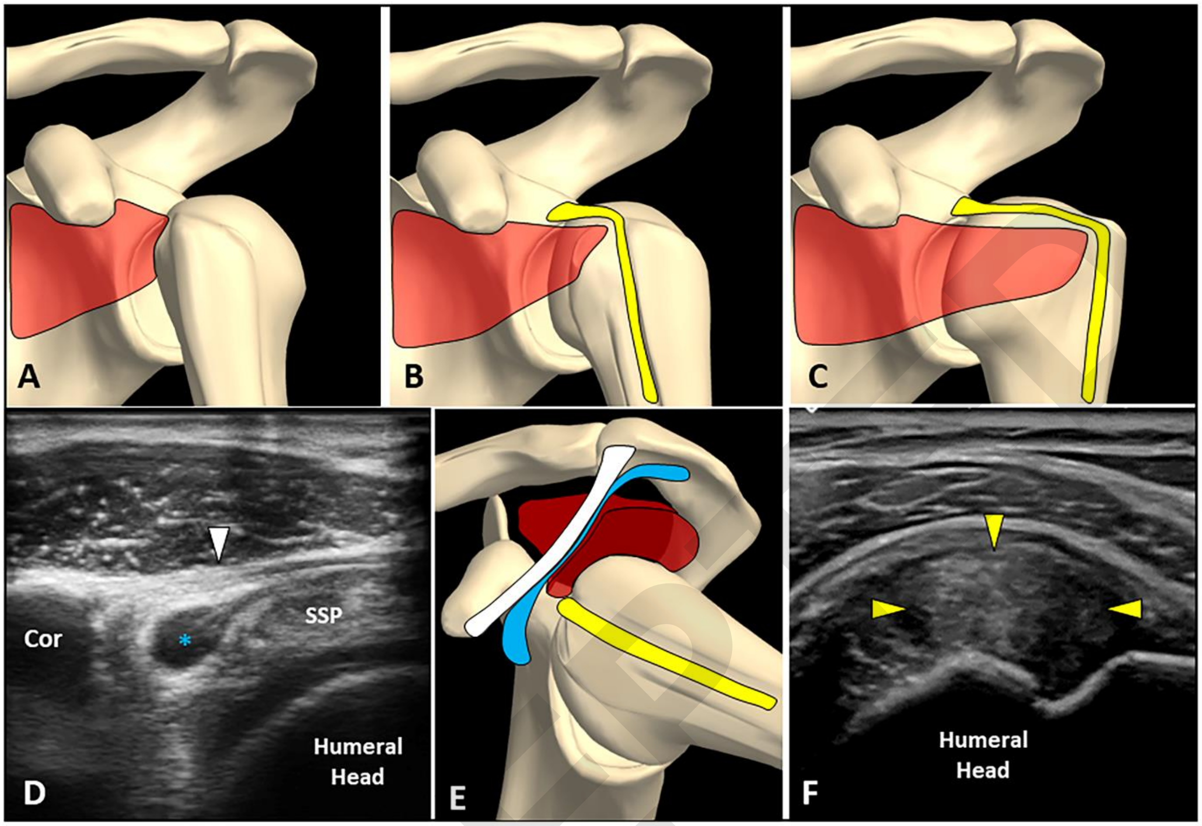

Figure 2

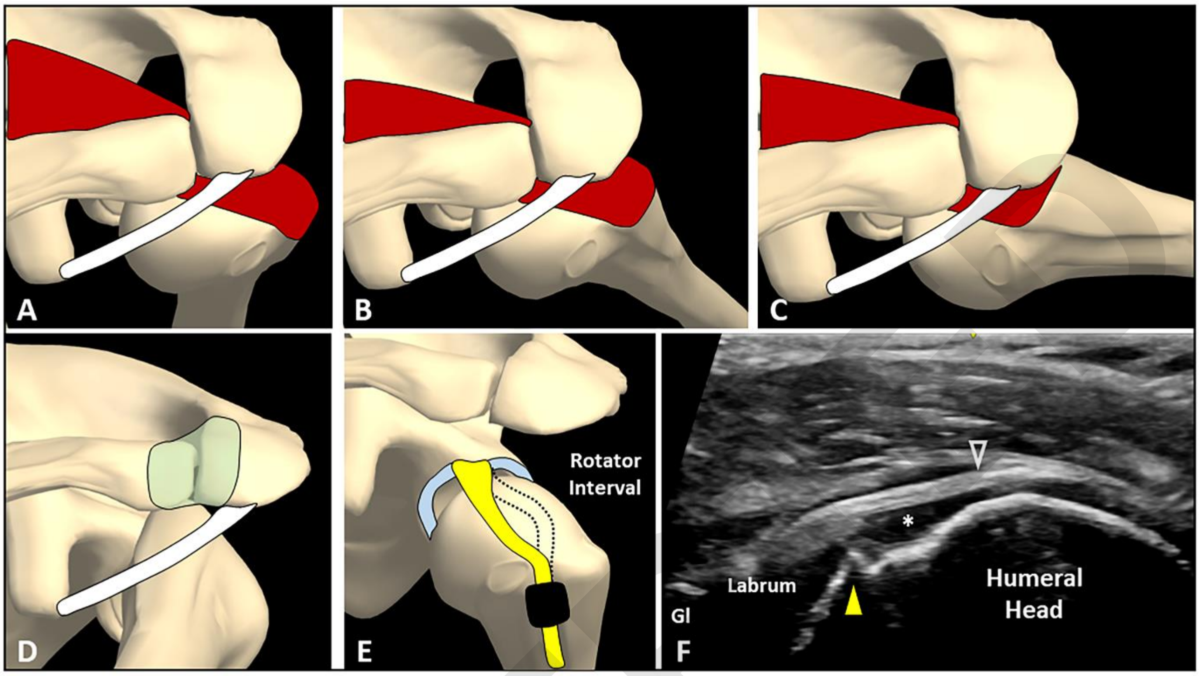

Figure 3