Pictorial essay

Cite as: Tamborrini G, Micheroli R, Ricci V, Becciolini M, Garcia-Pompermayer M, Serrano Belmar Gonzalo A, Müller-Gerbl M, Margenfeld F: Advancing high-resolution musculoskeletal ultrasound: A histology- and anatomy-driven approach for enhanced shoulder imaging. Part I: Posterior and coronal shoulder. J Ultrason 2024; 24: 26. doi: 10.15557/JoU.2024.0026.

Submitted: 11.02.2024
Accepted: 21.05.2024
Published: 27.08.2024

Advancing high-resolution musculoskeletal ultrasound: A histology- and anatomy-driven approach for enhanced shoulder imaging. Part I: Posterior and coronal shoulder

Giorgio Tamborrini*[,1,2], Raphael Micheroli*[,1,3], Vincenzo Ricci[4], Marco Becciolini[5,6], Mario Garcia-Pompermayer[7], Andres Serrano Belmar Gonzalo[8], Magdalena Müller-Gerbl[#,9], Felix Margenfeld[#,9]

[1] Ultrasound, UZR – Swiss Ultrasound Center, Institute of Rheumatology, Basel, Switzerland
[2] Clinic for Rheumatology, University Hospital of Basel, Basel, Switzerland
[3] Department of Rheumatology, University Hospital Zürich, Zürich, Switzerland
[4] Physical and Rehabilitation Medicine Unit, Luigi Sacco University Hospital, ASST Fatebenefratelli-Sacco, Milano, Italy
[5] Ultrasound, Misericordia di Pistoia, Pistoia, Italy
[6] Ultrasound, Scuola Siumb di Ecografia Muscoloscheletrica, Italy
[7] Rheumatology, Hospital San Jose, TecSalud, Tecnologico de Monterrey, Monterrey, Mexico
[8] Department of Radiology, Clínica Alemana, Santiago, Chile
[9] Institute of Anatomy, Department of Biomedicine, Musculoskeletal Research, University of Basel, Basel, Switzerland

** First author; # Last author*

Corresponding author: Giorgio Tamborrini; e-mail: msk_ultrasound@pm.me

DOI: 10.15557/JoU.2024.0026

Keywords
histology; anatomy; shoulder; sonography; ultrasound

Abstract

Ultrasound is a reliable imaging modality for diagnosing and assessing musculoskeletal disorders. Recent advancements in ultrasound technology have substantially improved image resolution, enabling the visualization of anatomic structures on a near-microscopic level. However, existing guidelines for standardized shoulder ultrasound primarily rely on earlier machine models and settings that may not harness the full potential of these high-resolution imaging capabilities. This article provides a simple and systematic guide to high-resolution sonography of the shoulder using anatomical and histological images from cadavers for comparison. International standard techniques are considered, and images were obtained using modern equipment. This two-article series systematically shows the examination and normal findings, presenting first the posterior, then frontal, then further anterior, followed by lateral and, optionally, the axillary examination. In this article, the focus is on the posterior and coronal shoulder.

Introduction

Ultrasound is a reliable imaging modality for diagnosing and assessing musculoskeletal disorders. Recent advancements in ultrasound technology have substantially improved image resolution, enabling visualization of anatomic structures on a near-microscopic level. However, there is as yet no atlas comparing ultrasound to anatomical and microscopic images that can be used for the proper allocation of ultrasound findings to anatomic structures. Existing guidelines for standardized shoulder ultrasound rely primarily on earlier machine models and settings that may not harness the full potential of these high-resolution imaging capabilities. Musculoskeletal ultrasound is a valuable diagnostic tool capable of observing soft tissue structures (Fig. 1) in addition to bone and cartilage[1]. Frequencies most often utilized vary from 5 MHz to 24 MHz, depending on the tissue or joint being studied. Musculoskeletal structures are evaluated statically with the benefit of multiplanar views as well as dynamically in real-time.

Objective

This study aims to propose a contemporary approach to shoulder ultrasound. This includes a standard atlas of images that compares ultrasound standard images to anatomy, respectively histology and leverages state-of-the-art high-resolution imaging technology to enhance the interpretation of ultrasound findings.

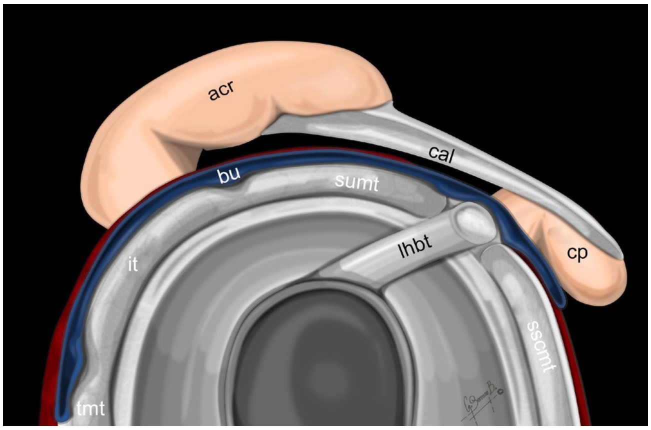

Fig. 1. *Illustration of the rotator cuff of the shoulder. acr – acromion; cal – coracoacromial ligament; cp – coracoid process; it – infraspinatus tendon; lhbt – long head biceps tendon; tmt – teres minor tendon, sscmt – subscapularis tendon, sumt – supraspinatus tendon, bu – bursa*

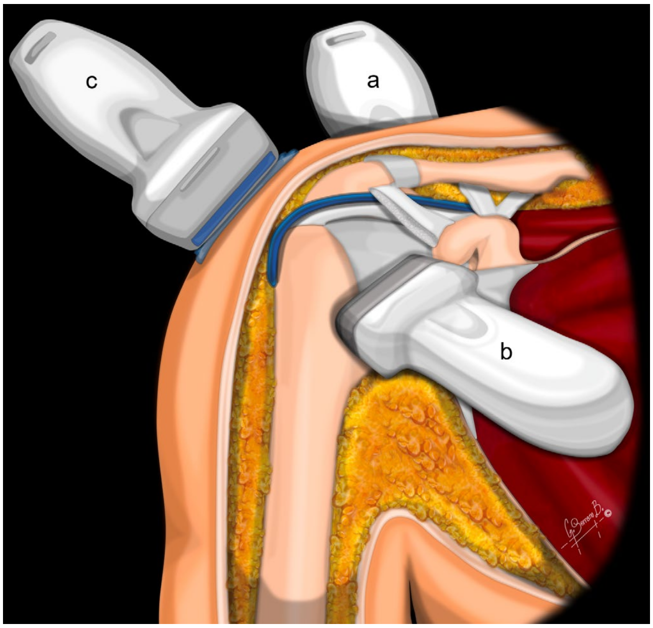

Fig. 2. *Illustration of a selection of probe positions, posterior/dorsal shoulder. a – posterior; b – anterior, c – lateral in the coronal plane*

Material and methods

To advance the standard of care in shoulder ultrasound, we implemented a series of systematic steps. Initially, we reviewed established ultrasound guidelines to identify recent developments in ultrasound anatomy, technology, and imaging settings, with a primary emphasis on enhancing the visualization of the detailed shoulder anatomy. In parallel, to establish a robust anatomical reference, anatomical and histological images were obtained from three body donors. Sections in different planes were prepared using standard methods and stained with hematoxylin and eosin (H&E) staining, ensuring a comprehensive understanding of the anatomical details. The preparation of the histological and anatomical images was performed in accordance with the Declaration of Helsinki.

To link anatomy and histology with ultrasound, we acquired ultrasound images from 10 volunteers and annotated the different anatomical and histological structures in the ultrasound images. To ensure reproducibility and validity, two sonographers performed this step. When structures were differently annotated, a decision was made based on consensus. The selected images and planes of views are based on official guidelines. The ultrasound device used is a LOGIQ E10 system from GE® with R3 software. The probes used are ML6-15-D, ML4-20, L8-18i-D and L6-24-D, and frequencies ranged from 8 MHz to 24 MHz, depending on the structure.

Tab. 1. Standard scans of the shoulder

- Posterior shoulder: longitudinal and transverse view, arm in neutral position
- Posterior shoulder: longitudinal and transverse view, arm in external rotation
- Posterior shoulder: longitudinal and transverse view, arm in internal rotation
- Frontal (coronal) view: longitudinal and transverse view, in neutral position
- Anterior shoulder: longitudinal and transverse view, in neutral position
- Anterior shoulder: longitudinal and transverse view, arm in external rotation
- Anterior shoulder: longitudinal and transverse view, arm in internal rotation
- Anterior shoulder: longitudinal and transverse view, arm in oblique position
- Lateral shoulder: longitudinal and transverse view, arm in neutral position
- Lateral shoulder: longitudinal and transverse view, arm in external and internal rotation

Shoulder examination procedure

A dynamic ultrasound examination from posterior (dorsal) to anterior (ventral) is the most common approach in clinical practice[2,3]. A chair or a rotating stool with or without a backrest is used to position the patient. The patient is seated upright in a relaxed position, with the patient's forearm resting on their thigh in a supinated position at the beginning of the examination. Depending on personal preference, the sonographer can stand or sit behind, in front of, or beside the patient. Based on our own experience, we suggest examining the posterior structures first, then the anterior and lateral structures (Fig. 2, Tab. 1). During this procedure, the examiner is seated behind the patient, with the ultrasound machine on the examiner's left side to adjust settings if necessary. Compared to having the patient in a supine position, sitting behind the patient and examining the posterior structures first allows for a more systematic, efficient, and ergonomic assessment with minimal patient repositioning, ensuring both thoroughness and patient comfort during the diagnostic process.

Ultrasound also allows the patient to view the examination via the device monitor or an optional second display, which may be helpful for explaining their pathology. This is, in our experience, well-accepted by patients and is a unique feature of ultrasound over other imaging modalities[4].

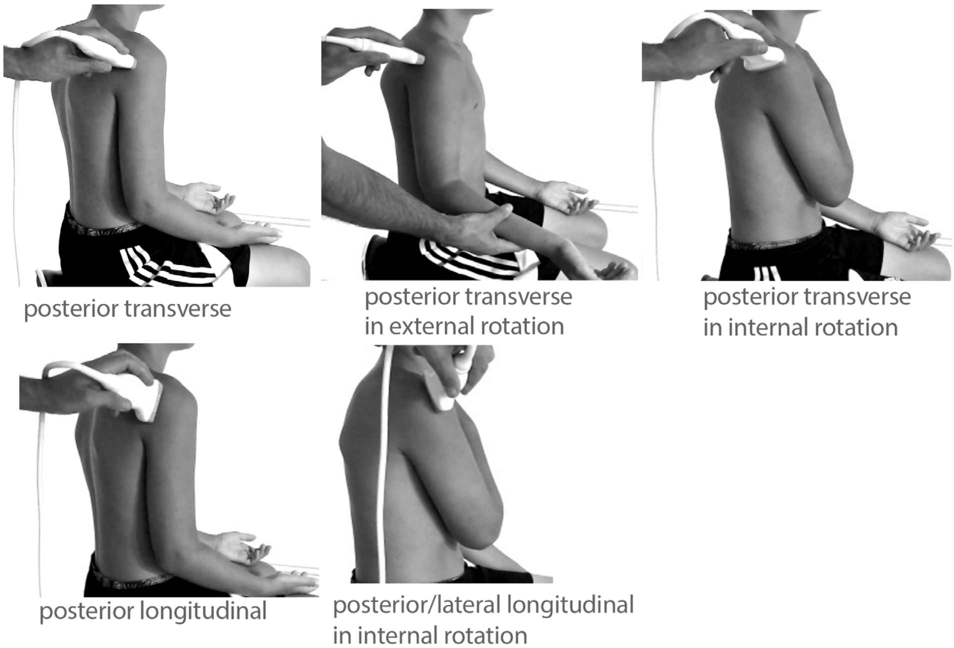

Fig. 3. *Probe positions, posterior/dorsal shoulder on the model*

Shoulder, posterior (dorsal)

Standard scans of the posterior shoulder (Fig. 3) (Tab. 2)

Anatomical structures of the posterior shoulder (Tab. 3)

Ultrasound scanning technique – posterior shoulder

The patient's hand is relaxed and placed on the thigh, with the elbow bent to examine the posterior part of the shoulder . The glenoid and humeral head are seen on opposite sides of the screen when the probe is positioned transversely above the glenohumeral joint (Fig. 4). From here the examiner may perform dynamic maneuvers; for example, internal rotation, external rotation, and place the hand on the opposite shoulder so that the muscles and tendons are put under tension. Rotating the arm both internally and externally allows the examiner to see how the humeral head moves inside the glenoid fossa (Fig. 5)[5]. The insertion of the teres minor tendon and the infraspinatus tendon on the inferior and posterior aspects of the greater tuberosity are the two main points of static and dynamic examination of the humeral head[6] (Fig. 6, Fig. 7).

While the teres minor tendon connects to both the surgical neck of the posterior humerus and the inferior facet of the greater tuberosity, the infraspinatus tendon is predominantly bound to the middle facet[7]. From the infraspinatus fossa, the infraspinatus muscle and the teres minor muscle may be visualized lower down. The probe is advanced laterally to demonstrate the myotendinous junction, and then the tendon until it reaches the insertion at the greater tuberosity. To better see the hyaline cartilage, bone, joint capsule, glenohumeral ligament, and separated enthesis of the tendons more clearly, it is useful to place the patient's hand on the opposite shoulder. When the arm is kept in the maximum external rotation position, special attention should be given to the dorsal and inferior recess of the joint

Tab. 2. Standard scans of the posterior shoulder

- Position: neutral position, elbow 90° flexion, hand in supination
- Dynamic active and passive internal and external rotation
- Longitudinal and transverse view, arm in neutral position
- Longitudinal and transverse view, arm in external position
- Longitudinal and transverse view, arm in internal and body cross position
- Dynamic ABER position (abduction + external rotation)

Tab. 3. Anatomical structures of the posterior shoulder

- Posterior aspect of the humeral head and humeral neck
- Glenoid, lateral angle of the scapula
- Scapular neck and spine
- Acromion (lateral)
- Glenohumeral joint recess (in between glenoid and humeral head, posterior glenoid fossa)
- Posterior glenoid labrum
- Spinoglenoid notch (suprascapular vessels and suprascapular nerve)
- Posterior joint capsule, glenohumeral ligament
- Deltoid muscle, dorsal part
- Infraspinatus muscle and tendon (from spine of the scapula / infraspinatus fossa to posterior facet of the greater tuberosity)
- Teres minor muscle and tendon (from infraspinatus fossa, follows intramuscular myotendinous connection; insertion: posterior/inferior facet of the greater tuberosity)
- Subdeltoid bursa, posterior part
- Quadrilateral space (posterior humeral circumflex vessels and axillary nerve)
- Triceps muscle

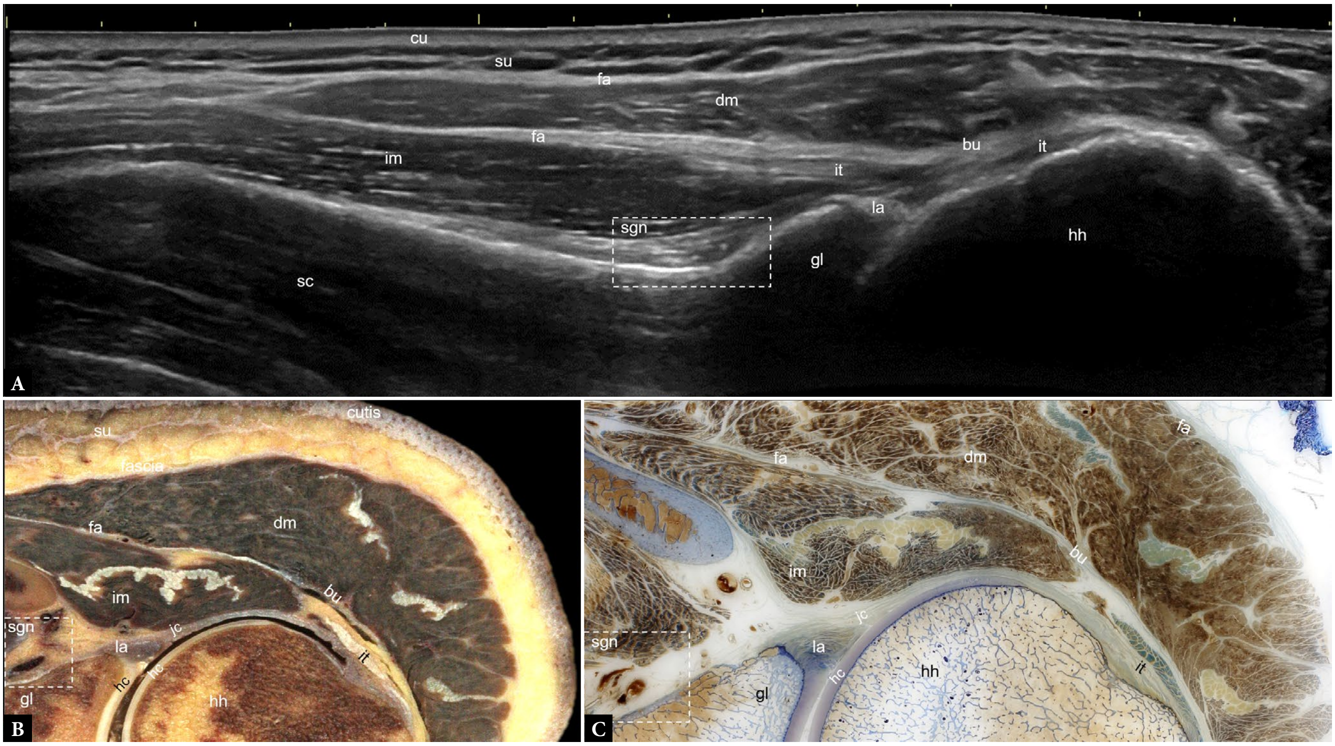

Fig. 4. *Posterior transverse overview.* **A.** *Gray-scale ultrasonography posterior transverse panoramic image.* **B.** *Anatomical image.* **C.** *Histological image. bu – bursa; cu – cutis; dm – deltoid muscle; fa – fascia; gl – glenoid; hc – hyaline cartilage; hh – humeral head; im – infraspinatus muscle; it – infraspinatus tendon; jc – joint capsule/ligament; la – labrum; sc – scapula; sgn – spinoglenoid notch; su – subcutis*

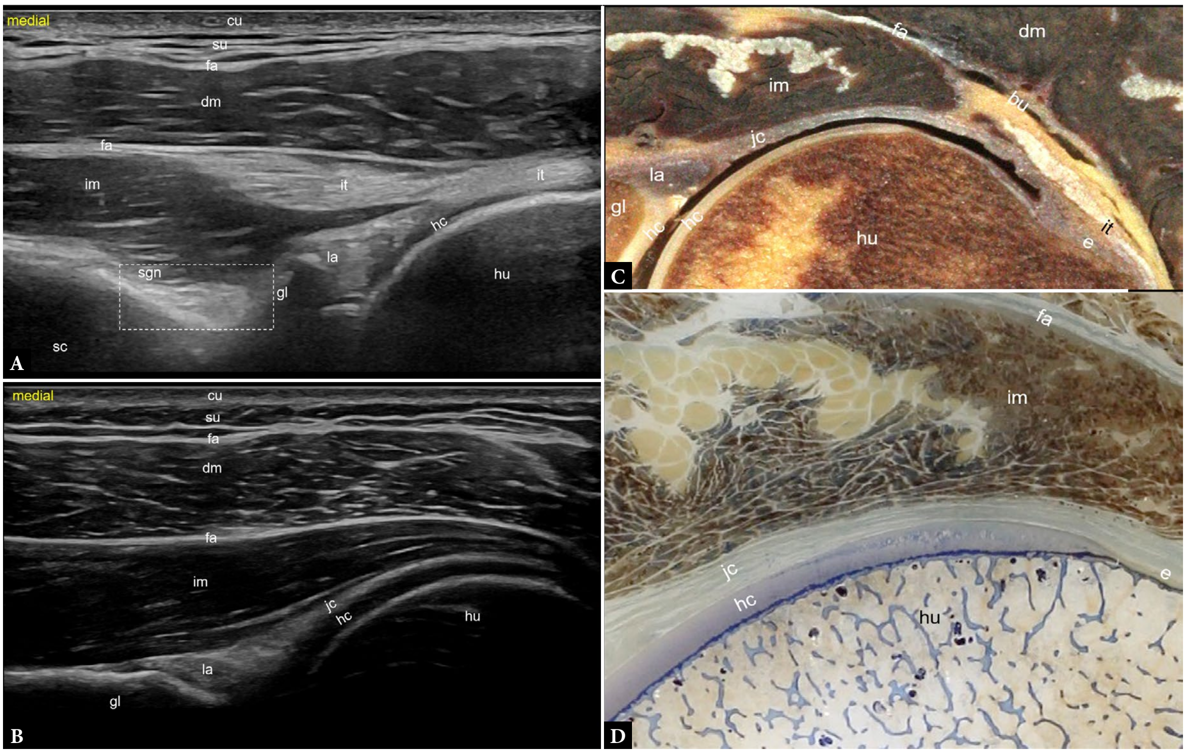

Fig. 5. *Posterior transverse.* **A.** *Gray-scale ultrasonography posterior transverse image in external rotation.* **B.** *Grayscale ultrasonography posterior transverse image in internal rotation.* **C.** *Anatomical image.* **D.** *Histological image. bu – bursa; cu – cutis; dm – deltoid muscle; e – enthesis; fa – fascia; gl – glenoid; hc – hyaline cartilage; hu – humeral head; im – infraspinatus muscle; it – infraspinatus tendon; jc – joint capsule/ligament; la – labrum; sc – scapula; sgn – spinoglenoid notch; su – subcutis*

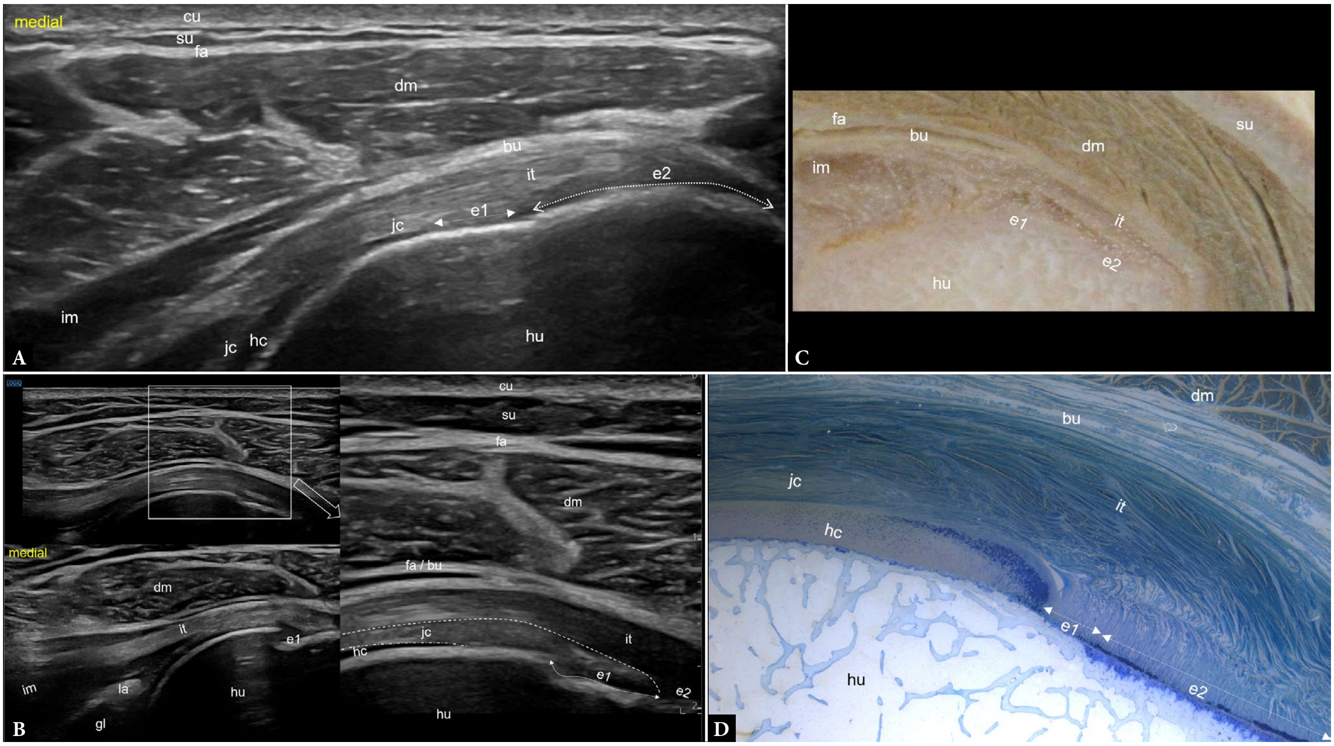

Fig. 6. *Posterior transverse.* **A**, **B.** *Gray-scale ultrasonography posterior transverse image in internal rotation.* **C.** *Anatomical image.* **D.** *Histological image. arrow – enlarged view of the cutout (box); bu – bursa; cu – cutis; dm – deltoid muscle; e1 – enthesis of the joint capsule/glenohumeral ligament; e2 – enthesis of the infraspinatus tendon; fa – fascia; gl – glenoid; hc – hyaline cartilage; hu – humeral head; im – infraspinatus muscle; it – infraspinatus tendon; jc – joint capsule/ligament; la – labrum; su – subcutis*

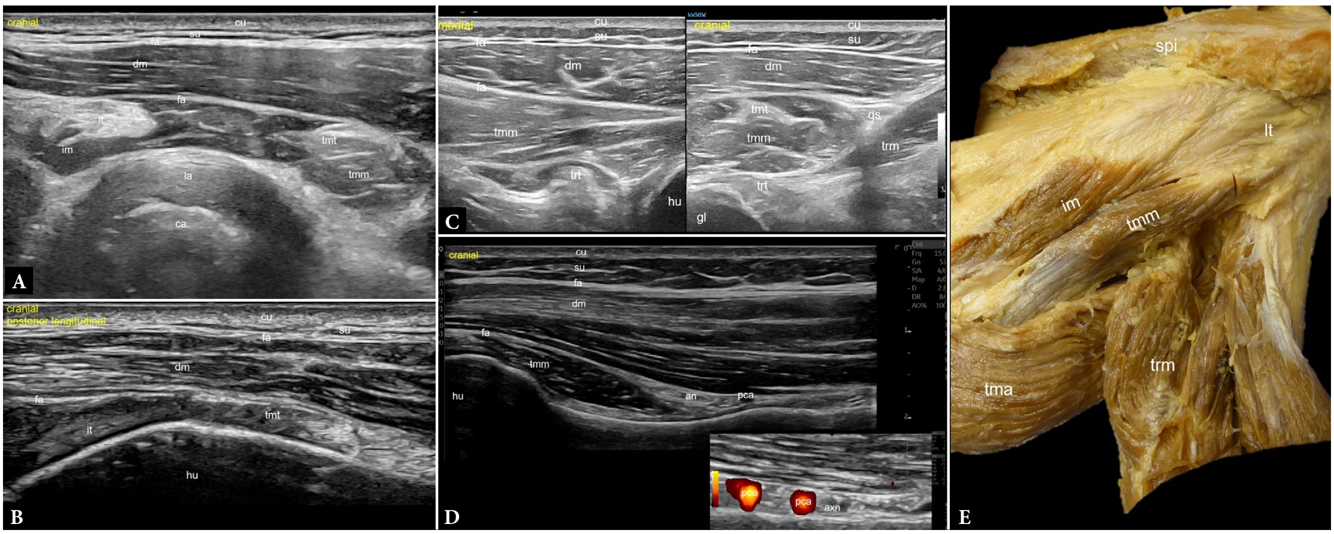

Fig. 7. *Posterior longitudinal.* **A.** *Gray-scale ultrasonography posterior longitudinal image.* **B.** *Gray-scale ultrasonography posterior longitudinal in internal rotation.* **C.** *Gray-scale ultrasonography posterior transverse (left) and longitudinal (right).* **D.** *Gray-scale and Power-Doppler ultrasonography posterior longitudinal.* **E.** *Anatomical image. axn – axillary nerve; ca –glenohumeral joint cavity; cu – cutis; dm – deltoid muscle; fa – fascia; gl – glenoid; gt – posterior facet of the greater tubercle; im – infraspinatus muscle; it – infraspinatus tendon; la – labrum; pca – posterior circumflex artery; su – subcutis; spi – scapular spine; tma – teres major muscle; tmm – teres minor muscle; tmt – teres minor tendon; trm – triceps muscle; trt –triceps tendon; qs – quadrilateral space*

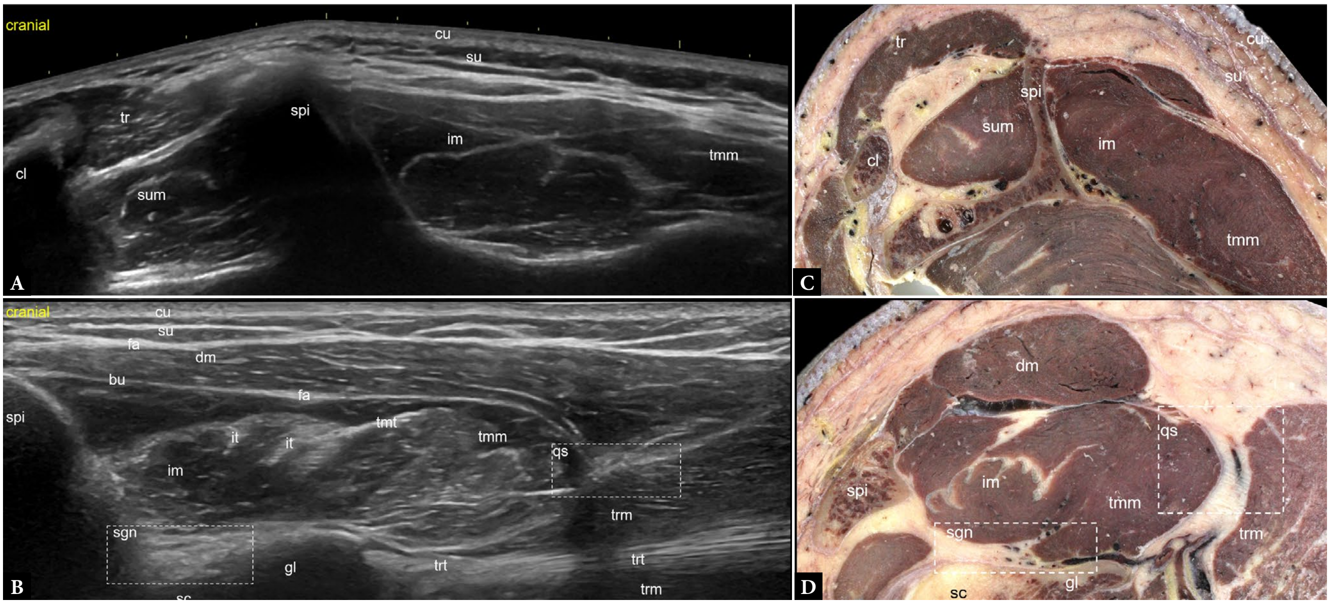

Fig. 8. *Posterior longitudinal overview.* **A, B.** *Gray-scale ultrasonography posterior longitudinal panoramic image.* **C, D.** *Anatomical image. bu – bursa; cl – clavicle; cu – cutis; dm – deltoid muscle; fa – fascia; gl – glenoid; im – infraspinatus muscle; it – infraspinatus tendon; sc – scapula; sgn –spinoglenoid notch; spi – scapular spine; su – subcutis; sum – supraspinatus muscle; tmm –teres minor muscle; tmt – teres minor tendon; tr – trapezius muscle; trm – triceps muscle; trt – triceps tendon; qs – quadrilateral space*

capsule, since intra-articular effusion is frequently observed in this position[5]. During the external rotation of the shoulder, the posterior capsule-synovial recess of the glenohumeral joint shows a "finger-shaped retroflection" in between the infraspinatus muscle/tendon and the posterior labrum. This sonographic finding is very important because it can be useful to both assess the intra-articular effusion and confirm the stiffness of the joint[8]. It is also frequently seen that during vigorous internal rotation, the posterior/inferior (axillary) recess fills up considerably. From the biomechanical point of view, during an additional ABER (abduction + external rotation) maneuver, the posterior capsule "rolls up" over the posterior labrum/glenoid[9]. This dynamic maneuver can be used to assess the eventual presence of internal posterior impingement of the shoulder with pinching of the posterior glenohumeral joint recess (capsule and synovium) and the deep fibers of the infraspinatus between the humeral head and glenoid of the scapula. To see the inferior glenohumeral ligament, the joint capsule, and the axillary recess, move the probe caudally. Examining the transition from muscle to tendon is aided by longitudinal sonograms of the muscles in the infraspinatus fossa and more distally at the level of the teres minor muscle. When evaluating the infraspinatus in the long axis, it is possible to observe bursitis, glenohumeral synovitis, and tears of the infraspinatus tendon at the insertion level[10]. The axillary nerve[11] and posterior humeral circumflex artery in the quadrilateral space, as well as the triceps muscle in the inferior section of the glenoid, can be observed (Fig. 7, Fig. 8). The quadrilateral space of Velpeau area is bounded by the triceps brachii long head medially, the surgical neck of the humerus laterally, the teres major inferiorly, and the teres minor superiorly[12].

Shoulder, frontal/coronal

Standard scans of the frontal shoulder (Tab. 4) (Fig. 9)

Anatomical structures of the frontal shoulder (Tab 5.)

Tab. 4. Standard scans of the frontal shoulder

- Position: neutral position, elbow 90° flexion, hand in supination
- Dynamic active and passive adduction, abduction, internal and external rotation
- Multiplanar, longitudinal and transverse frontal scans

Tab. 5. Anatomical structures of the frontal shoulder

- Joint capsule of the acromioclavicular (AC) joint
- Glenohumeral joint, cranial part, lateral to the suprascapular notch
- Superior and inferior AC ligament
- Acromion
- Clavicle
- Greater tuberosity, lateral part
- Labrum, joint capsule and glenohumeral ligament, cranial part
- Suprascapular notch with suprascapular vessels and suprascapular nerve (medial to the superior part of the glenoid, labrum)
- Superior transverse scapular ligament
- Deltoid muscle, lateral part
- Supraspinatus muscle in the supraspinatus fossa
- Tendon of the supraspinatus muscle with its insertion at the greater tuberosity
- Subdeltoid-subacromial bursa, subacromial part

Ultrasound scanning technique – frontal/coronal shoulder

The probe is advanced from the posterior shoulder region to the frontal (coronal) level and positioned across the top of the shoulder in the coronal plane[13]. The acromioclavicular (AC) joint is typically simple to locate (Fig. 10). As an alternative approach, the

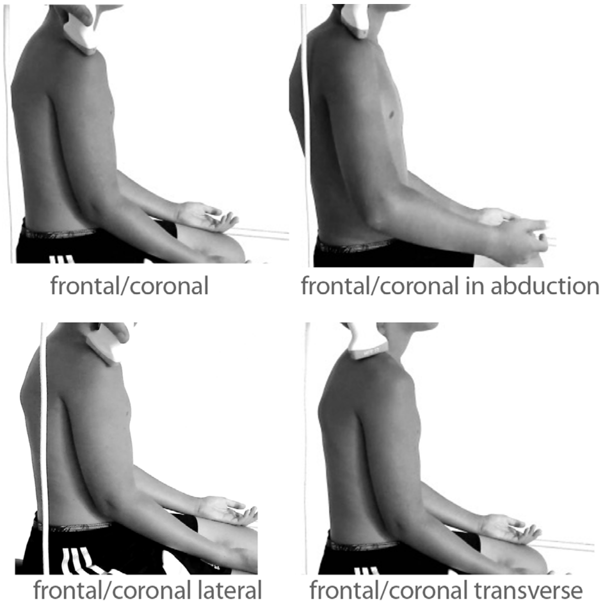

Fig. 9. *Probe positions, frontal/coronal*

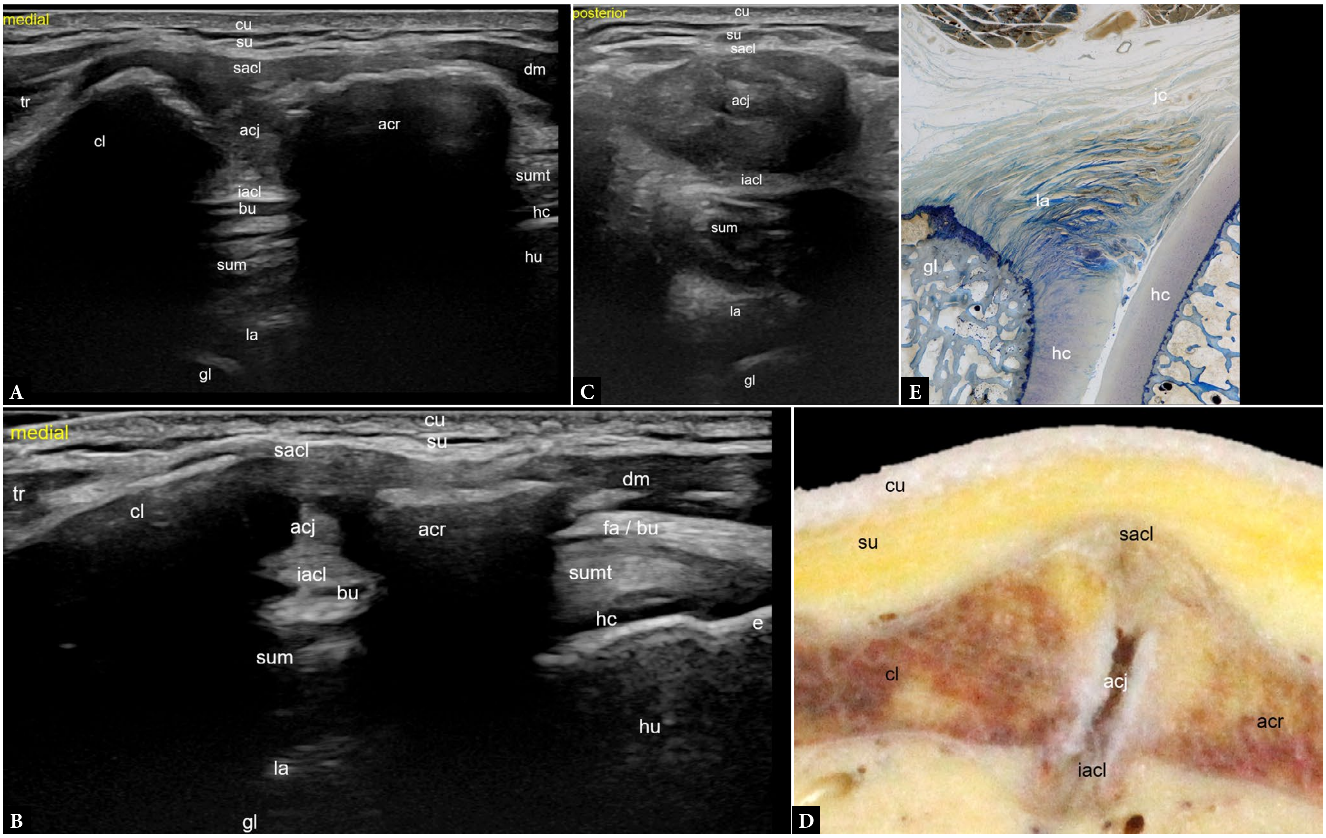

Fig. 10. *Coronal region.* **A**, **B.** *Gray-scale ultrasonography coronal transverse image.* **C.** *Gray-scale ultrasonography coronal longitudinal image.* **D.** *Anatomical image of the AC joint.* **E.** *Histological image of the superior part of the labrum and the glenohumeral joint. acj – acromioclavicular joint cavity; acr – acromion; cl – clavicle; cu – cutis; dm – deltoid muscle; hc – hyaline cartilage; hu – humeral head; iacl – inferior acromioclavicular ligament; jc – joint capsule; la – labrum; sacl – superficial acromioclavicular ligament; su – subcutis; sum – supraspinatus muscle; sumt – supraspinatus tendon; sun – suprascapular notch*

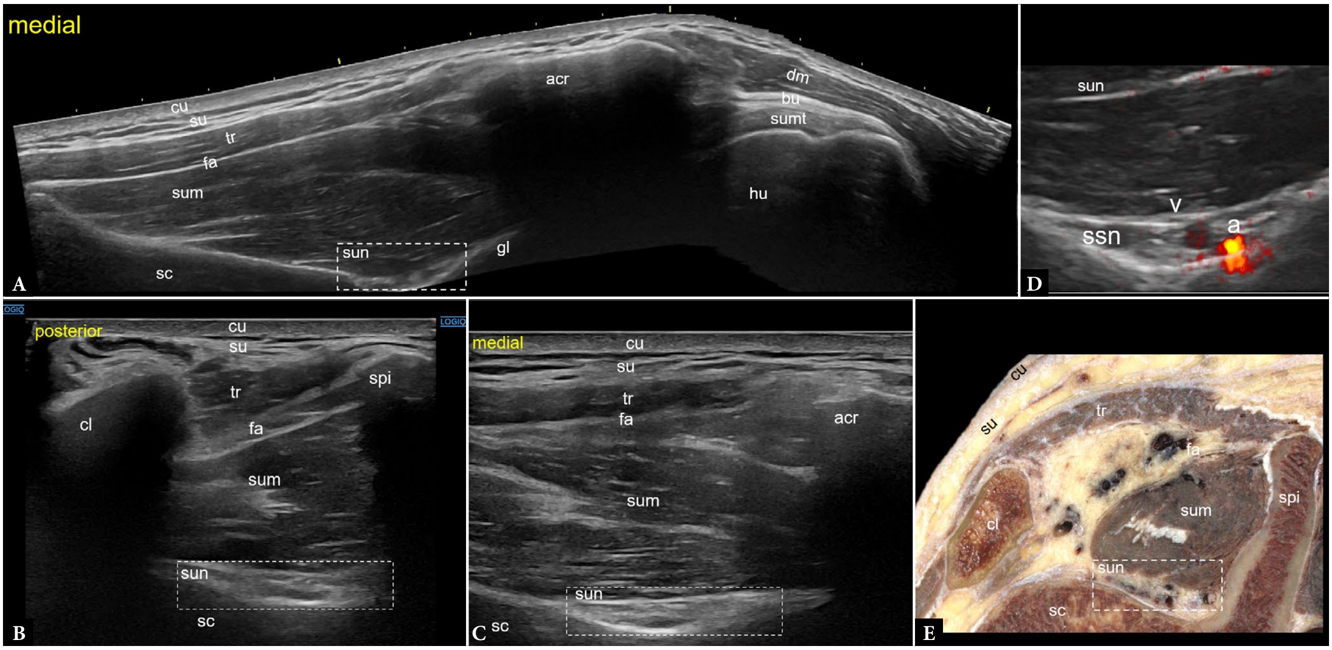

Fig. 11. *Coronal views.* **A.** *Gray-scale ultrasonography coronal transverse panoramic image.* **B.** *Gray-scale ultrasonography coronal longitudinal image.* **C.** *Gray-scale ultrasonography coronal transverse image.* **D.** *Power-Doppler ultrasonography coronal transverse image.* **E.** *Anatomical image. acr – acromion; a – artery; cl – clavicle; cu – cutis; dm – deltoid muscle; fa – fascia; hu – humeral head; sc – scapula; spi – scapular spine; ssn – suprascapular nerve; su – subcutis; sum – supraspinatus muscle; sumt – supraspinatus tendon; sun – suprascapular notch; v – vein*

probe is placed over the palpable clavicle; subsequently, the ultrasound transducer is shifted laterally in the direction of the acromion to the AC joint[14]. The superficial AC ligament, joint capsule, disc-like fibrocartilage, and surrounding bone structures are evaluated[15]. We suggest to continuously scan in both longitudinal and transverse planes. Observe the acromion and the transition to the scapular spine. The subacromial portion of the subdeltoid bursa, the greater tuberosity where the supraspinatus tendon inserts, the whole superior part, and the lateral humeral head are evaluated at the frontal level. In certain cases – and using deeper probe frequencies (<12 MHz) – the supraspinatus tendon, the subacromial-subdeltoid bursa, and the deep (inferior) AC ligament can be seen by scanning through the AC joint. When performing a dynamic movement (such as an abduction), the supraspinatus tendon may be seen moving through the AC joint window. The supraspinatus fossa is reached by moving the probe posteriorly and medially from the AC joint (Fig. 11). The supraspinatus fossa is concave[16], wider at the medial than at the lateral end, and smaller than the infraspinatus fossa. The supraspinatus muscle originates from its medial two-thirds[17]. Here, you may also evaluate the subacromial portion of the subdeltoid bursa under the trapezius muscle, the supraspinatus muscle, the myotendinous junction, the superior glenoid, the biceps-labral complex[18–21], the joint capsule, the suprascapular notch, and the superior labrum.

Conclusion

The shoulder is particularly accessible for ultrasonic imaging since the joint is covered by relatively few osseous structures. A thorough understanding of sonoanatomy is necessary to provide an accurate structural evaluation, which is the goal of high-resolution musculoskeletal ultrasonography of the shoulder. In optimal conditions, modern high-resolution musculoskeletal ultrasound can improve shoulder imaging by correlating structures to cross-sectional anatomy and detailed histology. This atlas provides an overview of the normal findings.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

Author contributions

Original concept of study: GT, RM, MMG, FM. Writing of manuscript: GT, RM, FM. Analysis and interpretation of data: GT, RM, VR, MB, MGP, FM. Final acceptance of manuscript: GT, RM, VR, MB, MGP, ASBG, MMG, FM. Collection, recording and/or compilation of data: GT, RM, FM. Critical review of manuscript: GT, RM, VR, MB, MGP, ASBG, MMG, FM.

References

1. Tamborrini G, Dejaco C, Mandl P: Musculoskeletal ultrasound. In: Dietrich CF (ed.): EFSUMB Course Book, 2nd Edition, 2019. doi: 10.37713/ECB05.
2. Tamborrini G, Bianchi S: Ultraschall der Schulter (adaptiert nach SGUM-Richtlinien) [Ultrasound of the Shoulder (Adapted According to SGUM Guidelines)]. Praxis (Bern 1994) 2020; 109: 521–530. German. doi: 10.1024/1661-8157/a003470.
3. Ricci V, Chang KV, Güvener O, Mezian K, Kara M, Leblebicioğlu G *et al*. EURO-MUSCULUS/USPRM Dynamic Ultrasound Protocols for Shoulder. Am J Phys Med Rehabil. 2022 Mar 1;101(3):e29-e36. doi: 10.1097/PHM.0000000000001833.
4. Sconfienza LM, Albano D, Allen G, Bazzocchi A, Bignotti B, Chianca V *et al*.: Clinical indications for musculoskeletal ultrasound updated in 2017 by European Society of Musculoskeletal Radiology (ESSR) consensus. Eur Radiol 2018; 28: 5338–5351. doi: 10.1007/s00330-018-5474-3.
5. Schmidt WA, Schicke B, Krause A: Schultergelenkerguss: Welcher Ultraschallschnitt ist der beste? [Which ultrasound scan is the best to detect glenohumeral joint effusions?]. Ultraschall Med 2008; 29 (Suppl 5): 250–255. German. doi: 10.1055/s-2008-1027330.
6. Erber B, Hesse N, Goller S, Reidler P: Pathologien des Schultergelenks: Anatomie und Untersuchungstechniken [Pathologies of the shoulder joint : Anatomy and examination techniques]. Radiologie (Heidelb) 2023; Dec 12. German. doi: 10.1007/s00117-023-01246-0.
7. Griffith JF: Top-Ten Pitfalls in Rotator Cuff Ultrasound. Semin Musculoskelet Radiol 2019; 23: 429–435. doi: 10.1055/s-0039-1693488.
8. Ricci V, Özçakar L: Looking into the joint when it is frozen: A report on dynamic shoulder ultrasound. J Back Musculoskelet Rehabil 2019; 32: 663–665. doi: 10.3233/BMR-181448.
9. Vincenzo R, Levent Ö: Dynamic ultrasound imaging of the posterior capsule in the shoulder: Tips and tricks. Kaohsiung J Med Sci 2020; 36: 471–472. doi: 10.1002/kjm2.12190.
10. Mezian K, Novotný T, Chomiak J, Hrazdira L: Sonografické vyšetření ramena [Scanning Technique in Shoulder Ultrasonography]. Acta Chir Orthop Traumatol Cech 2021; 88 (4 Suppl): 9–14. Czech. doi: 10.55095/achot2021/073.
11. Bruckmoser R, Antoniadis G, Katzensteiner M, Wutte C, Schlagheck J, Stuby FM *et al*.: High-resolution ultrasound of the supra- and infraclavicular levels of the brachial plexus including the axillary nerve: imaging anatomy based on multiplanar reconstructions and technical guide. Ultraschall Med 2023 Dec 27. English. doi: 10.1055/a-2191–1893.
12. Khan IA, Varacallo M: Anatomy, shoulder and upper limb, arm quadrangular space. 2023 Jul 30. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023.
13. Selame LAJ, Matsas B, Krauss B, Goldsmith AJ, Shokoohi H: A stepwise guide to performing shoulder ultrasound: the acromio-clavicular joint, biceps, subscapularis, impingement, supraspinatus protocol. Cureus 2021; 13: e18354. doi: 10.7759/cureus.18354.
14. Carretta G, De Nicola T, Gongolo R, Liberati L, Villabruna M: Ecografia della spalla: l'articolazione acromio-claveare [Ultrasonography of the shoulder: the acromioclavicular joint]. Radiol Med 1994; 88: 1–7. Italian.
15. Wong M, Kiel J: Anatomy, shoulder and upper limb, acromioclavicular joint. [Updated 2023 Jul 24]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK499858/
16. Jeno SH, Munjal A, Schindler GS: anatomy, shoulder and upper limb, arm supraspinatus muscle. [Updated 2023 Aug 28]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK537202/.
17. Schneebeli A, Egloff M, Giampietro A, Clijsen R, Barbero M: Rehabilitative ultrasound imaging of the supraspinatus muscle: Intra- and interrater reliability of thickness and cross-sectional area. J Bodyw Mov Ther 2014; 18: 266–272. doi: 10.1016/j.jbmt.2013.09.009.
18. 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. doi: 10.1097/PHM.0000000000000528.
19. 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. doi: 10.1097/PHM.0000000000001132.
20. 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. doi: 10.1097/PHM.0000000000001294.
21. Lee BJ, Han J, Lee H, Park D: Dynamic ultrasonography of a patient with posterosuperior labral tear. Am J Phys Med Rehabil 2020; 99: e19–e20. doi: 10.1097/PHM.0000000000001177.