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ULTRASOUND

Detection and quantification of glenohumeral joint effusion: reliability of ultrasound

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Abstract
Objectives To evaluate reliability of ultrasound for detection and quantification of glenohumeral joint effusion.
Methods With institutional review board approval and informed consent ultrasound of 30 consecutive patients before and after MR arthrography of the shoulder was performed. Presence and width of any anechoic collection was noted within various locations (biceps tendon sheath, subscapular recess (neutral position and internal rotation), posterior glenohumeral joint recess (neutral position and external rotation)). Injected fluid (8–12 ml) into the glenohumeral joint served as gold-standard. Widths of anechoic collections were correlated (Spearman rank correlation) with injected fluid.
Results Glenohumeral anechoic collection was consistently seen in the posterior glenohumeral joint recess with the arm in external rotation (100%, 30/30), and in the biceps tendon sheath (97%, 29/30). Ultrasound was not sensitive at other locations (7%–17%). Mean width in anterior-posterior direction of anechoic collection in the posterior glenohumeral joint recess was 7 mm (range: 3–18 mm), 2 mm (range: 1–7 mm) in the biceps tendon sheath. Significant correlation (R=0.390, p=0.033) was found between width of anechoic collection and injected fluid in the posterior glenohumeral joint recess.
Conclusions Glenohumeral joint effusion can be detected and quantified most reliably in the posterior glenohumeral joint recess with the arm in external rotation.

Keywords Effusion · Glenohumeral joint · Ultrasound · Quantification of joint effusion · Shoulder infection

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Introduction

Ultrasound is routinely used for the evaluation of shoulder abnormalities including lesions of the rotator cuff, subacromial subdeltoid bursitis, greater tuberosity fracture, adhesive capsulitis, synovial osteochondromatosis, osteoarthritis, haemarthrosis, and infectious disorders such as septic arthritis and bursitis [1–8].

Effusion in the glenohumeral joint is often encountered in many of these conditions. For the diagnosis of rheumatoid or septic shoulder arthritis, the detection of effusion is an important ancillary finding. In the presence of joint effusion in patients with suspected septic arthritis, a joint fluid aspiration is commonly performed. Reliable detection and localization, as well as unequivocal exclusion of glenohumeral joint effusion with ultrasound are important, especially in clinical conditions of severe shoulder pain and increased blood infection parameters.

Although the technique for shoulder ultrasound is well known and numerous well elaborated guidelines are available [9–13], information on the reliability of diagnosing a joint effusion diagnosis is missing.

No data in the English peer reviewed literature about the reliability of ultrasound for detecting and quantifying glenohumeral joint effusion nor information about the most appropriate examination technique for this assessment could be found. Thus, the purpose of this study was to evaluate the reliability of ultrasound for the detection and quantification of glenohumeral joint effusion.

Materials and methods

Study design

In this prospective study, anechoic collections seen with ultrasound at various locations before and after MR arthrography of the shoulder were compared with the injected amount of fluid used for MR arthrography. The study was approved by the local ethics review board. All patients gave written informed consent.

Patient population

Thirty consecutive patients (18 men, 12 women, mean age 51 years, range: 18–72 years) referred for MR arthrography of the shoulder were prospectively included into the study. Exclusion criterion was age younger than 18 years.

Ultrasound

Ultrasound of the shoulder was performed before and after (less than 5 min (1–5 min) MR arthrography of the shoulder by one of two musculoskeletal radiologists, one with 15 years, and the other with 3 years experience in ultrasound of the shoulder. A Philips iU22 ultrasound machine was used with a high-frequency 17-5 MHz linear-array transducer. In three patients, a 9-3 MHz linear-array transducer had to be used due to high corpulence. Examination was standardized and consistent in each session and in each patient.

The patients were sitting in the upright position, facing the ultrasound screen, with the radiologist standing behind the patient. The presence of fluid, identified as an anechoic collection, was noted and measured (mm) in two perpendicular planes in the following locations and positions: in the biceps tendon sheath (arm in slight internal rotation with the elbow flexed 90°, palm up); in the subscapular recess in neutral position and with internal rotation of the upper arm (arm internally rotated, elbow flexed 90° and held against the patient's side, placing the hand to the opposite hip); and in the posterior glenohumeral joint recess in neutral position and in external rotation (arm externally rotated as far as possible, thump upwards, elbow flexed 90° and held against the patient's side), respectively.

Arthrography

For MR arthrography, 1 ml of local anaesthetic (mepivacain hydrochloride 2%; Scandicain; AstraZeneca, London, England), 1–2 ml of iodinated contrast agent (Iopamidol, 200 mg/ml; Iopamiro 200; Bracco, Milan, Italy), and a maximum of 10 ml 2 mmol/l gadopentetate dimeglumine (Magnevist; Bayer HealthCare, Berlin, Germany) were injected under fluoroscopic control using an anterior approach [14]. The injection volume was reduced when the patient indicated increased pressure or pain (minimum 8 ml). The total quantity of intraarticular fluid varied between 8 and 12 ml (mean 10.5 ml). The delay between first ultrasound and injection as well as between injection and second ultrasound was less than 5 min (1–5 min). The delay between injection and MRI was less than 20 min (1–20 min).

MR protocol

MR imaging was performed on a 1.5- or 3T system (Avanto, Symphony or Esprit, Siemens Medical Solutions, Erlangen, Germany). The shoulder was placed in a dedicated receive-only shoulder coil. The arm position was standardized, with the thumb pointing upward. Water-excitation, true fast imaging with steady-state precession (trueFISP) images were obtained in the transverse plane (11–98/5.15 {repetition time msec/echo time msec}, 1.7-mm section thickness, 180×180-mm field of view). Fat-suppressed T1-weighted spin-echo images (667/12, 3-mm section thickness, 160×160-mm field of view) and intermediate-weighted fast spin-echo images (2,500/35, 4-mm section thickness, 160×160-mm field of view) were both obtained in the coronal oblique plane, perpendicular to the glenohumeral joint space. Fat-suppressed T2-weighted fast spin-echo images (4,140/77, 4-mm section thickness, 160×160-mm field of view) and T1-weighted spin-echo images (531/12, 4-mm section thickness, 160×160 field of view) were obtained in the sagittal plane.

Standard of reference, statistics

The total amount of fluid injected into the glenohumeral joint (8–12 ml) was used as the standard of reference. All ultrasound measurements were correlated (Spearman's rank correlation coefficient) to the injected fluid volume during the MR arthrography. If anechoic collection was seen on ultrasound imaging before MR arthrography, measurements before MR arthrography were subtracted from measurements after MR arthrography. The MR images verified the intraarticular fluid accumulation. All analyses were performed with statistical software (SPSS for Windows, release 16.0.1; SPSS, Chicago, Ill). A p-value <0.05 was considered as statistically significant.

Results

Anechoic collection before and after fluid injection, qualitative data (Table 1)

Before injection of fluid (=local anaesthetic, iodinated contrast agent, and gadopentetate dimeglumine) in the glenohumeral joint, anechoic collection (=joint effusion) was found in nine patients (9/30, 30%): in these nine patients, fluid was found only in the biceps tendon sheath in 4/30 (13.3%), in 2/30 patients (6.7%) only in the posterior glenohumeral joint recess in external rotation, and in 3/30 patients (10%) in both of these two locations. In the subscapular recess and in the posterior glenohumeral joint recess in neutral position, no anechoic collection was found before injection.

After injection of the fluid in the glenohumeral joint, anechoic collection was found in the biceps tendon sheath in 29 patients (97%) (Fig. 1). Anechoic collection was found in the subscapular recess in neutral position in 2/30 patients (7%), in the subscapular recess with internal rotation of the upper arm in 3/30 patients (10%) (Fig. 2). In the posterior glenohumeral joint recess in neutral position, anechoic collection was detected in 5/30 patients (17%). Anechoic collection was found in the posterior glenohumeral joint recess with the arm in external rotation in all patients (30/30, 100%) (Fig. 3).

Anechoic collection before and after fluid injection, quantitative data (Table 2)

Before injection of fluid the mean width of anechoic collection in the biceps tendon sheath was 0.6 mm in the transverse plane (range 0–5.7 mm), and 0.6 mm in the longitudinal plane (range 0–4.7 mm), respectively. *After* injection the mean width of anechoic collection in the biceps tendon sheath was 2 mm transverse and 2.3 mm longitudinal (ranges 0.9–6.9 and 0–7.1 mm); the difference of the mean width of anechoic collection was 0.9 mm and 1.2 mm (transverse plane/longitudinal plane).

In the subscapular recess no anechoic collection was found *before* injection. *After* injection, the mean width of anechoic collection detected in neutral position was in both directions 0.2 mm (range in the anterior-posterior direction 0–5 mm, in the medial-lateral direction 0–4.5 mm); in internal rotation it was each 0.4 mm (ranges 0–7.8 mm and 0–6.3 mm).

In the posterior glenohumeral joint recess in neutral position, fluid was found only after injection: the mean width was 0.7 mm (range 0–6.9 mm) in the anterior-posterior direction, and 2.9 mm (range 0–25 mm) in the medial-lateral direction.

In the posterior glenohumeral joint recess with external rotation, the detected mean width of anechoic collection was 0.7 mm (range 0–6.1 mm) in the anterior-posterior direction, and 2.1 mm (range 0–20.5 mm) in the medial-lateral direction *before* injection. *After* injection, the mean width was 7.2 mm (anterior-posterior direction) (range 2.8–18 mm) and 16.7 mm (medial-lateral direction) (range 4.6–33 mm). The differences of the mean values were 3.8 mm and 8.3 mm, respectively. The values in the anterior-posterior direction of the width of anechoic collection in the posterior glenohumeral joint recess in external rotation are shown in histogram format in Fig. 4. No anechoic collection value was smaller than 2.8 mm.

Correlation between anechoic collection and *injected* fluid (Table 3, Spearman's rank correlation)

The change in the detected anechoic collection before and after injection correlated significantly with the injected fluid only for the measurement in the anterior-posterior direction in the posterior glenohumeral joint recess with the arm in external rotation (R=0.390, p=0.033). In all other locations no significant correlation was found.

Discussion

The detection of effusion in the shoulder plays an overwhelmingly important role in the assessment of septic arthritis. Septic arthritis and bursitis of the shoulder may develop from haematogenous or contiguous spread, direct contamination, or after surgery [15]. Clinical diagnosis of an inflammation is not always evident [16, 17]. While severe shoulder pain is a reliable but unspecific symptom for shoulder infection, a visible swollen shoulder is usually not present. However, when infection of the shoulder joint

Table 1 Number and percentages of patients with anechoic collections before and after fluid injection in the various anatomical locations

	Before injection		After injection	
Biceps tendon sheath	7/30	23%	29/30	97%
Subcoracoidal, neutral	0	0%	2/30	7%
Subcoracoidal, internal rotation	0	0%	3/30	10%
Posterior glenohumeral joint recess, neutral	0	0%	5/30	17%
Posterior glenohumeral joint recess, external rotation	5/30	17%	30/30	100%

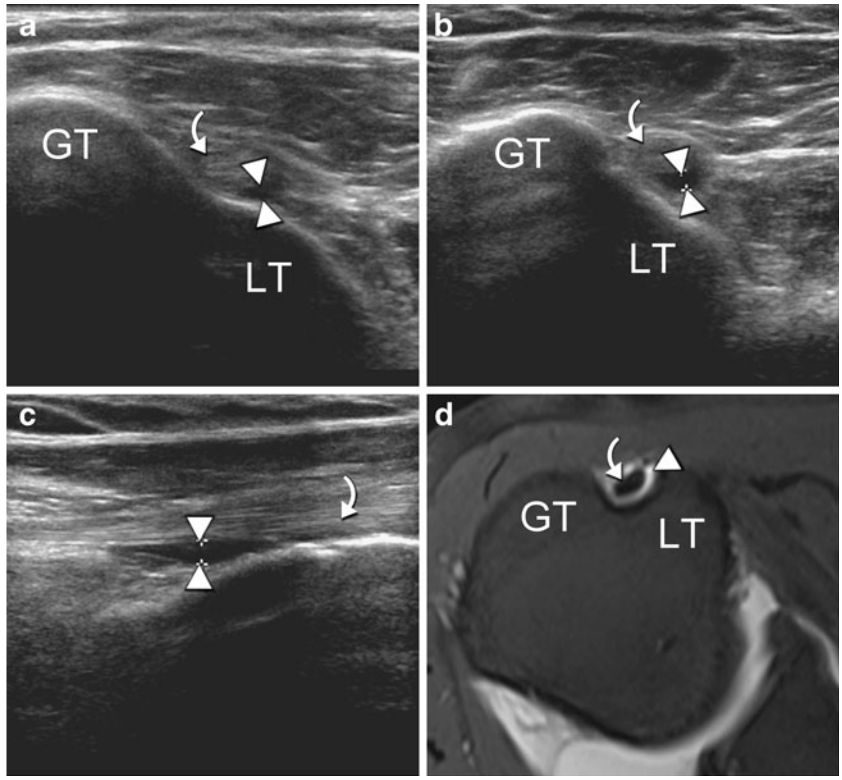

Fig. 1 Effusion in the biceps tendon sheath. (*GT*=greater tubercle, *LT*= lesser tubercle). Transverse (**a**, **b**) and longitudinal (**c**) ultrasound images of the long head of the biceps tendon (*curved arrow*) in its position in the bicipital groove are shown. Already before injection of fluid, a small edge (2 mm) of anechoic collection (joint effusion) is seen in the tendon sheath (*arrowheads*, **a**). After injection (**b**, **c**), no conspicuous increase of anechoic collection is detectable. **d** Correlative transverse trueFISP MR image after injection of fluid

is suspected clinically and increased blood infection parameters are present, an efficient, quick and reliable diagnosis is needed because immediate therapy is essential for preventing destruction of the joint. In these patients, the non-invasive, widely available and relatively inexpensive ultrasound procedure is a useful diagnostic tool. Ultrasound findings in septic arthritis and bursitis are fluid collections. Although fluid collection detection by ultrasound is not specific—the wall of a fluid collection may or may not thickened, the collection may be clear or complex, containing debris or septa—proof of fluid is an important ancillary information for further treatment.

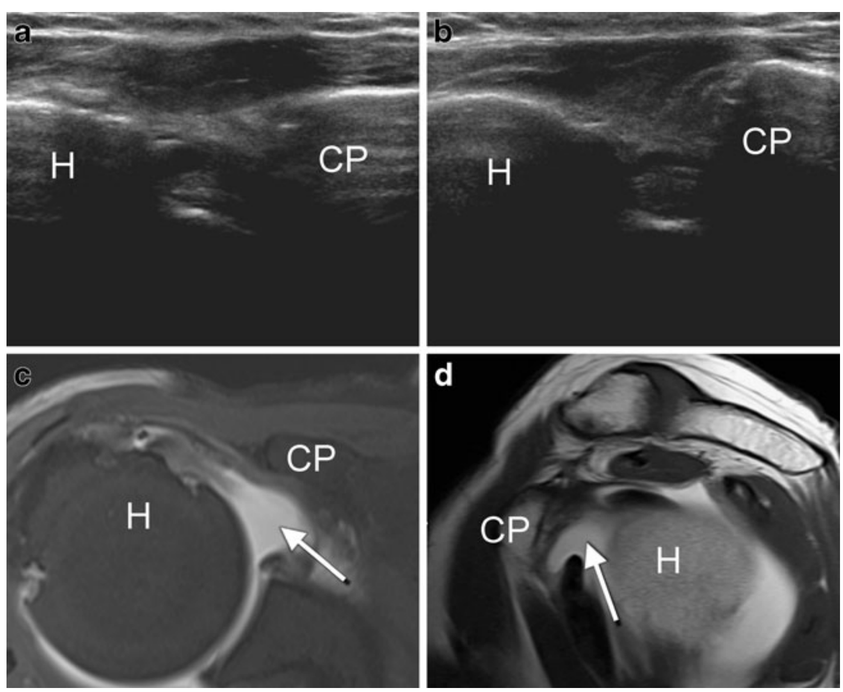

Fig. 2 Effusion in the subcapular recess (*H*= humeral head, *CP*= coracoid process). **a** and **b** Transverse ultrasound images at the level of the subscapular recess in neutral position (**a**) and with internal rotation of the upper arm (**b**) after injection of contrast fluid are shown. No anechoic collection is visible. **c** and **d** The correlative transverse trueFISP MR image (**c**) and the sagittal T1 w image (**d**) show a large effusion in the subscapular recess (*arrows*), by ultrasound not sufficient achievable because of the coracoid process, reflecting the ultrasound waves

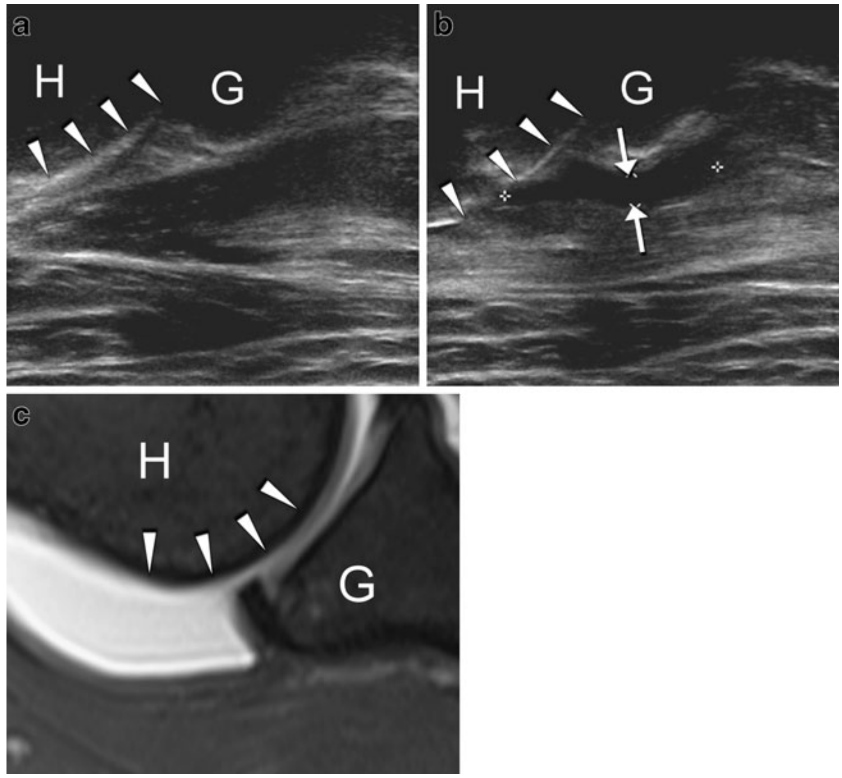

Fig. 3 Effusion in the posterior glenohumeral joint recess. (*H*= humeral head, *G*= glenoid). **a** In the transverse ultrasound image of the posterior glenohumeral joint recess in neutral position after injection of fluid, no anechoic collection is visible. **b** However, the transverse ultrasound at the same site with the arm external rotated shows a relatively large anechoic collection in the posterior glenohumeral joint recess (*asterisks*) with an edge of 3 mm in anterior-posterior direction (*arrows*). **c** The correlative transverse true-FISP MR image shows a clearly visible anechoic collection edge in the posterior glenohumeral joint recess on MR (arm position almost neutral). With external rotation of the arm the fluid in the joint space is pressed in the dorsal region of the joint and can been detected. *Arrowheads* show the contour of the humeral head

Our study indicates that glenohumeral joint effusion can be diagnosed reliably by ultrasound but only at few locations. The most reliable location to detect effusion was the posterior recess of the glenohumeral joint space with external rotation of the upper arm. The detection rate of effusion in the current study was 100% which is similar to the results of a German study published by Schmidt et al. [18] who described a sensitivity of 94%. In comparison to our study Schmidt et al. [18] had no objective confirmation for joint effusion. Moreover, our study emphasizes the importance of external rotation of the arm for detection of glenohumeral joint effusion with 100% detection rate. With neutral position of the arm, the glenohumeral joint effusion was missed in the posterior glenohumeral joint recess in more than 80% (25/30) although the joint was completely filled with fluid.

When we compare the transverse MR arthrograms, with complete filling of the glenohumeral joint, to the ultrasound images, it is hard to understand that the relative large amount of fluid is not consistently visible by ultrasound in all locations. Pooling of fluid in the axillary recess secondary to gravity helps to explain this finding. Obvi-

Table 2 Widths of anechoic collections before and after fluid injection in the various anatomical localizations (descriptive, in mm)

	Before injection			After injection			Diff.
	Min.	Max.	Mean	Min.	Max.	Mean	Mean
Biceps tendon sheath, *transverse*	0	5.7	0.6	0.9	6.9	2.0	0.9
Biceps tendon sheath, *longitudinal*	0	4.7	0.6	0	7.1	2.3	1.2
Subcoracoidal, neutral, *ap*	0	0	0	0	5.0	0.2	1.0
Subcoracoidal, neutral, *ml*	0	0	0	0	4.5	0.2	0.8
Subcoracoidal, internal rotation, *ap*	0	0	0	0	7.8	0.4	1.6
Subcoracoidal, internal rotation, *ml*	0	0	0	0	6.3	0.4	1.5
Posterior glenohumeral joint recess, neutral, *ap*	0	0	0	0	6.9	0.7	1.7
Posterior glenohumeral joint recess, neutral, *ml*	0	0	0	0	25.0	2.9	7.0
Posterior glenohumeral joint recess, external rotation, *ap*	0	6.1	0.7	2.8	18.0	7.2	3.8
Posterior glenohumeral joint recess, external rotation, *ml*	0	20.5	2.1	4.6	33.0	16.7	8.3

ap anterior-posterior, *ml* medial-lateral direction

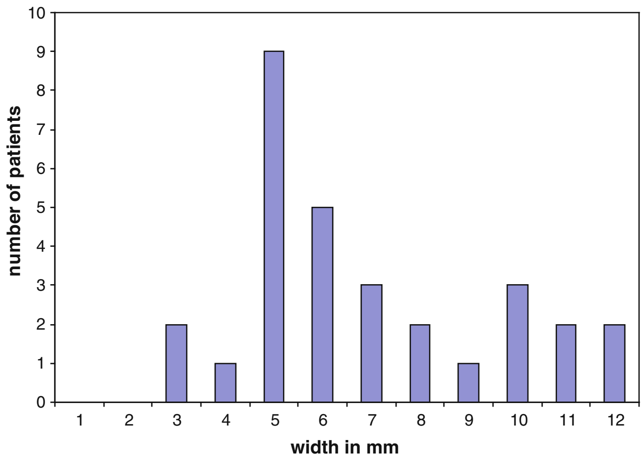

Fig. 4 Histogram shows the distributions of widths (in mm) of anechoic collections in the dorsal glenohumeral joint with the arm in external rotation. No value was smaller than 2.8 mm. X-axis shows width in millimetres

ously, with external rotation of the arm, fluid in the joint space is pressed in the dorsal region of the joint and allows the detection and quantification of glenohumeral joint effusion in spite of the gravity. Anechoic collection could not be seen in the anterior aspect of the glenohumeral joint due to anatomical reasons. The coracoid process produces reflections of the ultrasound waves which prevent, at least partially, the detection of anechoic collection in the anterior aspect. In the dynamic examination of the subscapular recess (neutral position and internal rotation) joint effusion could not be reliably verified by ultrasound (detection rate: 7%–10%) (Fig. 2).

The detection rate of effusion in the sheath of the biceps tendon was high (97%–100%) (Fig. 1). However, the biceps tendon fluid accumulation is a nonspecific finding and may be encountered in asymptomatic or degenerative shoulders [19–22]. This factor limits the clinical importance of effusion in the biceps tendon sheath when a glenohumeral joint infection has to be evaluated.

Some authors recommend performing ultrasound through the axilla for the detection of glenohumeral joint effusion [23–25]. Our own preliminary experiences with the axillary access were discouraging before we started our prospective study. First, we could not detect fluid collections at this location. Second, for this approach the patient needs to abduct the arm which is often very painful in patients with suspected inflammation/infection.

In the rheumatologic literature [19, 26, 27], the use of power Doppler sonography is recommended to detect flow in the examined tissues indicating synovitis [19, 26]. In our study we assessed only anechoic collections; therefore we exclusively used gray-scale ultrasound.

The quantification of joint effusion in patients with suspected inflammatory/infectious disease of the glenohumeral joint may be important for treatment monitoring. The quantification may receive further importance by setting a cut-off value between physiological fluid and effusion as performed e.g. in the hip [28]. In the hip joint, Moss et al. [28] demonstrated that pooling of fluid adjacent to the entire length of the femoral neck, measuring at least 5 mm in width, is compatible with a substantial joint effusion. Analogously, in our study are indications, that a correlation between ultrasound findings and effusion can be possible when performing ultrasound in the anterior-posterior direction through the posterior glenohumeral joint recess with the upper arm in external rotation (R=0.390, p=0.33). A value ≥3 mm implies a minimum of 8 ml fluid in the glenohumeral joint (Fig. 4). As limitation of our method, we admit that the quantification of effusion by ultrasound remains challenging.

In conclusion, a glenohumeral joint effusion can be best detected by ultrasound when anechoic collection is visible in the posterior glenohumeral joint recess with the arm in

Table 3 Correlation between anechoic collection and *injected* fluid

	Spearman's rank correlation factors	*P*-values
Biceps tendon sheath, *transverse*	R=0.130	p=0.494
Biceps tendon sheath, *longitudinal*	R=0.207	p=0.273
Subcoracoidal, neutral, *ap*	R=0.154	p=0.426
Subcoracoidal, neutral, *ml*	R=0.112	p=0.554
Subcoracoidal, internal rotation, *ap*	R=0.005	p=0.978
Subcoracoidal, internal rotation, *ml*	R=0.096	p=0.613
Posterior glenohumeral joint recess, neutral, *ap*	R=0.299	p=0.108
Posterior glenohumeral joint recess, neutral, *ml*	R=0.276	p=0.140
Posterior glenohumeral joint recess, external rotation, *ap*	R=0.390	*cursiv*
Posterior glenohumeral joint recess, external rotation, *ml*	R=0.215	p=0.254

Cursive indicates significant results (p<0.05)

ap anterior-posterior, *ml* medial-lateral direction external rotation. On this same ultrasound assessment, a certain quantitative estimation of the effusion is possible, and an anechoic fluid collection larger than 3 mm implies a substantial effusion (>8 ml).

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