UNSUSPECTED SONOGRAPHIC FINDINGS IN PATIENTS WITH POST-TRAUMATIC SHOULDER COMPLAINTS

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ABSTRACT

PURPOSE. To prospectively assess the frequency of abnormal sonographic findings in patients with posttraumatic shoulder pain and/or disability in whom ultrasound (US) was not considered and to assess the effect of sonographic findings on working diagnosis and therapeutic strategy, in order to analyse the possible role of US in the diagnostic work-up of these patients.

METHODS. A survey was performed under general practitioners and orthopaedic surgeons. They were requested to refer patients with persistent posttraumatic complaints for an US examination of the shoulder and to fill in a questionnaire concerning working diagnosis and therapy. In fifty patients examinations were performed by two radiologists separately. Findings were confirmed with additional radiographs and/or MRI and/or surgery. Shortly after US a survey was repeated.

RESULTS. Sonography showed relevant pathology in 45 (90%) of 50 patients, a proximal humerus fracture in 25 (50%) patients, and a rotator cuff tear in 43 (86%) patients. Twenty-three (92%) fractures were accompanied by a rotator cuff tear, and 23 (54%) rotator cuff tears were accompanied by a fracture. Ten fractures were initially missed radiographically. Sonographic findings changed the working diagnosis and therapeutic strategy in 37 (74%) and 26 (52%) patients, respectively.

CONCLUSION. In patients with posttraumatic shoulder complaints US showed a high rate (90%) of relevant pathology. This changed the initial working diagnosis in

74% of the patients and the therapeutic strategy in more than half of the patients. Active referral for sonographic examination may identify these abnormalities in an earlier phase and improve clinical outcome.

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INTRODUCTION

Shoulder pain is frequently caused by an injury. Of all patients with shoulder pain who visit primary care physicians in the United States, one third (33.2%) present after an injury and in the other two thirds the cause is non-traumatic.[1]

Males and younger adults (age ≤ 52) more often associate their shoulder pain with previous injury.[1] These shoulder injuries may remain undetected in the acute phase.

Many studies have proven the efficacy of ultrasound (US) in the diagnosis of partial- and full-thickness rotator cuff tears (RCT's) [2-8] but immediately following trauma US is often not performed because its value is considered limited. Furthermore conventional x-ray's are often inconclusive for the detection of nondisplaced fractures of the tuberosity complex of the humerus.[9] For this reason diagnosis is often delayed which may cause longstanding shoulder complaints, leading to temporary disability and considerable lost earnings.[10]

We hypothesize that many patients with shoulder complaints following trauma have undetected and unsuspected shoulder injuries which may have clinical consequences.

We prospectively assessed the frequency of abnormal sonographic findings in patients with shoulder complaints following trauma in whom US was not considered at the time of and following trauma and secondly we assessed the effect of these findings on therapeutic strategy.

MATERIAL AND METHODS

Our institutional review board approved the study protocol and informed consent was obtained from all patients. This prospective study was performed during a two year period. In this period referring physicians were requested to refer patients with shoulder complaints (pain and/or disability) following trauma in whom diagnostic imaging with US, CT or MRI was not considered. Trauma was defined as a serious injury to the shoulder, which urged the patient to seek medical care. Time between trauma and referral should be at least two weeks and should not exceed one year. Furthermore the referring physicians were requested to fill in a questionnaire about the working diagnosis and treatment before referral. A second survey within four weeks following US enquired about change in diagnosis and treatment.

Patients

Fifty consecutive patients (29 women and 21 men, age range 21-80, mean age 49 years) were included.

Patients were referred by general practitioners (n=22) and orthopedic surgeons (n=28). Time between trauma and the first visit to the general practitioner or orthopedic surgeon ranged from 0-285 days (mean 38 days), and the time between trauma and the US examination ranged from 14-304 days (mean 69 days). The referring physicians were asked about their working diagnosis and therapy strategy. Patients with pre-existent shoulder complaints or previous surgery were excluded from this study.

Two independent radiologists performed the US examinations during one patient visit.

In the follow up of the patients, who were examined with US, we retrospectively evaluated the patient files if conventional X-ray, MR imaging, and/or open or arthroscopic surgery was performed. In all fifty patients conventional plain radiographs were available, whereas US findings could be associated with MRI and surgical findings in 10 and 19 patients, respectively.

Ultrasound examination

The US examinations were performed with an APLIO (Toshiba Medical Systems, Tokyo, Japan) using a 12 (5 - 14) MHz broadband linear-array transducer (Toshiba PLF-805ST). Patients were examined seated on a swivel chair, facing the examiner. A standardized US imaging protocol of the shoulder was used.[11-14] All sonograms were performed by two radiologists, one experienced (>15 years) musculoskeletal radiologist (M.J.R.) and one experienced (>20 years) abdominal radiologist (G.J.), who had one year experience in performing US of the shoulder. The patients were examined by both examiners separately, one after the other. Both were blinded to the results of previously performed examinations and to their mutual findings. Following the US examinations consensus reading was performed. When discrepant findings between the two readers were found the patient was at the same sitting re-examined by both readers together to determine the cause of the discrepancy.

Plain radiographs

All 50 patients underwent a radiographic examination (i.e., trauma series), which consisted of an anteroposterior view (external and/or internal rotation of the humerus), an axillary view and a transscapular view of the shoulder. In 33 patients plain radiographs of the shoulder were obtained following trauma. In the remaining 17 patients a fracture was not suspected clinically. They underwent plain radiography subsequently in conjunction with their US examination.

Following the US examinations both sonologists performed a consensus reading of all 33 initially obtained plain radiographs. If there was a discrepancy between the US findings and the plain radiographic findings new trauma series were obtained and if these were not conclusive additional radiographic views were obtained. The image projection of these additional views were determined according to the US findings, tangent to the expected fracture (Fig. 1).

Magnetic Resonance Imaging (MRI)

In 10 patients MR images were obtained with a 1.5-T scanner (Vision, Siemens Medical systems, Erlangen, Germany) using a surface coil. Indications for the MR examinations were to verify sonographic findings e.g., fractures not visible on plain radiographs (n=2) and rotator cuff tears (n=2), to provide the surgeon with more anatomical information in case surgery was considered, and for the detection of intraarticular pathology (n=6). Four patients underwent MRI and 6 patients MR-arthrography of the shoulder. The MR imaging protocol included axial, sagittal and coronal T1 (repetition time (TR) 600 / echo time (TE) 30) and T2 weighted (TR

3000 / TE 50) spin-echo sequences. The field of view was 16 cm, and the data acquisition matrix 196 x 512. A section thickness of 3 mm was used with a 0.5 mm intersection gap. Three acquisitions were averaged.

The MR arthrography scanning protocol consisted of 3 dimensional (3D)-gradient T1-weighted (FLASH 3D) oblique coronal scans with fat saturation, which were reconstructed in the sagittal and transverse planes. FLASH 3D imaging (TR: 8.1 ms; TE: 4 ms; 2 acquisitions; 192 × 256 matrix; field of view (FOV): 24 cm) with 1-mm consecutive slices was used.

Image evaluation

Sonographic examinations were evaluated for abnormalities of the deltoid muscle, subacromial-subdeltoid bursa, rotator cuff, long head of the biceps tendon and the proximal humerus including the tuberosity complex.

According to the criteria as established in the literature,[15-20] a full-thickness rotator cuff tear (FTT) is defined as non-visualization or absence of the rotator cuff, or a full-thickness rotator cuff discontinuity, and a partial-thickness rotator cuff tear (PTT) as a focal thinning of the rotator cuff, loss of convexity of the outer cuff border and a hypoechoic defect involving the articular or bursal side or within the tendon.

Sonographic features of bone fracture are: periosteal elevation, cortical bone discontinuity (Fig. 2a and Fig. 3a and b), step-off deformity with one or more hyperechoic reflections (i.e., avulsed, dislocated (Fig. 1a) or impacted bone fragments),[9,21] and the double line sign (two parallel hyperechoic lines).[22]

Initial plain radiographs were evaluated prospectively in routine practice by residents and radiologists with a varying level of experience. The final retrospective reading of all 50 trauma series including the additionally obtained plain radiographs was performed by consensus by the two sonologists ~~(Table 1)~~.

Statistical analysis

For the analyses, we used descriptive statistics only. Because of the relatively small number of patients, it was not considered useful to use inferential statistics. For the descriptive statistics, we calculated means and standard deviations for continuous variables and percentages (i.e., prevalences) for categorical variables. For the interrater reproducibility between the 2 sonologists, we calculated Cohen's kappa statistic for fractures (yes vs. no) and ruptures (no vs. partial vs. total).

RESULTS

Fifty patients (30 right and 20 left shoulders) were sonographically examined within 14–304 days (average 69 days) following trauma. The mechanism of trauma was a direct fall on the shoulder (n=26), a fall on a hyperextended arm (n=8), falling while grabbing (hyperextension with traction) (n=10) and various other causes (n=6) such as luxation, forced external rotation or forced hyperextension with abduction.

US showed no abnormalities in 5 (10%) patients and pathologic findings (proximal humerus fracture, RCT's, long head of the biceps tendon luxation or dislocation) in 45 (90%) of the patients. Both observers detected all fractures. Therefore, the interobserver agreement for the sonographic detection of fractures

was perfect (Cohen's kappa is 1.0). The less experienced sonographer interpreted one PTT as tendinosis (Fig. 3), while in the remaining 49 (98%) cases both observers were in agreement, which each other's sonographic findings. The interobserver agreement for the sonographic detection of RCT's was almost perfect (Cohen's kappa is 0.96).

Rotator cuff tears

In 43 (86%) of the 50 patients one or more RCT's were detected with US. We identified 22 FTT and 16 PTT in the supraspinatus tendon and 7 FTT and 6 PTT in the subscapularis tendon. One FTT was detected in the infraspinatus tendon and no tears were detected in the teres minor tendon.

A RCT without other accompanying posttraumatic shoulder pathology was sonographically depicted in 15 of the 43 cases, whereas 28 patients with a RCT suffered from accompanying fractures of the proximal humerus (n=23) and/or subluxation (n=3) or dislocation (n=4) of the long head of the biceps tendon. Four PTT's were accompanied by 3 subluxated and 1 dislocated biceps tendon and 3 FTT's by a dislocated long head of the biceps tendon.

Fractures

In 25 (50%) of the 50 patients a fracture of the proximal humerus was detected sonographically and confirmed with the initially or additionally obtained plain radiographs and/or with MR imaging. In the remaining 25 patients no fracture could be detected with either imaging technique.

In the patient group, who initially underwent plain radiography (n=33), a total of 19 fractures were found. However, only 9 (47%) of these fractures were detected prospectively. At retrospective review of the initially obtained plain radiographs 5 additional fractures were detected.

Seven (28%) of the 25 fractures could only be depicted after obtaining additional projections (Fig. 1) or were only visible on additionally obtained radiographs (Fig. 2) or with MRI (Fig. 3). Sonography did not miss any fracture depicted by plain radiography.

In the patient group (n=17), who did not undergo radiography initially, 6 fractures were detected with sonography and confirmed with conventional radiographs.

According to Neer's four-segment classification for fractures of the proximal humerus,[23] 22 patients (92%) had a non- or minimally displaced one-part fracture, and 3 patients a two-part fracture. None of the patients suffered from a three-part or four-part fracture.

In 23 of the 25 patients with a fracture this was accompanied by a RCT (15 PTT and 8 FTT).

Associated posttraumatic pathologic musculoskeletal findings

A thickened subacromial-subdeltoid bursa (i.e., bursitis) (Fig. 2a) was sonographically diagnosed in 2 patients. This is either caused by trauma or due to chronic impingement. In neither patient was a fracture or RCT found.

Subluxation of the long head of the biceps tendon (Fig. 4a) was diagnosed in 3 patients and complete dislocation of the biceps tendon (Fig. 4b) was diagnosed in 4 patients. These biceps tendon subluxation and dislocations were accompanied by PTT (n=4) or FTT (n=3) of the subscapularis (n=2) and/or supraspinatus tendon (n=5).

Working diagnosis and therapeutic strategy changes

Compared to the initial diagnosis and therapy the referring physician stated that sonographic findings affected the working diagnosis and therapeutic strategy in 37 (74%) and 26 (52%) patients, respectively.

In 13 (26%) of the 50 patients US confirmed the working diagnosis. In 19 (38%) patients US confirmed the working diagnosis, but also detected additional traumatically caused pathology, and in 18 (36%) patients US findings were not concurrent with the clinical working diagnosis.

Therapy was changed because although the diagnosis was confirmed, probably due to more diagnostic certainty in 9 (69%) of the 13 patients. Therapy was also changed in 11 (58%) of the 19 patients with whom the working diagnosis was confirmed and additional posttraumatic pathology was found. Finally, in only 6 (33%) of the 18 patients with whom the sonographic findings and working diagnosis did not concurred, therapy did change. These six relatively young (37 to 52 years) patients presented with a FTT, who were operated upon following US after initially conservative treatment. In the remaining 12 patients the initially initiated conservative therapy was continued despite the sonographic finding of a

FTT in 4 patients, a PTT in 4 patients, a non-displaced fracture of the greater tuberosity in 4 patients.

In 26 of the 50 patients US changed therapy strategy. In 21 of these 26 patients conservative therapy (rest, physiotherapy, subacromial injections) was changed to surgical treatment following US. Twenty patients underwent surgical rotator cuff repair of 4 PTT and 16 FTT and one patient because of a luxation of the long head of the biceps tendon in combination with a FTT. In the remaining 5 of the 26 patients conservative treatment was changed in a lighter physiotherapy program (n=4) or rest (n=2).

DISCUSSION

Trauma-related shoulder disorders are frequently initially missed, affecting quality of life.[24,25] In this prospective study we demonstrate that patients with posttraumatic shoulder complaints, have a high prevalence of rotator cuff tears (86%) and fractures (50%) of the proximal humerus. This confirms the findings of Sørensen et al,[4] who reported that clinical examination underestimates the prevalence and severity of acute RCT's and fractures. This has also been indicated by Patten et al,[9] who showed that 10 (42%) of the 24 sonographically detected greater tuberosity fractures were missed with plain radiography. In our study, 10 (53%) of the 19 fractures were not depicted at the initial reading. Even retrospectively, 26% (5 of 19) of these fractures could not be depicted from the initially obtained trauma series. Of all 25 fractures in our study 7 (28%) could not be depicted from the trauma series, whereas all 25 fractures were depicted

sonographically.[9,22] A fracture can easily be identified sonographically as a discontinuity of the cortical bone, when scanning perpendicular to the fracture line. Another characteristic sonographic feature of a fracture is the double line sign.[22]

In all but two patients with a fracture of the proximal humerus a PTT or FTT could be detected. This is in contrast with Patten et al,[9] who suggests that this combination can be found in only 17-25%. The higher number of RCT in our study is probably due to the selected patients, e.g., patients with persistent shoulder complaints following trauma, and may also be related to the injury mechanism or severity of trauma. Age seems not to be the reason for the relatively high frequency of RCT in our study, in the age group of 21 to 30 years the frequency of RCT was 33%, in the other age groups the frequency was (80-100%). In this study no surgical therapy was performed in any of the 24 patients with a fracture of the proximal humerus.

In the current study US was not performed immediately after injury or in the emergency setting. Possible disadvantages of performing US in the acute phase is the detection of chronic, irrelevant asymptomatic RCT's [26] and the decreased diagnostic performance of US due to limited shoulder motion, necessary for visualization of the entire rotator cuff.[5] However, Teefey et al [27] showed that on the basis of location (midsubstance) and associated findings (the presence of joint or bursal fluid) acute and chronic RCT can be differentiated. Farin et al [5] and Sørensen et al [4] demonstrated that adequate sonographic examination was feasible in 88% in the acute phase.

In our study we found that referring physicians stated that US findings

changed the working diagnosis in 74% and the therapeutic strategy in more than half of the patients supporting the suggestion that sonography reveals clinically relevant findings.[28] We found no previous studies that addressed clinical efficacy, [29] which includes diagnostic impact and the therapeutic efficacy in patients with shoulder complaints following trauma. Change in therapy is more objectively ascertainable but it is difficult to assess to what extent the sonographic diagnosis contributes to the change in therapy e.g., we found that therapeutic strategy changed more often when the initial diagnosis was not changed.

When interpreting the results of our study, some limitations have to be considered. First, the number of patients included in this study is relatively small. Secondly, the high number of posttraumatic pathologic findings may be biased. It is possible that patient selection was not exactly according the study purpose (e.g., patients with shoulder complaints following trauma in whom US was not considered), but that patients with shoulder complaints following trauma in whom US was already considered also answered the call up.

Thirdly, the methods for assessing diagnostic and therapeutic efficacy are not well established. These are subjective and difficult to quantify.[29] It is possible that patient symptoms were increasing with time and sonographic findings were not the only reason for a change in treatment. Furthermore the second survey we performed 1 month following US, which is not ideal for the assessment of the diagnostic impact and therapeutic efficacy.[29] Therefore, the effect of US imaging on diagnosis and therapeutic strategy may be overestimated.

In the literature there is no consensus about the optimal therapeutic strategy

and timing of treatment of RCT's following trauma.[30,31] Therefore, additional prospective studies are needed to confirm the hypothesis that early sonographic assessment of the rotator cuff integrity in patients with post traumatic shoulder complaints improves patient outcome and to establish the best time to perform US in these patients.

The results of such studies could potentially change the approach of acute injury to the shoulder. It is arguable, considering the limited detection of fractures with conventional radiographs to propose the following algorithm. First do an ultrasound in the acute phase, and if the pain does not subside after a week then take an X-ray In our study we would not have missed any substantial abnormalities and would have made the right diagnosis in an earlier phase.. It would sure have clarified a lot of pain caused by missed fractures and rotator cuff tears. Dislocations with complete loss of function of course may have to be treated separately in this algorithm, and if US is negative and/or clinical symptoms are related to intraarticular disorders MR arthrography should be performed

CONCLUSION

Patients with posttraumatic shoulder complaints have a high prevalence of unsuspected and initially missed RCT's and fractures and US is accurate in the detection of clinically relevant trauma-related shoulder pathology.

Further studies are needed to prove that early and active referral of these patients for sonographic examination may improve patient outcome.

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FIGURES AND LEGENDS

Fig. 1. 52-year-old man with a limited and painful external rotation of the right shoulder following trauma.

A, Long axis sonogram of the subscapularis tendon (SSC) shows a linear hyperechoic reflection (arrows) in the midsubstance of the subscapularis tendon insertion, which is suggestive for an avulsion fracture of the lesser tuberosity (LT).

B, Additionally obtained radiographic projection (cranio-caudal view) confirmed the lesser tuberosity fracture, whereas this was not visible on the initially obtained conventional radiographs.

Fig. 2. 68-year-old woman with shoulder pain and disability following a fall on the right shoulder.

A, The initial radiographs, obtained 6 days following trauma, were interpreted as normal.

B, Long axis sonogram of the supraspinatus tendon (SSP) shows a cortical bone discontinuity (large arrow) at the junction between the greater tuberosity (GT) and the humeral head, representing a non-displaced greater tuberosity fracture. The thickened subacromial-subdeltoid bursa (small arrows) is either caused by trauma or due to chronic impingement.

C, The radiographs obtained 1 month following trauma showed a radiolucent zone (arrows) along the fracture line due to bone resorption indicative of active bone repair.

Fig. 3. 43-year-old man with pain and disability of the shoulder 19 days following a fall on the right shoulder.

A, B, Long axis sonograms of the supraspinatus tendon (SSP) showing corticol bone discontinuities (large arrows) and outpouchings of cortical bone (small arrows) representing fractures of the greater tuberosity (GT), which are frequently associated with intrasubstance rotator cuff tears (asterisks).

C, A radiograph obtained directly following US could not confirm the US findings.

D, Coronal T1-weighted FSE images with fat saturation of a MR arthrogram confirmed the US findings by showing an elevated signal of the greater tuberosity (GT) due to oedema because of a fracture and a longitudinally orientated intrasubstance tear (arrow) of the supraspinatus tendon (SSP).

Fig. 4 Subluxation (**A**) and complete dislocation (**B**) of the long head of the biceps tendon.

A, 49-year-old man. Transverse US image obtained at the level of the intertubercular groove shows subluxation of the long head of the biceps tendon (arrow), which is located over the lesser tuberosity (LT). D = Deltoid muscle, GT = greater tuberosity.

B, 60-year-old woman. Transverse US image obtained at the level of the intertubercular groove shows medial dislocation of the long head of the biceps tendon (arrow) and an empty, fluid filled intertubercular groove (small black arrows). B = distended subacromial-subdeltoid bursa, GT = greater tuberosity, LT = lesser tuberosity.

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The US examinations were performed with an APLIO (Toshiba Medical Systems, Tokyo, Japan) using a 12 (5 - 14) MHz broadband linear-array transducer (Toshiba PLF-805ST). Patients were examined seated on a swivel chair, facing the examiner. A standardized US imaging protocol of the shoulder was used.[11-14] All sonograms were performed by two radiologists, one experienced (>15 years) musculoskeletal radiologist (M.J.R.) and one experienced (>20 years) abdominal radiologist (G.J.), who had one year experience in performing US of the shoulder. The patients were examined by both examiners separately, one after the other. Both were blinded to the results of previously performed examinations and to their mutual findings. Following the US examinations consensus reading was performed. When discrepant findings between the two readers were found the patient was at the same sitting re-examined by both readers together to determine the cause of the discrepancy.

Plain radiographs

All 50 patients underwent a radiographic examination (i.e., trauma series), which consisted of an anteroposterior view (external and/or internal rotation of the humerus), an axillary view and a transscapular view of the shoulder. In 33 patients plain radiographs of the shoulder were obtained following trauma. In the remaining 17 patients a fracture was not suspected clinically. They underwent plain radiography subsequently in conjunction with their US examination.

Following the US examinations both sonologists performed a consensus reading of all 33 initially obtained plain radiographs. If there was a discrepancy between the US findings and the plain radiographic findings new trauma series were obtained and if these were not conclusive additional radiographic views were obtained. The image projection of these additional views were determined according to the US findings, tangent to the expected fracture (Fig. 1).

Magnetic Resonance Imaging (MRI)

In 10 patients MR images were obtained with a 1.5-T scanner (Vision, Siemens Medical systems, Erlangen, Germany) using a surface coil. Indications for the MR examinations were to verify sonographic findings e.g., fractures not visible on plain radiographs (n=2) and rotator cuff tears (n=2), to provide the surgeon with more anatomical information in case surgery was considered, and for the detection of intraarticular pathology (n=6). Four patients underwent MRI and 6 patients MR-arthrography of the shoulder. The MR imaging protocol included axial, sagittal and coronal T1 (repetition time (TR) 600 / echo time (TE) 30) and T2 weighted (TR

3000 / TE 50) spin-echo sequences. The field of view was 16 cm, and the data acquisition matrix 196 x 512. A section thickness of 3 mm was used with a 0.5 mm intersection gap. Three acquisitions were averaged.

The MR arthrography scanning protocol consisted of 3 dimensional (3D)-gradient T1-weighted (FLASH 3D) oblique coronal scans with fat saturation, which were reconstructed in the sagittal and transverse planes. FLASH 3D imaging (TR: 8.1 ms; TE: 4 ms; 2 acquisitions; 192 × 256 matrix; field of view (FOV): 24 cm) with 1-mm consecutive slices was used.

Image evaluation

Sonographic examinations were evaluated for abnormalities of the deltoid muscle, subacromial-subdeltoid bursa, rotator cuff, long head of the biceps tendon and the proximal humerus including the tuberosity complex.

According to the criteria as established in the literature,[15-20] a full-thickness rotator cuff tear (FTT) is defined as non-visualization or absence of the rotator cuff, or a full-thickness rotator cuff discontinuity, and a partial-thickness rotator cuff tear (PTT) as a focal thinning of the rotator cuff, loss of convexity of the outer cuff border and a hypoechoic defect involving the articular or bursal side or within the tendon.

Sonographic features of bone fracture are: periosteal elevation, cortical bone discontinuity (Fig. 2a and Fig. 3a and b), step-off deformity with one or more hyperechoic reflections (i.e., avulsed, dislocated (Fig. 1a) or impacted bone fragments),[9,21] and the double line sign (two parallel hyperechoic lines).[22]

Initial plain radiographs were evaluated prospectively in routine practice by residents and radiologists with a varying level of experience. The final retrospective reading of all 50 trauma series including the additionally obtained plain radiographs was performed by consensus by the two sonologists ~~(Table 1)~~.

Statistical analysis

For the analyses, we used descriptive statistics only. Because of the relatively small number of patients, it was not considered useful to use inferential statistics. For the descriptive statistics, we calculated means and standard deviations for continuous variables and percentages (i.e., prevalences) for categorical variables. For the interrater reproducibility between the 2 sonologists, we calculated Cohen's kappa statistic for fractures (yes vs. no) and ruptures (no vs. partial vs. total).

RESULTS

Fifty patients (30 right and 20 left shoulders) were sonographically examined within 14–304 days (average 69 days) following trauma. The mechanism of trauma was a direct fall on the shoulder (n=26), a fall on a hyperextended arm (n=8), falling while grabbing (hyperextension with traction) (n=10) and various other causes (n=6) such as luxation, forced external rotation or forced hyperextension with abduction.

US showed no abnormalities in 5 (10%) patients and pathologic findings (proximal humerus fracture, RCT's, long head of the biceps tendon luxation or dislocation) in 45 (90%) of the patients. Both observers detected all fractures. Therefore, the interobserver agreement for the sonographic detection of fractures

was perfect (Cohen's kappa is 1.0). The less experienced sonographer interpreted one PTT as tendinosis (Fig. 3), while in the remaining 49 (98%) cases both observers were in agreement, which each other's sonographic findings. The interobserver agreement for the sonographic detection of RCT's was almost perfect (Cohen's kappa is 0.96).

Rotator cuff tears

In 43 (86%) of the 50 patients one or more RCT's were detected with US. We identified 22 FTT and 16 PTT in the supraspinatus tendon and 7 FTT and 6 PTT in the subscapularis tendon. One FTT was detected in the infraspinatus tendon and no tears were detected in the teres minor tendon.

A RCT without other accompanying posttraumatic shoulder pathology was sonographically depicted in 15 of the 43 cases, whereas 28 patients with a RCT suffered from accompanying fractures of the proximal humerus (n=23) and/or subluxation (n=3) or dislocation (n=4) of the long head of the biceps tendon. Four PTT's were accompanied by 3 subluxated and 1 dislocated biceps tendon and 3 FTT's by a dislocated long head of the biceps tendon.

Fractures

In 25 (50%) of the 50 patients a fracture of the proximal humerus was detected sonographically and confirmed with the initially or additionally obtained plain radiographs and/or with MR imaging. In the remaining 25 patients no fracture could be detected with either imaging technique.

In the patient group, who initially underwent plain radiography (n=33), a total of 19 fractures were found. However, only 9 (47%) of these fractures were detected prospectively. At retrospective review of the initially obtained plain radiographs 5 additional fractures were detected.

Seven (28%) of the 25 fractures could only be depicted after obtaining additional projections (Fig. 1) or were only visible on additionally obtained radiographs (Fig. 2) or with MRI (Fig. 3). Sonography did not miss any fracture depicted by plain radiography.

In the patient group (n=17), who did not undergo radiography initially, 6 fractures were detected with sonography and confirmed with conventional radiographs.

According to Neer's four-segment classification for fractures of the proximal humerus,[23] 22 patients (92%) had a non- or minimally displaced one-part fracture, and 3 patients a two-part fracture. None of the patients suffered from a three-part or four-part fracture.

In 23 of the 25 patients with a fracture this was accompanied by a RCT (15 PTT and 8 FTT).

Associated posttraumatic pathologic musculoskeletal findings

A thickened subacromial-subdeltoid bursa (i.e., bursitis) (Fig. 2a) was sonographically diagnosed in 2 patients. This is either caused by trauma or due to chronic impingement. In neither patient was a fracture or RCT found.

Subluxation of the long head of the biceps tendon (Fig. 4a) was diagnosed in 3 patients and complete dislocation of the biceps tendon (Fig. 4b) was diagnosed in 4 patients. These biceps tendon subluxation and dislocations were accompanied by PTT (n=4) or FTT (n=3) of the subscapularis (n=2) and/or supraspinatus tendon (n=5).

Working diagnosis and therapeutic strategy changes

Compared to the initial diagnosis and therapy the referring physician stated that sonographic findings affected the working diagnosis and therapeutic strategy in 37 (74%) and 26 (52%) patients, respectively.

In 13 (26%) of the 50 patients US confirmed the working diagnosis. In 19 (38%) patients US confirmed the working diagnosis, but also detected additional traumatically caused pathology, and in 18 (36%) patients US findings were not concurrent with the clinical working diagnosis.

Therapy was changed because although the diagnosis was confirmed, probably due to more diagnostic certainty in 9 (69%) of the 13 patients. Therapy was also changed in 11 (58%) of the 19 patients with whom the working diagnosis was confirmed and additional posttraumatic pathology was found. Finally, in only 6 (33%) of the 18 patients with whom the sonographic findings and working diagnosis did not concurred, therapy did change. These six relatively young (37 to 52 years) patients presented with a FTT, who were operated upon following US after initially conservative treatment. In the remaining 12 patients the initially initiated conservative therapy was continued despite the sonographic finding of a

FTT in 4 patients, a PTT in 4 patients, a non-displaced fracture of the greater tuberosity in 4 patients.

In 26 of the 50 patients US changed therapy strategy. In 21 of these 26 patients conservative therapy (rest, physiotherapy, subacromial injections) was changed to surgical treatment following US. Twenty patients underwent surgical rotator cuff repair of 4 PTT and 16 FTT and one patient because of a luxation of the long head of the biceps tendon in combination with a FTT. In the remaining 5 of the 26 patients conservative treatment was changed in a lighter physiotherapy program (n=4) or rest (n=2).

DISCUSSION

Trauma-related shoulder disorders are frequently initially missed, affecting quality of life.[24,25] In this prospective study we demonstrate that patients with posttraumatic shoulder complaints, have a high prevalence of rotator cuff tears (86%) and fractures (50%) of the proximal humerus. This confirms the findings of Sørensen et al,[4] who reported that clinical examination underestimates the prevalence and severity of acute RCT's and fractures. This has also been indicated by Patten et al,[9] who showed that 10 (42%) of the 24 sonographically detected greater tuberosity fractures were missed with plain radiography. In our study, 10 (53%) of the 19 fractures were not depicted at the initial reading. Even retrospectively, 26% (5 of 19) of these fractures could not be depicted from the initially obtained trauma series. Of all 25 fractures in our study 7 (28%) could not be depicted from the trauma series, whereas all 25 fractures were depicted

sonographically.[9,22] A fracture can easily be identified sonographically as a discontinuity of the cortical bone, when scanning perpendicular to the fracture line. Another characteristic sonographic feature of a fracture is the double line sign.[22]

In all but two patients with a fracture of the proximal humerus a PTT or FTT could be detected. This is in contrast with Patten et al,[9] who suggests that this combination can be found in only 17-25%. The higher number of RCT in our study is probably due to the selected patients, e.g., patients with persistent shoulder complaints following trauma, and may also be related to the injury mechanism or severity of trauma. Age seems not to be the reason for the relatively high frequency of RCT in our study, in the age group of 21 to 30 years the frequency of RCT was 33%, in the other age groups the frequency was (80-100%). In this study no surgical therapy was performed in any of the 24 patients with a fracture of the proximal humerus.

In the current study US was not performed immediately after injury or in the emergency setting. Possible disadvantages of performing US in the acute phase is the detection of chronic, irrelevant asymptomatic RCT's [26] and the decreased diagnostic performance of US due to limited shoulder motion, necessary for visualization of the entire rotator cuff.[5] However, Teefey et al [27] showed that on the basis of location (midsubstance) and associated findings (the presence of joint or bursal fluid) acute and chronic RCT can be differentiated. Farin et al [5] and Sørensen et al [4] demonstrated that adequate sonographic examination was feasible in 88% in the acute phase.

In our study we found that referring physicians stated that US findings

changed the working diagnosis in 74% and the therapeutic strategy in more than half of the patients supporting the suggestion that sonography reveals clinically relevant findings.[28] We found no previous studies that addressed clinical efficacy, [29] which includes diagnostic impact and the therapeutic efficacy in patients with shoulder complaints following trauma. Change in therapy is more objectively ascertainable but it is difficult to assess to what extent the sonographic diagnosis contributes to the change in therapy e.g., we found that therapeutic strategy changed more often when the initial diagnosis was not changed.

When interpreting the results of our study, some limitations have to be considered. First, the number of patients included in this study is relatively small. Secondly, the high number of posttraumatic pathologic findings may be biased. It is possible that patient selection was not exactly according the study purpose (e.g., patients with shoulder complaints following trauma in whom US was not considered), but that patients with shoulder complaints following trauma in whom US was already considered also answered the call up.

Thirdly, the methods for assessing diagnostic and therapeutic efficacy are not well established. These are subjective and difficult to quantify.[29] It is possible that patient symptoms were increasing with time and sonographic findings were not the only reason for a change in treatment. Furthermore the second survey we performed 1 month following US, which is not ideal for the assessment of the diagnostic impact and therapeutic efficacy.[29] Therefore, the effect of US imaging on diagnosis and therapeutic strategy may be overestimated.

In the literature there is no consensus about the optimal therapeutic strategy

and timing of treatment of RCT's following trauma.[30,31] Therefore, additional prospective studies are needed to confirm the hypothesis that early sonographic assessment of the rotator cuff integrity in patients with post traumatic shoulder complaints improves patient outcome and to establish the best time to perform US in these patients.

The results of such studies could potentially change the approach of acute injury to the shoulder. It is arguable, considering the limited detection of fractures with conventional radiographs to propose the following algorithm. First do an ultrasound in the acute phase, and if the pain does not subside after a week then take an X-ray In our study we would not have missed any substantial abnormalities and would have made the right diagnosis in an earlier phase.. It would sure have clarified a lot of pain caused by missed fractures and rotator cuff tears. Dislocations with complete loss of function of course may have to be treated separately in this algorithm, and if US is negative and/or clinical symptoms are related to intraarticular disorders MR arthrography should be performed

CONCLUSION

Patients with posttraumatic shoulder complaints have a high prevalence of unsuspected and initially missed RCT's and fractures and US is accurate in the detection of clinically relevant trauma-related shoulder pathology.

Further studies are needed to prove that early and active referral of these patients for sonographic examination may improve patient outcome.

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FIGURES AND LEGENDS

Fig. 1. 52-year-old man with a limited and painful external rotation of the right shoulder following trauma.

A, Long axis sonogram of the subscapularis tendon (SSC) shows a linear hyperechoic reflection (arrows) in the midsubstance of the subscapularis tendon insertion, which is suggestive for an avulsion fracture of the lesser tuberosity (LT).

B, Additionally obtained radiographic projection (cranio-caudal view) confirmed the lesser tuberosity fracture, whereas this was not visible on the initially obtained conventional radiographs.

Fig. 2. 68-year-old woman with shoulder pain and disability following a fall on the right shoulder.

A, The initial radiographs, obtained 6 days following trauma, were interpreted as normal.

B, Long axis sonogram of the supraspinatus tendon (SSP) shows a cortical bone discontinuity (large arrow) at the junction between the greater tuberosity (GT) and the humeral head, representing a non-displaced greater tuberosity fracture. The thickened subacromial-subdeltoid bursa (small arrows) is either caused by trauma or due to chronic impingement.

C, The radiographs obtained 1 month following trauma showed a radiolucent zone (arrows) along the fracture line due to bone resorption indicative of active bone repair.

Fig. 3. 43-year-old man with pain and disability of the shoulder 19 days following a fall on the right shoulder.

A, B, Long axis sonograms of the supraspinatus tendon (SSP) showing corticol bone discontinuities (large arrows) and outpouchings of cortical bone (small arrows) representing fractures of the greater tuberosity (GT), which are frequently associated with intrasubstance rotator cuff tears (asterisks).

C, A radiograph obtained directly following US could not confirm the US findings.

D, Coronal T1-weighted FSE images with fat saturation of a MR arthrogram confirmed the US findings by showing an elevated signal of the greater tuberosity (GT) due to oedema because of a fracture and a longitudinally orientated intrasubstance tear (arrow) of the supraspinatus tendon (SSP).

Fig. 4 Subluxation (**A**) and complete dislocation (**B**) of the long head of the biceps tendon.

A, 49-year-old man. Transverse US image obtained at the level of the intertubercular groove shows subluxation of the long head of the biceps tendon (arrow), which is located over the lesser tuberosity (LT). D = Deltoid muscle, GT = greater tuberosity.

B, 60-year-old woman. Transverse US image obtained at the level of the intertubercular groove shows medial dislocation of the long head of the biceps tendon (arrow) and an empty, fluid filled intertubercular groove (small black arrows). B = distended subacromial-subdeltoid bursa, GT = greater tuberosity, LT = lesser tuberosity.

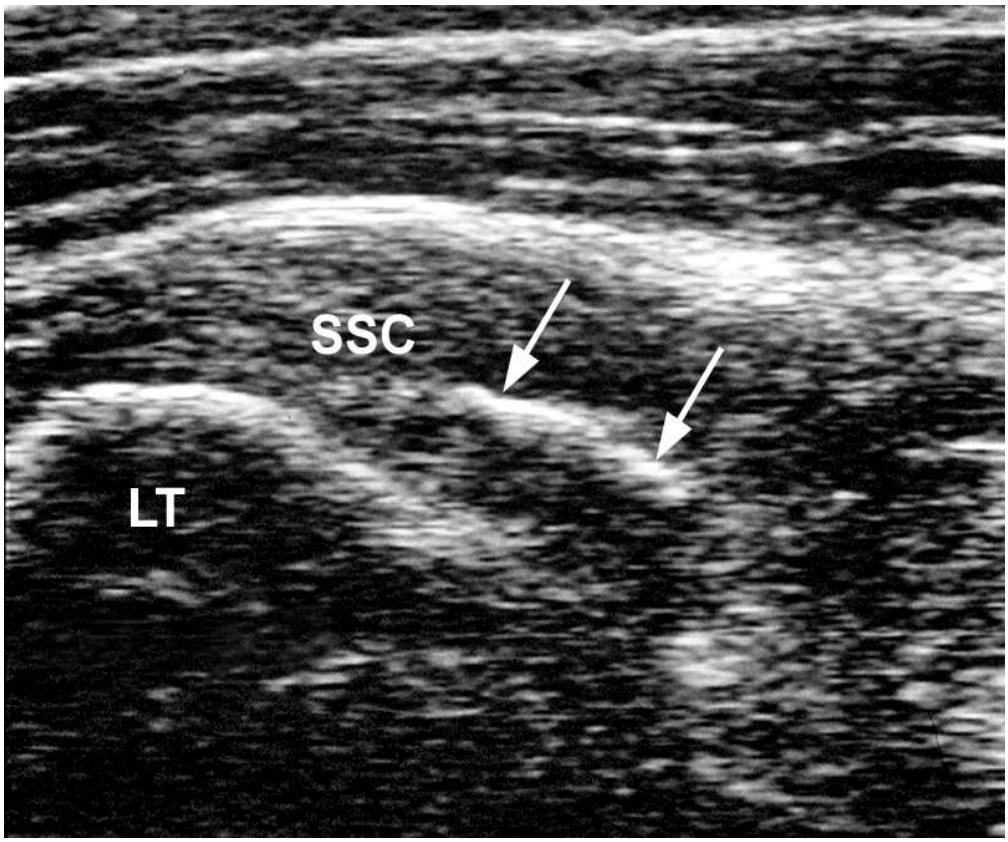

Fig 1A

Fig. 1. 52-year-old man with a limited and painful external rotation of the right shoulder following trauma.
A, Long axis sonogram of the subscapularis tendon (SSC) shows a linear hyperechoic reflection (arrows) in the midsubstance of the subscapularis tendon insertion, which is suggestive for an avulsion fracture of the lesser tuberosity (LT).
B, Additionally obtained radiographic projection (cranio-caudal view) confirmed the lesser tuberosity fracture, whereas this was not visible on the initially obtained conventional radiographs.

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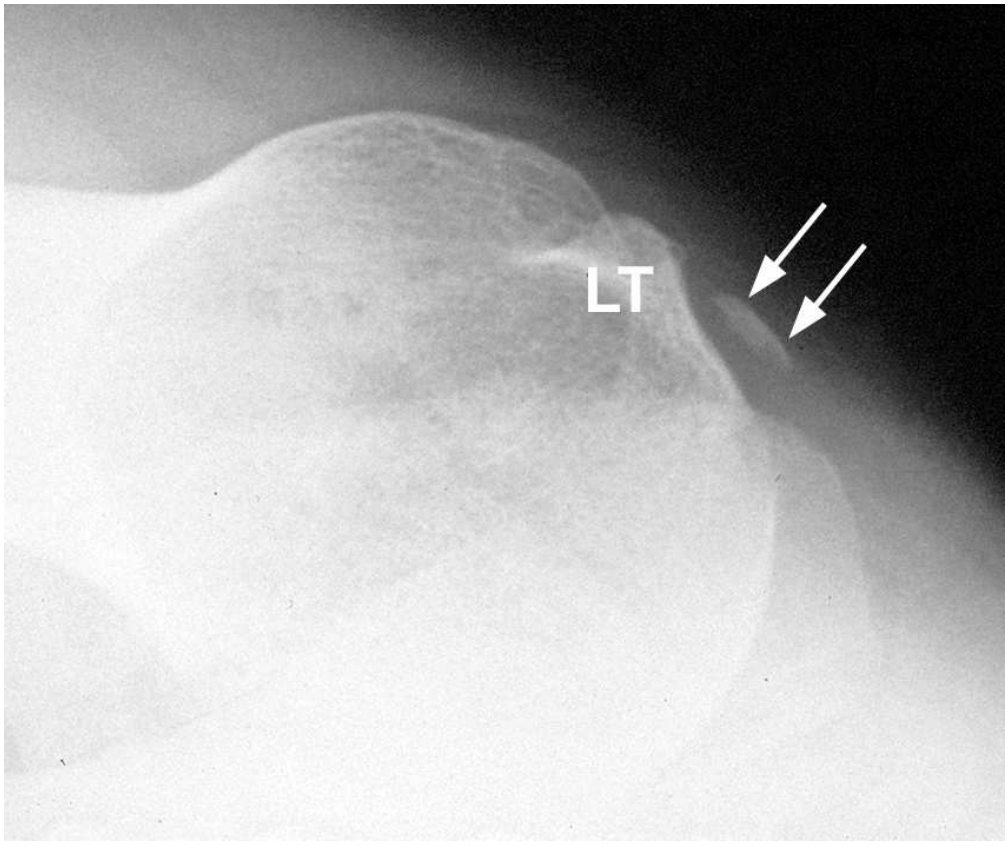

Fig 1B

Fig. 1. 52-year-old man with a limited and painful external rotation of the right shoulder following trauma.
A, Long axis sonogram of the subscapularis tendon (SSC) shows a linear hyperechoic reflection (arrows) in the midsubstance of the subscapularis tendon insertion, which is suggestive for an avulsion fracture of the lesser tuberosity (LT).
B, Additionally obtained radiographic projection (cranio-caudal view) confirmed the lesser tuberosity fracture, whereas this was not visible on the initially obtained conventional radiographs.

53x45mm (400 x 400 DPI)

Fig 2A

Fig. 2. 68-year-old woman with shoulder pain and disability following a fall on the right shoulder.
A, The initial radiographs, obtained 6 days following trauma, were interpreted as normal.
B, Long axis sonogram of the supraspinatus tendon (SSP) shows a cortical bone discontinuity (large arrow) at the junction between the greater tuberosity (GT) and the humeral head, representing a non-displaced greater tuberosity fracture. The thickened subacromial-subdeltoid bursa (small arrows) is either caused by trauma or due to chronic impingement.
C, The radiographs obtained 1 month following trauma showed a radiolucent zone (arrows) along the fracture line due to bone resorption indicative of active bone repair.

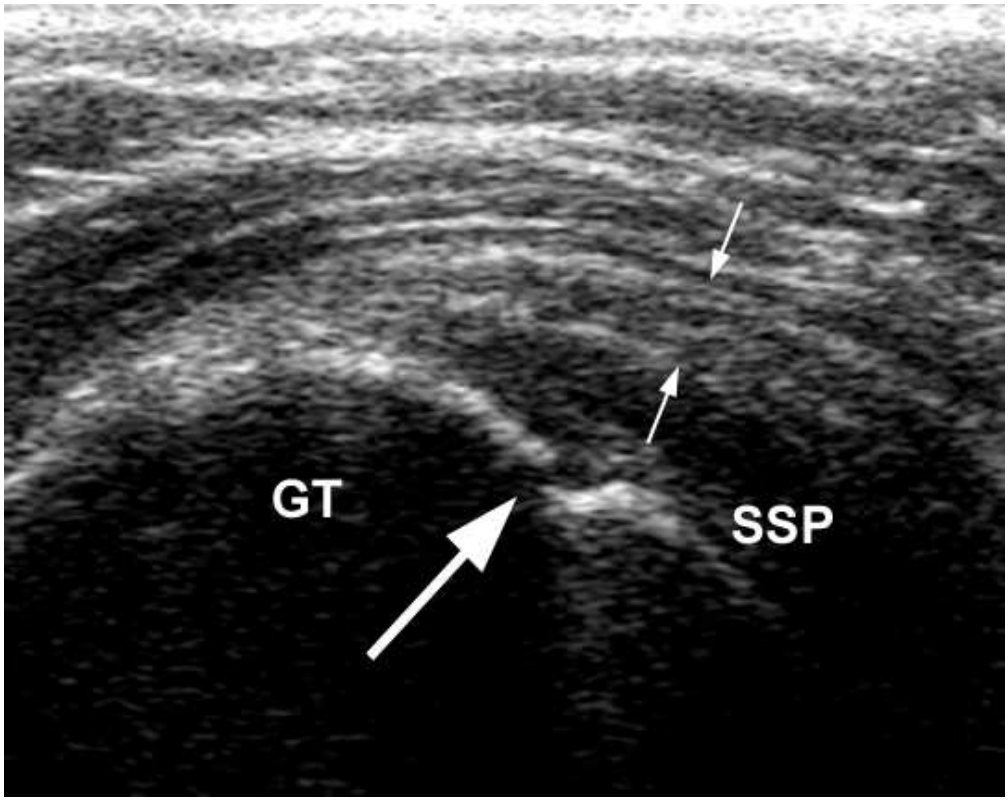

Fig 2B

Fig. 2. 68-year-old woman with shoulder pain and disability following a fall on the right shoulder. A, The initial radiographs, obtained 6 days following trauma, were interpreted as normal. B, Long axis sonogram of the supraspinatus tendon (SSP) shows a cortical bone discontinuity (large arrow) at the junction between the greater tuberosity (GT) and the humeral head, representing a non-displaced greater tuberosity fracture. The thickened subacromial-subdeltoid bursa (small arrows) is either caused by trauma or due to chronic impingement. C, The radiographs obtained 1 month following trauma showed a radiolucent zone (arrows) along the fracture line due to bone resorption indicative of active bone repair.

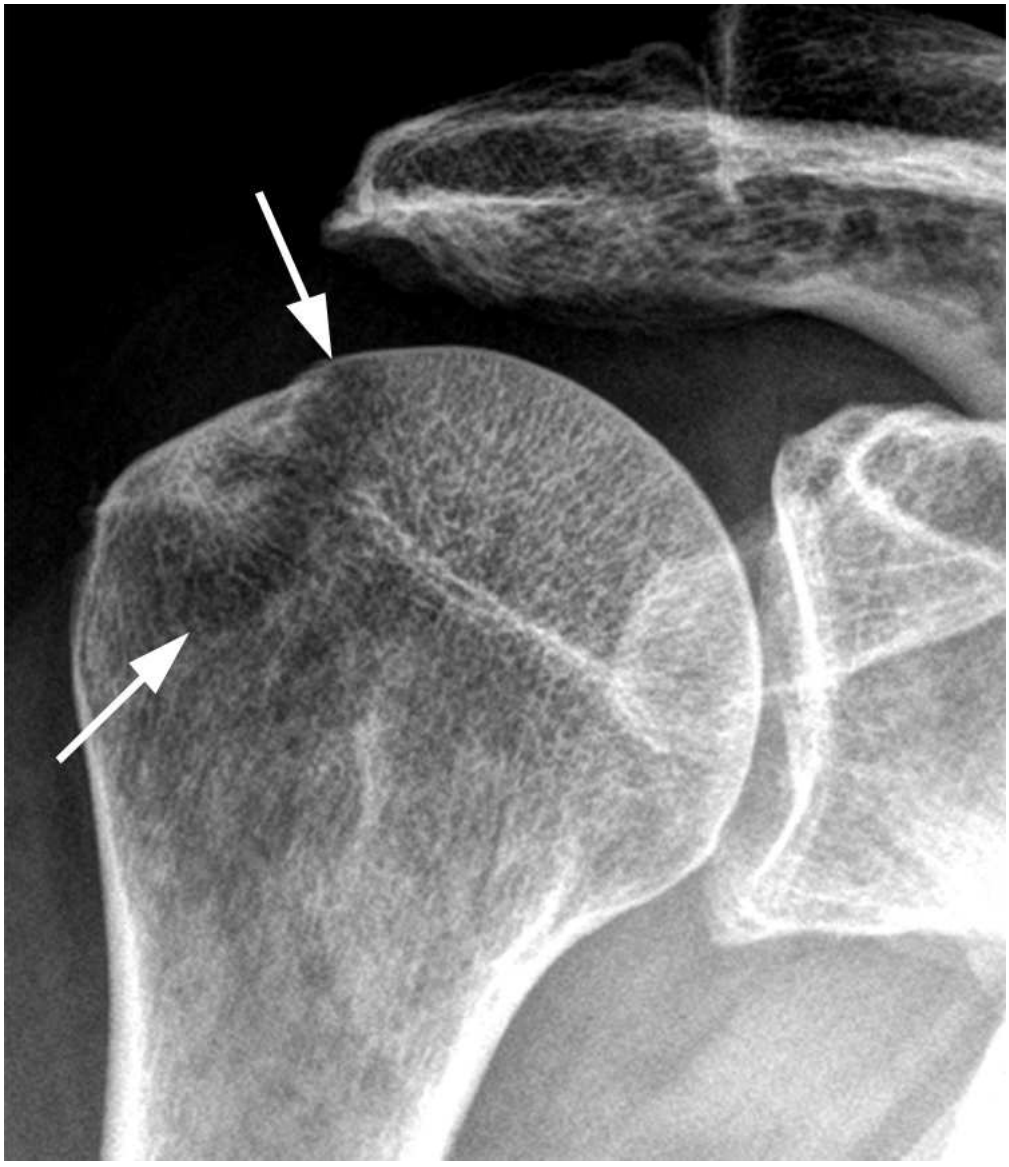

Fig 2C

Fig. 2. 68-year-old woman with shoulder pain and disability following a fall on the right shoulder.
A, The initial radiographs, obtained 6 days following trauma, were interpreted as normal.
B, Long axis sonogram of the supraspinatus tendon (SSP) shows a cortical bone discontinuity (large arrow) at the junction between the greater tuberosity (GT) and the humeral head, representing a non-displaced greater tuberosity fracture. The thickened subacromial-subdeltoid bursa (small arrows) is either caused by trauma or due to chronic impingement.
C, The radiographs obtained 1 month following trauma showed a radiolucent zone (arrows) along the fracture line due to bone resorption indicative of active bone repair.

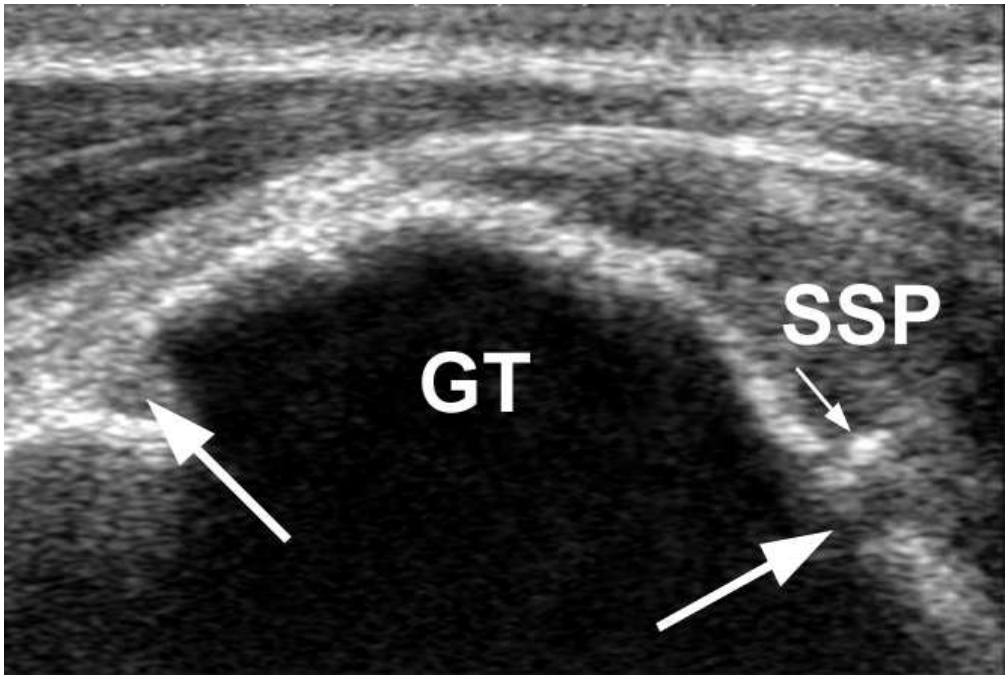

Fig 3A

Fig. 3. 43-year-old man with pain and disability of the shoulder 19 days following a fall on the right shoulder.
A, B, Long axis sonograms of the supraspinatus tendon (SSP) showing corticol bone discontinuities (large arrows) and outpouchings of cortical bone (small arrows) representing fractures of the greater tuberosity (GT), which are frequently associated with intrasubstance rotator cuff tears (asterisks).
C, A radiograph obtained directly following US could not confirm the US findings.
D, Coronal T1-weighted FSE images with fat saturation of a MR arthrogram confirmed the US findings by showing an elevated signal of the greater tuberosity (GT) due to oedema because of a fracture and a longitudinally orientated intrasubstance tear (arrow) of the supraspinatus tendon (SSP).

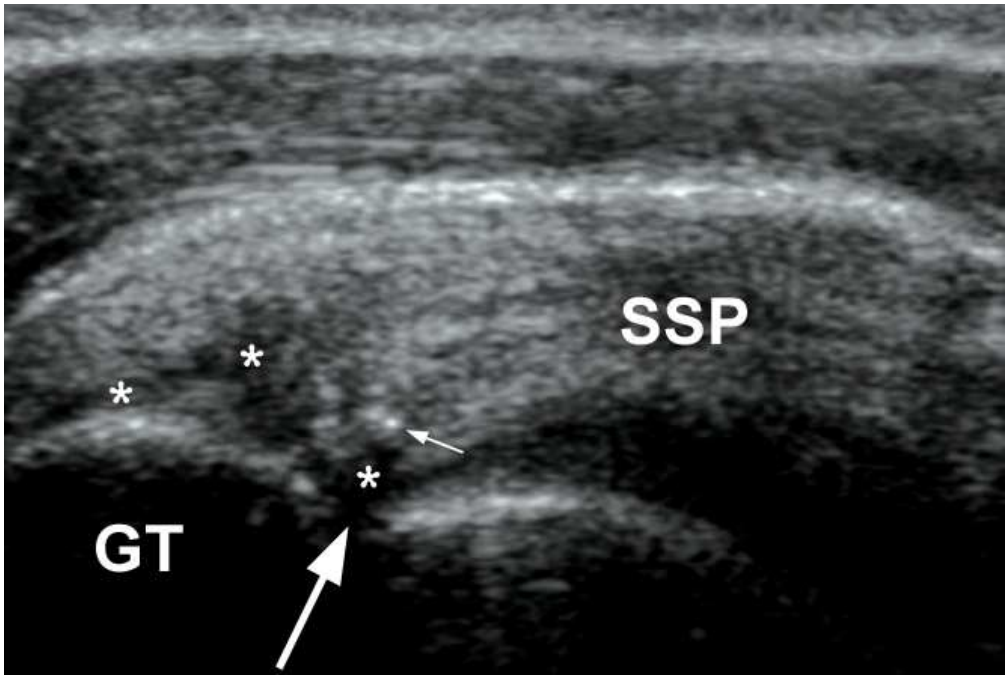

Fig 3B

Fig. 3. 43-year-old man with pain and disability of the shoulder 19 days following a fall on the right shoulder.
A, B, Long axis sonograms of the supraspinatus tendon (SSP) showing corticol bone discontinuities (large arrows) and outpouchings of cortical bone (small arrows) representing fractures of the greater tuberosity (GT), which are frequently associated with intrasubstance rotator cuff tears (asterisks).
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Fig 3C

Fig. 3. 43-year-old man with pain and disability of the shoulder 19 days following a fall on the right shoulder.
A, B, Long axis sonograms of the supraspinatus tendon (SSP) showing corticol bone discontinuities (large arrows) and outpouchings of cortical bone (small arrows) representing fractures of the greater tuberosity (GT), which are frequently associated with intrasubstance rotator cuff tears (asterisks).
C, A radiograph obtained directly following US could not confirm the US findings.
D, Coronal T1-weighted FSE images with fat saturation of a MR arthrogram confirmed the US findings by showing an elevated signal of the greater tuberosity (GT) due to oedema because of a fracture and a longitudinally orientated intrasubstance tear (arrow) of the supraspinatus tendon (SSP).

Fig 3D

Fig. 3. 43-year-old man with pain and disability of the shoulder 19 days following a fall on the right shoulder.
A, B, Long axis sonograms of the supraspinatus tendon (SSP) showing corticol bone discontinuities (large arrows) and outpouchings of cortical bone (small arrows) representing fractures of the greater tuberosity (GT), which are frequently associated with intrasubstance rotator cuff tears (asterisks).
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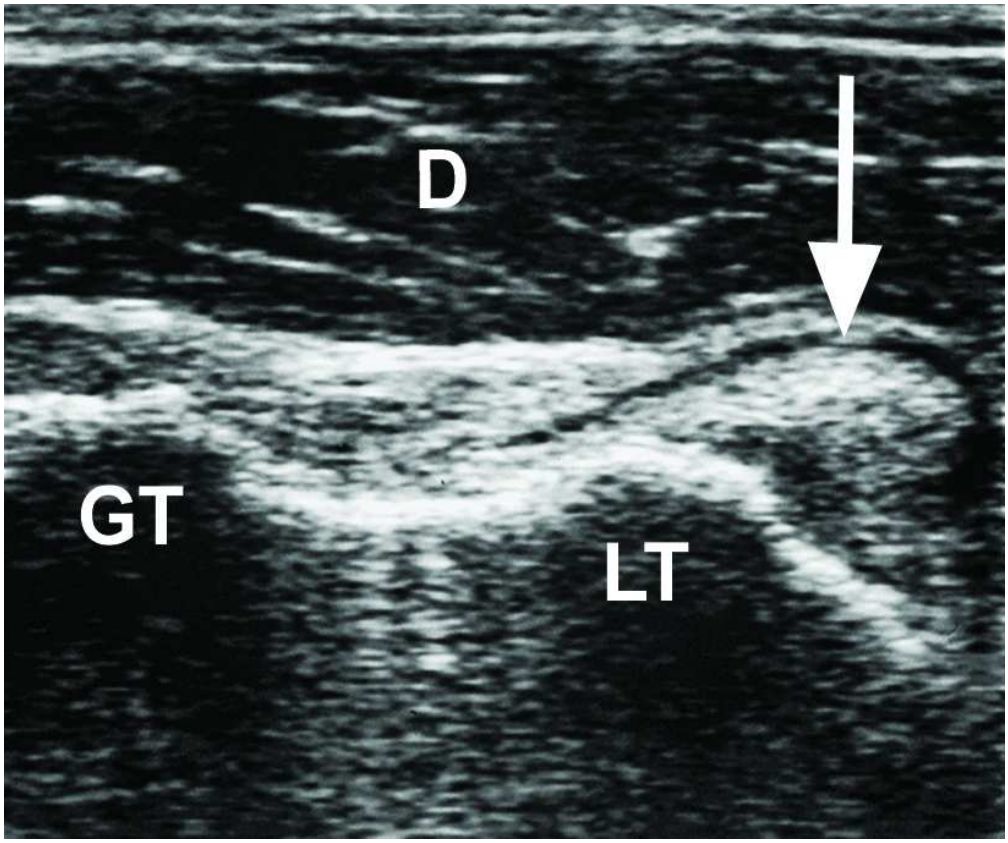

Fig 4A

Fig. 4 Subluxation (A) and complete dislocation (B) of the long head of the biceps tendon.
A, 49-year-old man. Transverse US image obtained at the level of the intertubercular groove shows subluxation of the long head of the biceps tendon (arrow), which is located over the lesser tuberosity (LT). D = Deltoid muscle, GT = greater tuberosity.
B, 60-year-old woman. Transverse US image obtained at the level of the intertubercular groove shows medial dislocation of the long head of the biceps tendon (arrow) and an empty, fluid filled intertubercular groove (small black arrows). B = distended subacromial-subdeltoid bursa, GT = greater tuberosity, LT = lesser tuberosity.

51x43mm (400 x 400 DPI)

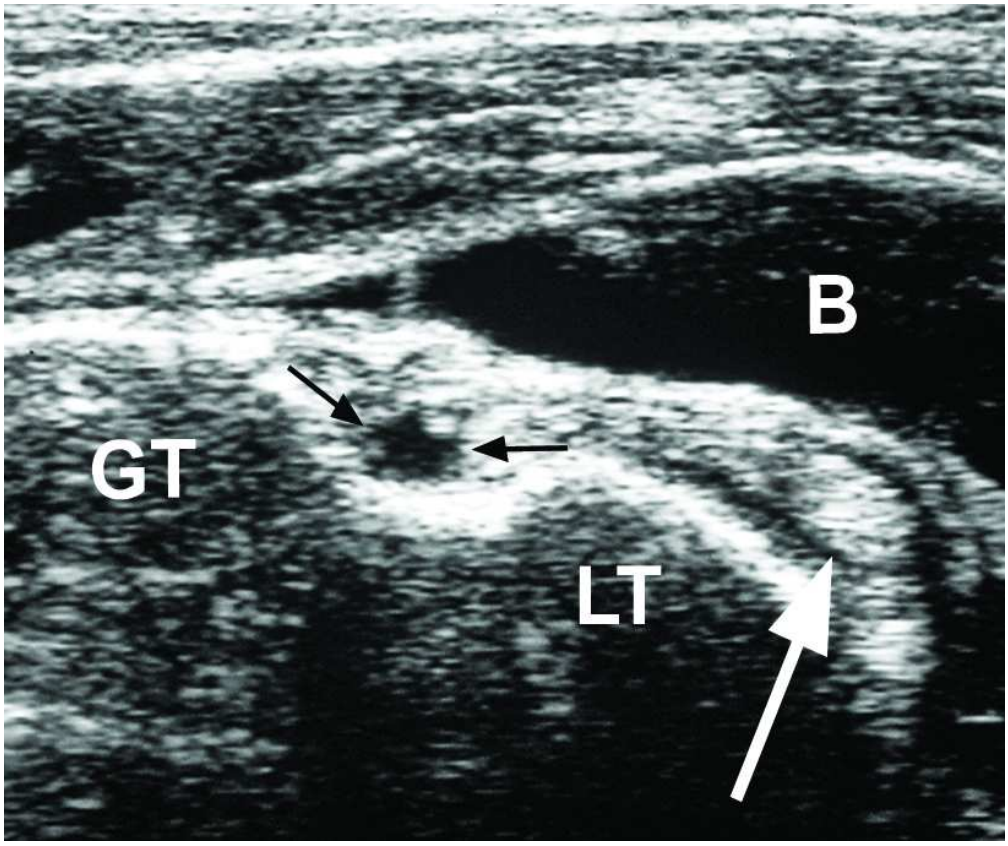

Fig 4B

Fig. 4 Subluxation (A) and complete dislocation (B) of the long head of the biceps tendon.
A, 49-year-old man. Transverse US image obtained at the level of the intertubercular groove shows subluxation of the long head of the biceps tendon (arrow), which is located over the lesser tuberosity (LT). D = Deltoid muscle, GT = greater tuberosity.
B, 60-year-old woman. Transverse US image obtained at the level of the intertubercular groove shows medial dislocation of the long head of the biceps tendon (arrow) and an empty, fluid filled intertubercular groove (small black arrows). B = distended subacromial-subdeltoid bursa, GT = greater tuberosity, LT = lesser tuberosity.

51x43mm (400 x 400 DPI)