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Role of dynamic ultrasound versus MRI in diagnosis and assessment of shoulder impingement syndrome

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Abstract

Background: Subacromial impingement is the most frequent cause of shoulder pain, accounting for up to 60% of all shoulder complaints; dynamic high-resolution ultrasonography can be used in the detection of different abnormalities causing and related to shoulder impingement. This is compared to MRI, which we considered as a standard in our cases.

Results: Fifty patients presented with symptoms of painful shoulder with 42 patients of them having limited movements of their shoulders. All patients had a conventional B-mode ultrasound examination, and dynamic sonographic examination was also performed in all patients. The results were compared to the MRI examination results of those patients. The addition of dynamic ultrasound examination for diagnosis of the painful shoulder showed the highest sensitivity in the assessment of impingement syndrome and for detection of different abnormalities affecting the shoulder joint (e.g., 85.7% for rotator cuff partial-thickness tear, 90% for rotator cuff full-thickness tear).

Conclusion: Based on our results, the static US combined with dynamic study can be a helpful tool in detecting different abnormalities of the painful shoulder especially impingement syndrome and its different causes.

Keywords: Dynamic ultrasonography, MRI, Shoulder impingement, Rotator cuff disorders

Background

Injuries of shoulder joints are common. The unique structure of the shoulder joint makes it more liable for joint dislocation [1]. Different causes of the painful shoulder are encountered; shoulder impingement comes on the top with multiple factors causing it. They are divided into two major groups: structural factors (related to the Acromion, acromio-clavicular joint, rotator cuff, coracoid process, bursa, and humerus) and functional factors [2].

MRI is considered an effective technique for the evaluation of the different causes of painful shoulder, with its main disadvantage being a static evaluation of the shoulder joint [3]. Dynamic ultrasonography is a beneficial technique for the evaluation of many disorders affecting musculoskeletal organs, including painful shoulder syndrome [4].

Rotator cuff tendon disorders constitute the most common group of pathologies that affect the shoulder joints [5]. Diagnostic radiological procedures such as ultrasonography (US), MRI, and MR arthrography (MRA) provide useful information that can help clinicians to establish the proper treatment plan for each patient [6]. The role of diagnostic imaging is to help guide surgical or non-surgical management. The ideal imaging technique should have a high rate of true positive and an acceptable rate of false positive to limit unnecessary surgical intervention [7].

The advantages of US driving its recent increased use include low cost, accessibility, and capability for real-time high-resolution imaging that enables a dynamic assessment and needle guidance [8].

Methods

The aim of this study is to assess the role of dynamic high-resolution ultrasonography in the detection of different abnormalities of the shoulder joint,

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Table 1 Frequency tables with percentages

Statistic	Acromio-clavicular osteoarthritis		Rotator cuff tendinosis		Calcific tendinitis		Partial-thickness tear	
	Value	95% CI	Value	95% CI	Value	95% CI	Value	95% CI
Sensitivity	94.74%	82.25% to 99.36%	83.33%	58.58% to 96.42%	100.00%	29.24% to 100.00%	85.71%	57.19% to 98.22%
Specificity	100.00%	90.26% to 100.00%	100.00%	78.20% to 100.00%	100.00%	29.24% to 100.00%	100.00%	73.54% to 100.00%
Negative likelihood ratio	0.05	0.01 to 0.20	0.17	0.06 to 0.47	0.00		0.14	0.04 to 0.52
Disease prevalence	51.35%	39.44% to 63.15%	54.55%	36.35% to 71.89%	50.00%	11.81% to 88.19%	53.85%	33.37% to 73.41%
Positive predictive value	100.00%		100.00%		100.00%		100.00%	
Negative predictive value	94.74%	82.37% to 98.58%	83.33%	64.02% to 93.35%	100.00%		85.71%	62.45% to 95.58%
Accuracy	97.30%	90.58% to 99.67%	90.91%	75.67% to 98.08%	100.00%	54.07% to 100.00%	92.31%	74.87% to 99.05%

to find out the value added by dynamic ultrasonography to the static examination of such cases. This is compared to MRI which we considered as a standard to our cases.

We followed the Essential Items for Reporting Diagnostic Accuracy Studies (STARD) list during the preparation of this study.

This study included 50 patients, 32 females and 18 males, with an age range from 26 to 64 years (mean age 45 years); they all complaining from painful shoulder; and 42 of them complaining from a limitation of movement.

The present study was a prospective diagnostic test accuracy study that was conducted from October 2016 and June 2017. Patients were investigated with both ultrasound (US) and magnetic resonance (MR) imaging for the painful shoulder.

Adults' patients who presented with painful or limited movement of the shoulder were included in a consecutive manner. While patients with shoulder dislocation, neoplastic lesions, or contraindication for MRI were excluded from the study. Pregnant women were excluded as well. Eligible patients underwent a full history and clinical examination.

Ultrasonography examination

Grayscale US examination was utilized using S-6 general electric (USA) ultrasound device that is equipped with 5–12 MHz linear array transducer to characterize the etiologic

factors of painful shoulder and/or causes of limitation of shoulder movements as well as any associated abnormality. While the patient is seated in a backless chair, the following were examined: biceps brachii tendon, subscapularis and biceps tendon subluxation/dislocation, supraspinatus and rotator interval, acromio-clavicular joint, subacromial-subdeltoid bursa, subacromial impingement, infraspinatus, teres minor, and posterior labrum. The detailed ultrasonographic examination of this shoulder was described elsewhere [2].

MRI examination

MRI was performed on a high field system (1.5 Tesla) magnet units (Philips Intera). The patient should be supine with the head directed towards the scanner bore. The preferred positioning of the patient's arm is neutral to slightly externally rotated. Surface coil (flexible coils) are those that wrap around and conform to the anatomic area of interest. Preliminary scout localizers in axial, coronal, and sagittal planes were done.

Statistical analysis

The statistical analysis was carried with SPSS software (Statistical Package for the Social Sciences, version 24, SPSS Inc., Chicago, IL, USA). Frequency tables with percentages (Tables 1, 2, and 3) were used for categorical variables, and descriptive statistics (mean and standard

Table 2 Frequency tables with percentages

Statistic	Full-thickness tear		Infraspinatus tendinopathy		Infraspinatus tear		Subscapularis tendinopathy	
	Value	95% CI	Value	95% CI	Value	95% CI	Value	95% CI
Sensitivity	90.00%	55.50% to 99.75%	83.33%	35.88% to 99.58%	100.00%	15.81% to 100.00%	50.00%	6.76% to 93.24%
Specificity	100.00%	66.37% to 100.00%	100.00%	47.82% to 100.00%	100.00%	15.81% to 100.00%	100.00%	15.81% to 100.00%
Negative likelihood ratio	0.10	0.02 to 0.64	0.17	0.03 to 1.00	0.00		0.50	0.19 to 1.33
Disease prevalence	52.63%	28.86% to 75.55%	54.55%	23.38% to 83.25%	50.00%	6.76% to 93.24%	66.67%	22.28% to 95.67%
Positive predictive value	100.00%		100.00%		100.00%		100.00%	
Negative predictive value	90.00%	58.37% to 98.30%	83.33%	45.52% to 96.77%	100.00%		50.00%	27.29% to 72.71%
Accuracy	94.74%	73.97% to 99.87%	90.91%	58.72% to 99.77%	100.00%	39.76% to 100.00%	66.67%	22.28% to 95.67%

Table 3 Frequency tables with percentages

Statistic	Biceps teno-synovitis		Joint effusion		Subacromial bursitis	
	Value	95% CI	Value	95% CI	Value	95% CI
Sensitivity	100.00%	79.41% to 100.00%	94.29%	80.84% to 99.30%	93.33%	77.93% to 99.18%
Specificity	100.00%	79.41% to 100.00%	100.00%	89.42% to 100.00%	100.00%	87.66% to 100.00%
Negative likelihood ratio	0.00		0.06	0.01 to 0.22	0.07	0.02 to 0.25
Disease prevalence	50.00%	31.89% to 68.11%	51.47%	39.03% to 63.78%	51.72%	38.22% to 65.05%
Positive predictive value	100.00%		100.00%		100.00%	
Negative predictive value	100.00%		94.29%	81.12% to 98.45%	93.33%	78.59% to 98.16%
Accuracy	100.00%	89.11% to 100.00%	97.06%	89.78% to 99.64%	96.55%	88.09% to 99.58%

deviation) were used for numerical variables. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPP) of US examinations of different pathologies were calculated. A *p* value of less than 0.05 was considered statistically significant.

Results

- All cases were examined with static and dynamic ultrasonography as well as detailed conventional MRI.
- The ultrasonographic findings were compared to that obtained by MRI in all cases.
- The frequency and percentage according to sex in the study population, where female patients represented 64%, while male patients represented 36%.
- The frequency of pathological injuries, according to the mean age revealed that patients below 45 years showed higher incidence of intrinsic factors of impingement with high incidence of tendinopathy and partial-thickness rotator cuff tendon tears, while those above 45 years old had higher incidence of

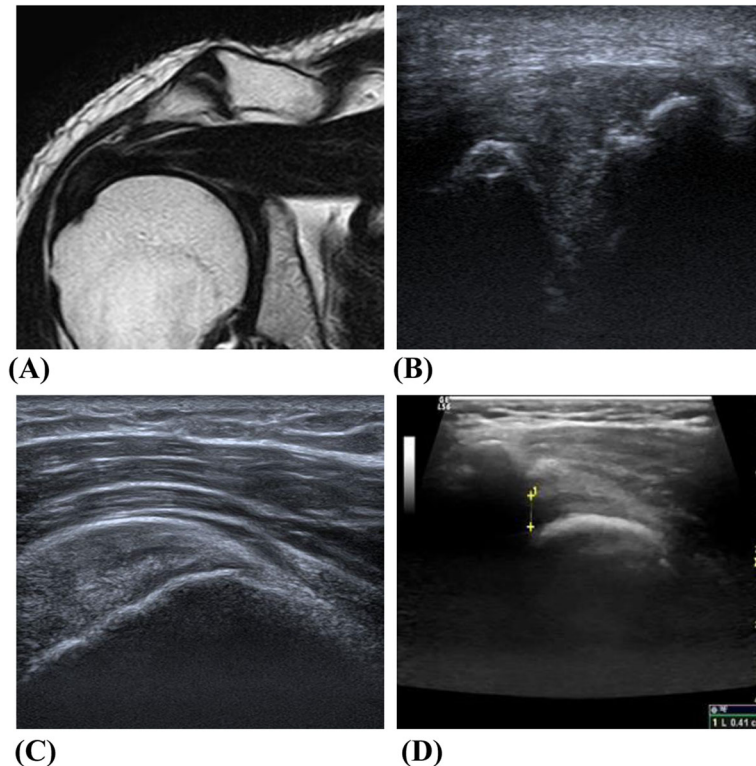


Fig. 1 **a** MRI, coronal T2WIs: acromio-clavicular osteoarthritis and thickening of supraspinatus tendon with increased signal intensity yet no fiber discontinuity. **b** Static US image showed evidence of acromio-clavicular osteoarthritis. **c** Static US image showing swollen supraspinatus tendon with ill-defined hypoechogenicity yet with preserved fiber continuity. **d** Dynamic ultrasonography showed narrowing of the subacromial tunnel in stress position

extrinsic factors, especially the acromio-clavicular osteoarthropathy, with a relatively higher incidence of full-thickness rotator cuff tendon tears.

- The frequency and the percentage of affection of the right and left shoulder side were 34 patients (68%) and 16 patients (32%), respectively.
- The frequency and the percentage of affection of shoulders by different pathologies by US and MRI were obtained.
- According to results obtained, the U/S is superior to MRI in two conditions: dynamic evaluation of subacromial impingement and in addition to the detectable increased synovial vascularity by added color-Doppler examination.
- While the MRI is superior to US in bony lesions, including acromio-clavicular osteoarthritis and the description of acromial shape, that may be the basic factor for incidence of subacromial impingement as well as detecting marrow infiltrative lesions (Figs. 1, 2, 3, and 4).

Discussion

- In this study, we have confirmed the fact that MR examination is a valuable diagnostic modality that

can give us valuable information as regards the different anatomic information and variations (e.g., the acromial shape), detecting rotator cuff abnormalities including tendinosis, partial-thickness, and full-thickness tears as well as degenerative changes of the acromio-clavicular joint. But, its main disadvantage of being a static examination that cannot reveal the exact relationship between the acromion, humeral head, and intervening soft tissues during active shoulder movement.

- In this study, with dynamic evaluation for shoulder impingement is performed in all our cases through measuring the vertical dimension of the osseous subacromial tunnel in both neutral and stress positions in which the arm is semi-flexed and semi-abducted, and the hand is pronated, during stress position: the greater tuberosity of the humeral head is brought underneath the acromion, to assess if there is considerable reduction in the dimension that causes repeated shearing trauma of the rotator cuff tendon during shoulder movement (osseous impingement). It was found that the vertical dimension of the subacromial tunnel measures less than 6 mm in a neutral position and shows further reduction (about 25%) in stress position in cases of subacromial impingement.

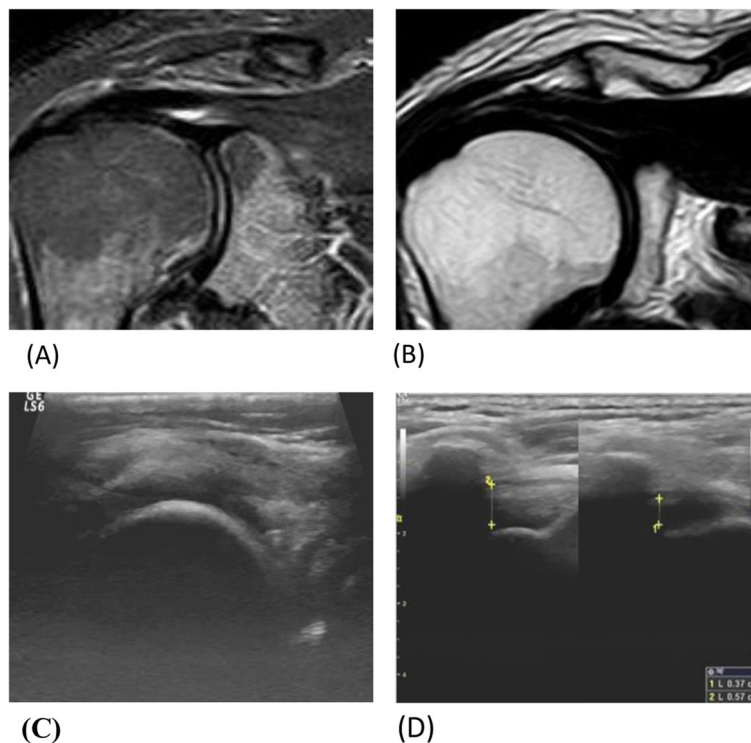


Fig. 2 **a** MRI, sagittal STIR WIs: fluid signal seen at the articular surface of the musculo-tendinous junction of supraspinatus tendon (arrow). No evidence complete fiber interruption detected. **b** MRI, Coronal T2WIs of the shoulder showing acromio-clavicular osteoarthritis. **c** Static US images show partial-thickness tear of the humeral surface of the supraspinatus tendon, seen as a hypoechoic linear defect interrupting the tendon fibers (arrow). **d** Dynamic ultrasonography showed narrowing of the subacromial tunnel that became accentuated in stress position

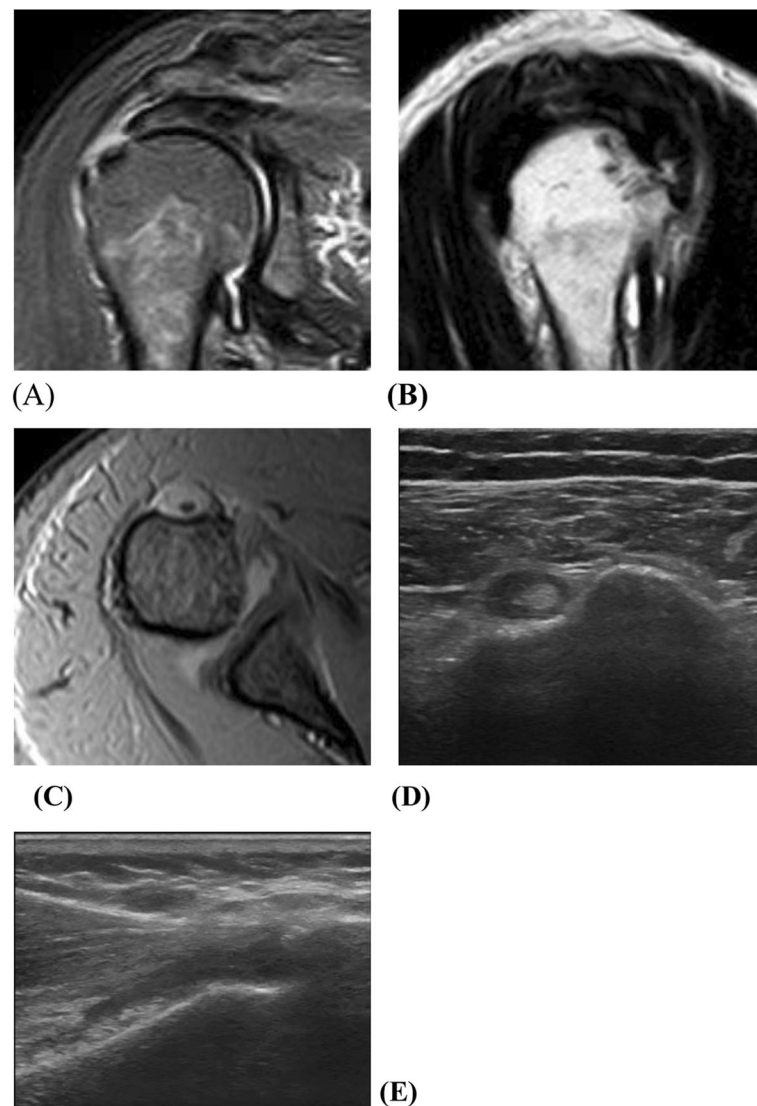


Fig. 3 **a** MRI, sagittal STIR WIs: fluid signal is seen filling the gap as a result of full-thickness tear of the supraspinatus tendon (arrow), also shows acromio-clavicular osteoarthritis changes. **b** MRI, sagittal T2WIs of the shoulder showing focal fiber interruption of the subscapularis tendon with fluid signal noted (arrow). **c** MRI, axial T2 of the shoulder shows marked fluid signal along the sheath of long head of biceps tendon. **d** Static US images show distension of long head of biceps tendon sheath by hypoechoic fluid. **e** Static US shows hypoechoic linear defect interrupting the fibers of supraspinatus tendon (arrow)

- This agreed with the study of Nathalie et al. [3] that had detected—by dynamic ultrasonography—the significant reduction of the subacromial tunnel during active shoulder movement to stress position, with the rotator cuff tendon becomes more prone to compression, eliciting shoulder pain.
- In this study, 10 patients were diagnosed by MRI as having full-thickness tears of the supraspinatus tendon, 9 patients of them were detected in the US. Regarding partial-thickness tear, 14 patients were detected by MRI while in the US two of them were consistently described as degenerated tendons. This inconsistency in

the evaluation of partial-thickness tears has likewise been reported by other authors. Lenza et al. [6] stated that small partial-thickness tears can be missed. In conclusion, the exact size of the partial tear should be measured to ascertain that partial-thickness tears are frequently missed due to the dimension of the injury.

- In this study, US agreement to MRI for the supraspinatus tendon assessment was 90% for full-thickness tears and 85.5% for partial-thickness tears so that US can be used to rule out complete supraspinatus tears, especially in patients that are not apt to receive an MRI.

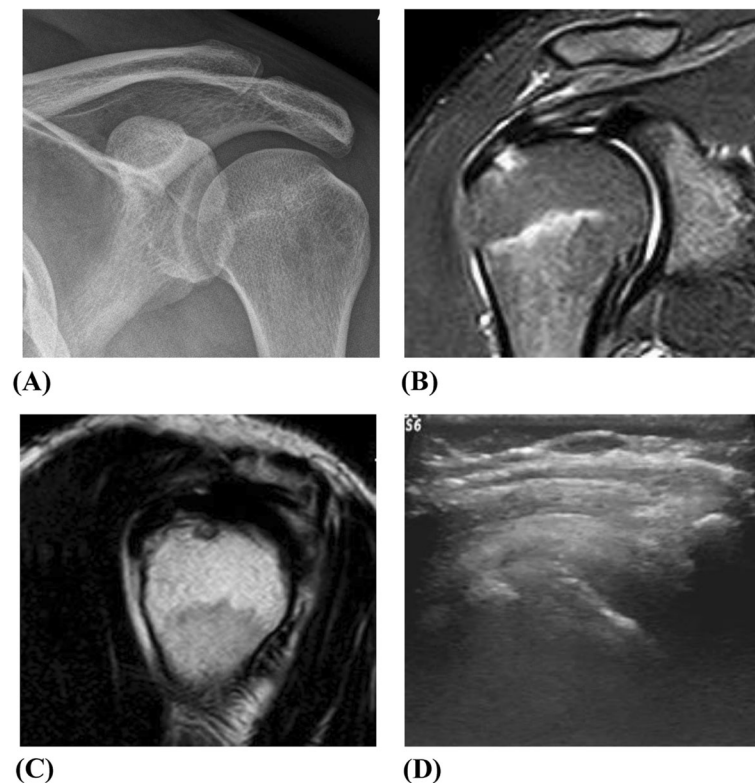


Fig. 4 **a** Digital radiography shows evidence of lateral downsloping of the acromion process. **b** MRI, sagittal STIR WIs: fluid signal seen at the articular surface of the supraspinatus tendon near its insertion (arrow). No evidence complete fiber interruption detected. Mild joint effusion is also noted. **c** MRI, sagittal T2WIs of the shoulder shows also partial-thickness tear of supraspinatus tendon. **d** Static US images show partial-thickness tear of the humeral surface of the supraspinatus tendon, seen as a small hypoechoic linear defect interrupting the tendon fibers (arrow)

- This disagreeing with studies of Melanie et al. [9] and Nathalie et al. [3] that reported the very high sensitivity (about 100%) of dynamic ultrasonography in detection of different types of partial-thickness rotator cuff tears.
- In this study, we stated that ultrasonography is relatively less sensitive than MRI in the detection of rotator cuff tendinosis (83.3% sensitivity) that appears as a focal or diffuse area of decreased reflectivity, with no disruption of the fiber continuity. In the current study, 15 cases were diagnosed by ultrasonography to have rotator cuff tendinosis, such cases in addition to another three cases were detected by MRI, with ultrasonography reported normal rotator cuff tendon in such missed case.
- This is agreed with the study done by Ian Beggs and reported the accepted accuracy of ultrasonography in detection of rotator cuff tendinosis, especially in cases with resultant focal or diffuse tendon thickening that could be easily compared to the adjacent normal part of the tendon or the contralateral normal one.
- In this study, three cases showed evidences of calcific tendinitis detected by both ultrasonography and MRI that was seen as a tiny intra-tendinous echoic calcific focus with faint acoustic shadowing by ultrasonography and seen as a small intra-tendinous focus of signal-void in MRI. It was associated with hypertrophic acromio-clavicular osteoarthritis and subacromial bursitis (plain radiography was done for these three cases and assured the diagnosis).
- Although the exact pathogenesis of calcific tendinitis condition remains unknown, it is probably multifactorial—likely being related to degeneration, reactive change, predisposing medical conditions, and genetics [10].
- This is agreed with (Chiou et al.), who reported the high accuracy of the ultrasonography in detection of calcific tendinitis.
- In this study, results showed accepted accuracy (about 94.7% sensitivity) of dynamic ultrasonography in detection of acromio-clavicular joint osteoarthritic changes compared to MR.
- This is agreed with the study of Melanie et al. [9] who reported the value of dynamic ultrasonography in direct visualization of the rotator cuff tendon injury by acromio-clavicular joint degenerative changes.

- In this study, 28 cases showed evidences of subacromial bursitis with bursal fluid distension by ultrasonography, while MRI had detected 30 cases. It was noticed that the cases missed by U/S showed very minimal bursal effusion, which means that ultrasonography has the disadvantage in the detection of minimal amounts of fluid.
- In this study, regarding joint effusion, among the cases of the study there were 35 cases having joint effusion, two of them missed by ultrasonography. But, ultrasonography had the advantage of being capable of detecting any degree of synovial thickening and differentiating the hypoechoic synovium from fluid by using the compression test.
- This is agreed with almost all the reviewed studies done in the same field, like those carried out by Melanie et al. [9], Mc Nally et al. [11].
- In this study, the 16 cases detected by MRI could be also detected by ultrasonography to have biceps teno-synovitis, and this ensures the fact that ultrasonography is efficient in detecting minimal fluid and subtle synovial changes.
- This is agreed with the studies carried out by Nathalie et al. [3] who reported the high diagnostic value of static and dynamic ultrasonography in cases of bicep teno-synovitis.

Conclusion

The study has proved that dynamic ultrasonography is a highly accurate, highly sensitive diagnostic modality in different types of the painful shoulder.

Abbreviations

AC: Acromion; ACJ: Acromio-clavicular joint; AHD: Acromio-humeral distance; AHI: Acromio-humeral interval; AP: Antero-posterior; CHL: Coraco-humeral ligament; CL: Clavicle; Del: Deltoid muscle; Fig: Figure; GT: Greater tuberosity; HAD: Calcium hydroxyapatite deposition; HH: Humeral head; InfraS: Infraspinatus muscle; INT R: Internal rotation; LHB: Long head of biceps; LS: Longitudinal section; LT: Lesser tuberosity; Max: Maximum; Min: Minimum; MRI: Magnetic resonance imaging; PA: Postero-anterior; RC: Rotator cuff; TS: Transverse section; US: Ultrasound

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Authors' contributions

IEA put the idea of the study, edited the manuscript, participated in the study design, performed the US exams, and recorded the results. HME participated in the study design and gathering data. AAH patients collected and aided in statistical data. All authors read and approved the final manuscript.

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Availability of data and materials

All the datasets used and analyzed in this study are available with the corresponding author on reasonable request.

Ethics approval and consent to participate

Written informed consent was signed by all patients before the examination. The study was approved by the research committee of the Faculty of Medicine, Kasr Al Ainy Hospital, Cairo University, 2017. No reference number provided as the committee just say yes or no according to the system in our faculty of medicine at 2017 (date of starting of this research).

Consent for publication

All patients included in this research were fully conscious and older than 16-year old and gave written informed consent to publish the data contained within this study.

Competing interests

The authors declare that they have no competing interests.

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