Effectiveness Comparison Between High Frequency Ultrasonography and MRI in Diagnosing Rotator Cuff Tears

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Abstract

Objectives: To evaluate the clinical value of high frequency ultrasonography (HF-US) in diagnosing rotator cuff tears (RCTs) by comparing it and magnetic resonance imaging (MRI) with arthroscopy as the gold standard. Methods: A retrospective analysis was performed on 249 patients who were suspect cases of RCTs and going to receive shoulder arthroscopy. 87 patients who underwent HF-US and MRI during the same period before surgery were enrolled in this study. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and the rates of accurate diagnosis, misdiagnosis and missed diagnosis of HF-US and MRI were calculated. The two tools were compared to analyze their effectiveness differences in diagnosing full thickness tears (FTT) and partial thickness tears (PTT). Results: The sensitivity, specificity, PPV, NPV, and accuracy of HF-US and MRI were 0.783-0.935 vs. 0.913-0.957, 0.833-0.833 vs. 0.889-0.889, 0.857-0.953 vs. 0.917-0.970, 0.652-0.833 vs. 0.762-0.941, and 0.805-0.906 vs. 0.825-0.927, respectively. HF-US had a lower sensitivity, NPV and accuracy and a higher rate of missed diagnosis in diagnosis of PTT than MRI, however, the differences were not statistically significant (P > 0.05). Conclusions: Both HF-US and MRI have high effectiveness in diagnosing FTT and PTT. HF-US can be used as a main imaging modality of examining patients with shoulder pain who are suspected of having RCTs in clinical settings.

Keywords

High frequency ultrasonography; Magnetic resonance imaging; Rotator cuff tears.

1. Introduction

Rotator cuff tears (RCTs) are common musculoskeletal injuries, affecting the supraspinatus tendon most frequently. The incidence of RCTs gets higher as humans age and have a longer lifespan. The prevalence of RCTs in symptomatic individuals is 64%. Asymptomatic individuals can also have RCTs and the incidence is 39%[1]. RCTs are the main causes of shoulder pain, and the spontaneous healing rate of torn tendons is approximately zero[2]. Accurate diagnosis of RCTs is crucial to subsequent treatment: improper diagnosis and management can lead to disability and dysfunction. If no intervention is administered, the tears are likely to enlarge in area and secondary medical conditions, such as steatosis, muscle atrophy and traumatic arthritis, are likely to occur with a prolonged disease course[3]. The pain and functional outcomes are significantly improved in patients receiving surgery compared to those who not[4, 5].

Magnetic resonance imaging (MRI) is currently the preferred modality of RCTs evaluation[6]. MRI can not only provide excellent contrast resolution and good spatial resolution of the shoulder and surrounding structures, but also reveal bone marrow edema and help with a relatively comprehensive evaluation of shoulder injuries [6, 7]. However, arthrography is usually needed to enhance its diagnostic accuracy, and it is not well tolerated by some patients, expensive and with some contraindications[6]. Recently, ultrasonography has been attracting increasing attention to its value in diagnosing shoulder joint diseases with promotion of standardized examination methods and improvement to its resolution. Use of high frequency ultrasonography (HF-US) in detecting RCTs is a hot research topic because of continuous improvement to the sensitivity and specificity. HF-US has

excellent spatial resolution and is particularly useful in examining suspect cases of supraspinatus or infraspinatus tendon tears; practitioners can also perform dynamic imaging with high frequency ultrasound, which is quite helpful to detect long biceps tendon subluxation, subscapularis tendon tears and subacromial impingement syndrome[7].

Both HF-US and MRI can help diagnose RCTs. However, there is still a dispute over which one of the two is more accurate, especially in diagnosing partial thickness rotator cuff tears[8-11]. This study aimed to evaluate the clinical value of HF-US in diagnosing RCTs by comparing it and MRI with arthroscopy as the gold standard.

2. Patients and Methods

2.1 Patients

A retrospective analysis was performed on 249 patients who were suspect cases of RCTs and going to receive shoulder arthroscopy in the First Affiliated Hospital of Jinan University from September 2017 to September 2019. Eighty-seven patients (41 males and 46 females) who underwent HF-US and MRI during the same period before surgery were enrolled in this study. They were 18 to 88 years old with an average age of 56.6 ± 14.5. The duration varied from 2 to 11 months. 31 cases of RCTs occurred to the left shoulder, while 56 cases to the right one. The interval between HF-US and MRI ranged from 0 to 27 days.

Inclusion criteria: 1) shoulder pain or a history of shoulder injuries; or 2) positive drop arm sign, or positive shoulder impingement test, or positive painful arc sign, or friction between the humerus and the glenoid.

Exclusion criteria: 1) shoulder joint dislocation or humeral fracture; 2) a history of shoulder surgery; 3) a history of shoulder tumor(s); 4) congenital shoulder abnormality; or 5) a history of shoulder arthritis.

2.2 HF-US

HF-US of the affected should joint was performed according to standardized procedures with Philips iU Elite ultrasound system (Philips ultrasound system, Holland) equipped with a L12-5 transducer or with TOSIBA Aplio 500 ultrasound system (Toshiba medical systems corporation, Tokyo, Japan) equipped with a L14-5 transducer or a L18-7 transducer[12-14]. The patient sat on a swivel chair facing the examiner who did longitudinal and transverse scans of the long biceps tendon, subscapularis tendon, supraspinatus tendon, infraspinatus tendon and teres minor tendon consecutively and observed their thickness, continuity and echo signals. The patient's body position was adjusted according to needs during the examination. Tendon motion was observed, and bilateral comparisons were done. The examiner also checked whether there were effusions inside the subacromial-subdeltoid bursa and glenohumeral joint cavity, whether there was synovial hyperplasia, and whether the cortex of the greater tuberosity was smooth. RCTs were classified into full thickness tears (FTT) and partial thickness tears (PTT) according to the diagnostic standards. FTT referred to hypoechoic or anechoic tendon defects that involved the entire tendon, extending from the humeral articular surface to the subacromial-subdeltoid bursa, while PTT manifested as discontinuous echoes on the articular or bursal surfaces or inside the tendons which did not change on shorter or longer axis scans or tilting-transducer scans, and as dysconnectivity between the glenohumeral joint cavity and subacromial-subdeltoid bursa[15].

2.3 MRI

MRI was performed with a 3.0T MRI scanner (Discovery MRI 750 System; GE Healthcare, Milwaukee, Wisconsin) equipped with an 8-channel HD Shoulder coil. The patient was in a supine position with the humeral head on the central line. The sequences included axial and oblique sagittal fat-suppressed proton density weighted imaging (PDWI-FS), axial and oblique coronal T1WI, and oblique coronal and oblique sagittal fat-suppressed T2WI (T2WI-FS). The parameters of the sequences were as follows:

PDWI-FS: TR/TE = 2550 ms/40 ms; FOV = 16 cm × 16 cm; slice spacing = 4 mm; slice thickness = 4 mm

T1WI: TR/TE = 750 ms/15 ms; FOV = 16 cm × 16 cm; slice spacing = 4 mm; slice thickness = 4 mm

T2WI-FS: TR/TE = 3250 ms/70 ms; FOV = 16 cm × 16 cm; slice spacing = 4 mm; slice thickness = 3 mm

The MRI manifestations of supraspinatus tendon FTT were as follows:1) Direct manifestations: linear signals extending from the articular surface through the supraspinatus tendon to the bursal surface, moderate signal intensity on T1WI and PDWI-FS, and high signal intensity on T2WI-FS. Absence of the supraspinatus tendon was seen in severe cases, indicating rupture of the tendon and manifesting as retroversion of the muscle-tendon junction. 2) Indirect manifestations: subacromial-subdeltoid bursa effusions, or glenohumeral joint cavity effusions of various degrees.

The MRI manifestations of supraspinatus tendon PTT were: visible localized fluid signal intensity on the bursal or articular surface, or in torn regions inside the tendon; hypo- to isointense oblique coronal T1WI signal; iso- to hyperintense PDWI-FS signal; high signal intensity on T2WI-FS.

2.4 Statistical analysis

SPSS19.0 and MedCalc were used in statistical analysis. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and the rates of accurate diagnosis, misdiagnosis and missed diagnosis of HF-US and MRI were calculated with arthroscopy as the gold standard. ROC curves were plotted to analyze the differences between the two tools in diagnosing RCTs. The count data were represented with percentages (%) and compared with $\chi 2$ test. A P value of less than 0.05 was considered to indicate statistical significance.

3. Results

3.1 Arthroscopy

Arthroscopy detected 94 RCTs in 74 of the 87 suspect cases. 70 supraspinatus tendon tears were found in 69 cases (1 case of tears of both the articular surface and the bursal surface). Among the rest 24 tears, 14 were diagnosed as subscapularis tendon tears, 2 as infraspinatus tendon tears, 6 as long biceps tendon tears and 2 as long biceps tendon ruptures. Among the 70 supraspinatus tendon tears, there were 46 FTT, 18 bursal surface tears, and 6 articular surface tears.

3.2 HF-US

With arthroscopy as the gold standard, there were 61, 3 and 8 cases of accurate diagnosis, misdiagnosis and missed diagnosis of any supraspinatus tendon tears, respectively, 43, 3 and 3 of supraspinatus tendon FTT, respectively, and 18, 3 and 5 of supraspinatus tendon PTT, respectively.

3.3 MRI

With arthroscopy as the gold standard, there were 64, 2 and 5 cases of accurate diagnosis, misdiagnosis and missed diagnosis of any supraspinatus tendon tears, respectively, 42, 2 and 4 of supraspinatus tendon FTT, respectively, and 22, 2 and 1 of supraspinatus tendon PTT, respectively.

3.4 Comparison of diagnostic effectiveness between HF-US and MRI

For diagnosis of supraspinatus tendon FTT, the sensitivity, specificity, PPV, NPV, and the rates of accurate diagnosis, misdiagnosis and missed diagnosis of HF-US were 0.935, 0.833, 0.935, 0.833, 0.906, 0.167 and 0.116, respectively, while those of MRI were 0.913, 0.889, 0.955, 0.800, 0.906, 0.111 and 0.087, respectively. For diagnosis of supraspinatus tendon PTT, those of HF-US were 0.783, 0.833, 0.857, 0.750, 0.805, 0.167 and 0.217, respectively, while those of MRI were 0.957, 0.889, 0.917, 0.941, 0.927, 0.111, and 0.043, respectively. Refer to Table 1 for detailed information.

Fig. 1 shows that the area under the curve of the HF-US ROC curve and MRI ROC curve about diagnosis of any supraspinatus tendon tears is 0.859 (95% CI: 0.768-0.924) and 0.908 (95% CI: 0.827-0.960) (z = 0.906, P = 0.36), respectively. HF-US and MRI had an area under the curve of 0.884 (95% CI: 0.779-0.95) and 0.901 (95% CI: 0.800-0.962) (z = 0.297, P = 0.77), respectively, for

diagnosis of supraspinatus tendon FTT. When it came to diagnosis of supraspinatus tendon PTT, HF-US and MRI had an area under the curve of 0.808 (95% CI: 0.655-0.914) and 0.923 (95% CI: 0.795-0.983) (z = 1.806, P = 0.07), respectively.

Table 1. The diagnostic effectiveness of HF-US and MRI in supraspinatus tendon tears

	Types	Sensitivity	Specificity	PPV	NPV	Accuracy	Missed diagnosis	Misdiagnosis
HF-US	**RCTs**	0.884	0.833	0.953	0.652	0.809	0.116	0.167
	FTT	0.935	0.833	0.935	0.833	0.906	0.065	0.167
	PTT	0.783	0.833	0.857	0.750	0.805	0.217	0.167
MRI	**RCTs**	0.928	0.889	0.970	0.762	0.825	0.072	0.111
	FTT	0.913	0.889	0.955	0.800	0.906	0.087	0.111
	PTT	0.957	0.889	0.917	0.941	0.927	0.043	0.111

PPV: positive predictive value; NPV: negative predictive value; RCTs: rotator cuff tears; PTT: partial-thickness rotator cuff tears; FTT: full-thickness rotator cuff tears; MRI: magnetic resonance imaging

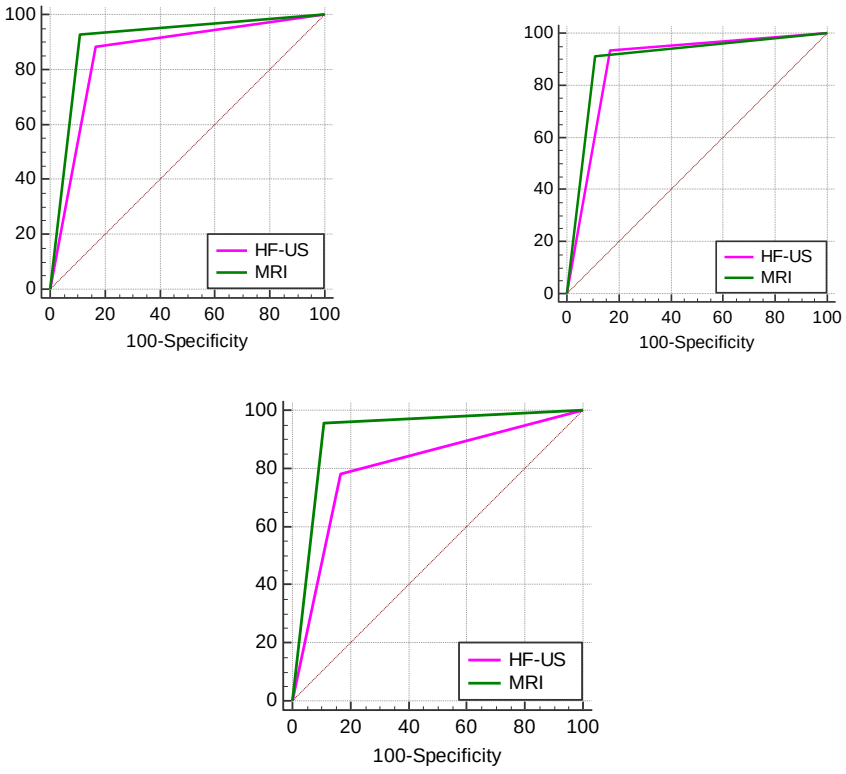

Fig. 1. Comparison of ROC curves between HF-US and MRI in diagnosing supraspinatus tendon tear

Any supraspinatus tendon tears (A); Full thickness rotator cuff tears (B); Partial thickness rotator cuff tears (C); P＞0.05

MRI: magnetic resonance imaging; HF-US: high frequency ultrasonography.

4. Discussion

The accuracy rates of HF-US and MRI in diagnosing RCTs were compared in this study. MRI and HF-US have similar good performance in diagnosing any supraspinatus tendon tears and FTT with

high accuracy. The performance of MRI is relatively better than that of HF-US in diagnosis of supraspinatus tendon PTT, however, the difference between the two modalities is not statistically significant ($P > 0.05$).

Research findings are inconsistent over the effectiveness of HF-US and MRI in diagnosing supraspinatus tendon tears. Roy et al. [8] meta-analyzed 76 studies (29 of MRI and 47 of HF-US) which set "having surgery" (arthroscopy or open surgery) as the standard and found that the sensitivity and specificity of HF-US in diagnosing any supraspinatus tendon tears, PTT and FTT were 0.91 and 0.86, 0.91 and 0.93, and 0.68 and 0.94, respectively, while those of MRI were 0.90 and 0.90, 0.90 and 0.93, and 0.67 and 0.94, respectively. Liu et al. [11] conducted a meta-analysis of 65 MRI studies and 64 HF-US studies and reported that the sensitivity and specificity of HF-US in diagnosing any supraspinatus tendon tears, PTT and FTT were 0.81 and 0.82, 0.87 and 0.88, and 0.62 and 0.85, respectively, while those of MRI were 0.84 and 0.86, 0.91 and 0.88, and 0.67 and 0.86, respectively. Lenza et al. [16] suggested that HF-US and MRI performed well in diagnosing FTT, while their sensitivity to PTT was low (0.52 and 0.74, respectively). Elmorsy et al. [9] performed a retrospective analysis on 125 cases of pre-arthroscopy HF-US and 130 cases of pre-arthroscopy MRI and calculated their sensitivity, specificity, PPV and NPV, reporting that HF-US and MRI had a high specificity (0.901 and 0.726, respectively) but a low sensitivity (0.23 and 0.541, respectively) in diagnosing PTT. In the present study, both HF-US and MRI have relatively high effectiveness in diagnosing any supraspinatus tendon tears, PTT and FTT, with their sensitivity being 0.783-0.935 and 0.913-0.957, specificity being 0.833-0.833 and 0.889-0.889, PPV being 0.857-0.953 and 0.917-0.970, NPV being 0.652-0.833 and 0.762-0.941, and accuracy being 0.805-0.906 and 0.825-0.927. Interpretation of ultrasonography results is dependent on the operator, and there are still differences between different operators even though well-defined protocols are used[17]. However, in fact, HF-US is used by many non-radiologists, such as practitioners of physical medicine, rheumatology, orthopedics and family medicine, while they are doing physical examination. In this study, shoulder joint HF-US was performed according to standardized procedures by two sonographers who had had over 5 years of experience in musculoskeletal ultrasonography. Thus, the scanning quality is guaranteed.

Liu et al. [11] and Roy et al. [8] reported that both HF-US and MRI had similar performance in diagnosing RCTs, FTT and PTT. Elmorsy et al. [9] found that HF-US had a lower sensitivity but a higher specificity in diagnosing PTT than MRI and that the differences were not statistically significant (0.23 vs. 0.541, $P = 0.333$; 0.901 vs. 0.726, $P = 0.0008$). Lenza et al. [16] also suggested that there was no statistically significant difference in the sensitivity to PTT between HF-US and MRI (0.52 vs. 0.74, $P = 1.0$). In the present study, HF-US has a lower sensitivity, NPV and accuracy and a higher rate of missed diagnosis in diagnosis of PTT than MRI, however, the differences are not statistically significant ($P > 0.05$). Even if there are slight differences in the effectiveness between HF-US and MRI in diagnosing PTT, the differences will not have significant impact on the clinical outcomes since the primary treatment of PTT is not surgery[18].

There are two limitations. One is that the sample is small. Inclusion of more cases will enhance the accuracy of this study. The other one is there may be selection bias in this study since the subjects were clinically suspected of experiencing RCTs and were going to receive arthroscopy, making the findings not applicable to patients with shoulder pain in the primary health care settings.

5. Conclusions

Both HF-US and MRI have high effectiveness in diagnosing FTT and PTT. HF-US can be used as a main imaging modality of examining patients with shoulder pain who are suspected of having RCTs in clinical settings.

References

[1] Sambandam, S.N., et al.: Rotator Cuff Tears: An Evidence Based Approach. World J Orthop, 2015. 6(11): p. 902-18.

[2] Longo, U.G., et al.: Histopathology of Rotator Cuff Tears. Sports Med Arthrosc Rev, 2011. 19(3): p. 227-36.

[3] Kim, H.M., et al.: Relationship of Tear Size and Location to Fatty Degeneration of the Rotator Cuff. J Bone Joint Surg Am, 2010. 92(4): p. 829-39.

[4] Jain, N.B., et al.: Comparative Effectiveness of Operative Versus Nonoperative Treatment for Rotator Cuff Tears: A Propensity Score Analysis From the ROW Cohort. Am J Sports Med, 2019. 47(13): p. 3065-3072.

[5] Ramme, A.J., et al.: Surgical Versus Nonsurgical Management of Rotator Cuff Tears: A Matched-Pair Analysis. J Bone Joint Surg Am, 2019. 101(19): p. 1775-1782.

[6] Lin, A., G. Gasbarro, and M. Sakr: Clinical Applications of Ultrasonography in the Shoulder and Elbow. The Journal of the American Academy of Orthopaedic Surgeons, 2018. 26(9): p. 303-312.

[7] Tuite, M.J. and K.M. Small: Imaging Evaluation of Nonacute Shoulder Pain. AJR. American journal of roentgenology, 2017. 209(3): p. 525-533.

[8] Roy, J.-S., et al.: Diagnostic Accuracy of Ultrasonography, MRI and MR Arthrography in the Characterisation of Rotator Cuff Disorders: a Systematic Review and Meta-analysis. British journal of sports medicine, 2015. 49(20): p. 1316-1328.

[9] Elmorsy, A., A. Keightley, and M. Flannery: Accuracy of Ultrasonography (US) and Magnetic Resonance Imaging (MRI) in Detection of Rotator Cuff Tears in District General Hospital. Polish journal of radiology, 2017. 82: p. 634-637.

[10] Yazigi Junior, J.A., et al.: Sensitivity and Specificity of Ultrasonography in Diagnosing Supraspinatus Lesions: a Prospective Accuracy Diagnostic Study. Sao Paulo medical journal = Revista paulista de medicina, 2018. 136(4): p. 292-297.

[11] Liu, F., et al.: Detecting Rotator Cuff Tears: A Network Meta-analysis of 144 Diagnostic Studies. Orthopaedic journal of sports medicine, 2020. 8(2): p. 2325967119900356-2325967119900356.

[12] Klauser, A.S., et al.: Clinical Indications for Musculoskeletal Ultrasound: a Delphi-based Consensus Paper of the European Society of Musculoskeletal Radiology. Eur Radiol, 2012. 22(5): p. 1140-8.

[13] Lee, M.H., et al.: Comprehensive Shoulder US Examination: A Standardized Approach with Multimodality Correlation for Common Shoulder Disease. Radiographics : a review publication of the Radiological Society of North America, Inc, 2016. 36(6): p. 1606-1627.

[14] Sconfienza, L.M., et al.: Clinical Indications for Musculoskeletal Ultrasound Updated in 2017 by European Society of Musculoskeletal Radiology (ESSR) consensus. Eur Radiol, 2018. 28(12): p. 5338-5351.

[15] Zheng, F., et al.: Role of Ultrasound in the Detection of Rotator-Cuff Syndrome: An Observational Study. Medical science monitor : international medical journal of experimental and clinical research, 2019. 25: p. 5856-5863.

[16] Lenza, M., et al.: Magnetic Resonance Imaging, Magnetic Resonance Arthrography and Ultrasonography for Assessing Rotator Cuff Tears in People With Shoulder Pain for Whom Surgery is being Considered. The Cochrane database of systematic reviews, 2013. 2013(9): p. CD009020-CD009020.

[17] Murphy, R.J., et al.: An Independent Learning Method for Orthopaedic Surgeons Performing Shoulder Ultrasound to Identify Full-thickness Tears of the Rotator Cuff. J Bone Joint Surg Am, 2013. 95(3): p. 266-72.

[18] Lambers Heerspink, F.O., et al.: Specific Patient-related Prognostic Factors for Rotator Cuff Repair: a Systematic Review. J Shoulder Elbow Surg, 2014. 23(7): p. 1073-80.