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Role of ultrasound elastography in the evaluation of rotator cuff tendon in patients with shoulder pain and its comparison with magnetic resonance imaging

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ABSTRACT

Background: Pain in the shoulder is the third-most prevalent musculoskeletal pain type. Most frequently involved in tendinopathy/tendon tears is the supraspinatus tendon, followed by a combination of the supraspinatus and infraspinatus tendon. At present, gray-scale ultrasound and MRI are used to determine the tear size, gross morphology, and postsurgical tendon repair. However, they are unable to determine the material characteristics of the muscle or tendon. **Aims and Objectives:** The aim of this study is to assess the role of ultrasound elastography in the evaluation of the rotator cuff tendon and to compare gray scale ultrasound and shear wave elastography (SWE) findings of the supraspinatus tendon with MRI in patients with shoulder pain. **Materials and Methods:** This prospective observational study included 50 patients. They were examined using a 1.5-T MRI machine and the ACUSON S3000 (Siemens Medical Solution) machine. The radiologist performing the ultrasound was blinded by the results of the MRI. **Results:** Age varied from 19 to 75 years. The majority (34%) were in the range of 31–40 years. Males were predominately affected. In MRI, the most common type of injury was mild tendinosis (34%), followed by moderate/severe tendinosis (26%). About 30% were diagnosed with moderate/severe tendinosis, 24% with mild tendinosis, 22% with partial tears, and 18% with full-thickness tears in gray-scale ultrasound. When SWE was combined, 32% were diagnosed with moderate/severe tendinosis, 28% with mild tendinosis, 20% with a partial tear, and 14% with a full-thickness tear. **Conclusion:** SWE showed better diagnostic performance than gray-scale ultrasound in the detection of supraspinatus tendinopathy.

Key words: Supraspinatus tendon; Ultrasound; Elastography; Shear wave elastography; MRI

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INTRODUCTION

After lower back and knee pain, pain in shoulder is the third-most prevalent musculoskeletal pain type, with a prevalence of 16–26% in the general population worldwide. According to some estimates, its yearly incidence is up to 14.7/1000 patients. The most common cause of shoulder discomfort is rotator cuff disorders and it causes substantial impairment and a decreased quality of life.[1] Among the various tendons of the shoulder, the one most frequently involved in tendinopathy/tendon tears is the supraspinatus (SST), followed by a combination of the supraspinatus and infraspinatus tendon.[2] It is believed that the pathophysiology of rotator cuff disorders has a dynamic nature, with subacromial impingement as the first stage and rotator cuff rupture as the last one.[3] At present, gray-scale ultrasound and MRI are the modalities for planning before surgery in order to determine the size of the tear (or re-tear), gross morphology, the presence of fatty degeneration, and postsurgical monitoring of the

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repair of the tendons. However, these methods fall short in their ability to determine the material characteristics of the muscle or tendon.[4] Given that tendon quality affects the prognosis for rotator cuff surgery, knowledge of tendon stiffness may be helpful to the surgeon. The recently launched ultrasound-based technology known as shear wave elastography (SWE) allows for qualitative and quantitative assessment of mechanical tissue characteristics as well as the evaluation of alterations in tissue stiffness.[5] While comparing tissue stiffness to nearby structures using a particular application based on acoustic radiation force impulse (ARFI), SWE does not require the operator to compress the tissue and provide an indirect estimate of the tissue stiffness based on the velocity of the shear waves.[6] However, it is not yet frequently employed in clinical musculoskeletal practice. Therefore, measuring tissue elasticity may potentially be a valuable method for identifying intratendinous lesions in individuals who have rotator cuff tendinopathy.[7] Ultrasound elastography has been proven to be fast, convenient, and easily available, as well as non-invasive, safe, inexpensive, and reproducible.[4,8] A further benefit of ultrasound elastography is that it helps identify patients at higher risk of re-tears and poorer healing.[9] It has been suggested that the quantitative characteristics of SWE may provide an objective tool for monitoring the progression of disease or can be used as a follow-up post-treatment measure.[10] Therefore, its potential in the prediction of recovery time following treatment may guide the timely return to an active lifestyle after having a normal elastogram.[11] With this background, the aim of the current study was to assess the role of ultrasound elastography in the evaluation of the supraspinatus tendon in patients with shoulder pain and its comparison with magnetic resonance imaging.

Aims and objectives

To assess the role of ultrasound elastography in evaluation of rotator cuff tendon and to compare Grey scale Ultrasound and Shear wave elastography (SWE) findings of supraspinatus tendon with MRI in patients with shoulder pain.

MATERIALS AND METHODS

This prospective observational study was conducted in the radiodiagnosis department in a tertiary care hospital in northern India and was a time-bound study conducted for a period of 1½ years (August 2021–January 2022) in the COVID pandemic after approval from the college research committee and Institutional Ethics Committee (IEC) under the letter number (TMU/IEC/20-21/036) dated July 28, 2021. The data was collected from the corresponding hospital.

Inclusion criteria

All patients complaining of shoulder pain with suspected rotator cuff disease referred from the orthopedics department to the Department of Radiodiagnosis for shoulder MRI were included.

Exclusion criteria

Exclusion criteria were as follows: patients who had undergone previous surgery on rotator cuff tendons/shoulder joints, patients with grossly calcified tendon, and patients with absolute contraindications for undergoing MRI were excluded from the study.

A total of 50 patients were taken after meeting the inclusion and exclusion criteria. Prior written consent after a proper explanation of the procedure was obtained from the patients. The patients were examined using the shoulder coil in a 1.5T MRI machine (Siemens MagnetomAvanto). Conventional MRI images were obtained first, followed by gray-scale ultrasound and SWE of the supraspinatus tendon using the ACUSON S3000 (Siemens Medical Solution) machine with the help of the 9L4 linear array probe. The radiologist performing the ultrasound was blinded by the results of the MRI.

The MRI sequences that acquired were coronal oblique T2 FS/STIR, T1 FSE and T2 FSE, sagittal oblique T2 FS/STIR, and axial PD FS. MRI findings were assessed as tendon degeneration indicated by an increase in T2W signal intensity in coronal images, partial tear as having an increased T2W signal and area of tendon discontinuation focally, and full thickness/complete tear presenting as fiber discontinuation in articular and bursal regions focally or complete discontinuation associated with muscle degeneration.[7]

A gray-scale ultrasound examination was performed as per shoulder protocol in short and long axis planes in crass or modified crass position. Findings that were looked at as tendinopathy signs or pathologic changes were tendon thickening, fluid in the paratenon/tendon sheath, inhomogeneous echotexture, tendon calcification, or loss of striations.[12] Gray-scale ultrasound of tendon pathologies was categorized as mild tendinosis without a tear (patchy hypoechoic regions lacking thickening of tendon or disruption of fibrillar morphology), Moderate/severe tendinosis without a tear (appearing as regions of hypoechogenicity having disruption in fibrillar morphology and clefts, fraying, and thickening of tendon), partial tear (articular, bursal, or intrasubstance defects that do not involve complete thickness), and full thickness tear (discretely marginated hypoechoic defects involving full thickness of tendon).[13]

For sonoelastography, the patient's position was the same as for gray-scale ultrasound. SWE assessment was made using

ARFI pulses in the long axis only. The machine software for virtual touch imaging quantification (VTIQ) automatically calculated the shear wave velocity (SWV) for the area of interest from raw radiofrequency data and displayed it as a colorized map. It provides an image-based assessment of SWV using color-coded scales. It classified tendons on the basis of their stiffness. Depending on stiffness, there were three types: blue for low rigidity, green to yellow for intermediate rigidity, and red for high rigidity. Samples were taken roughly at even intervals within the selected ROI at approximately the same depth to acquire SWV and were measured in meter per second. We set the dynamic range of the SWV measurement from 0.5 to 10 m/s. The final value was given as the average of the values taken.[13]

All statistical analysis was done using a Microsoft Excel spreadsheet with SPSS software (version 22), and different statistical procedures were applied when required. $P<0.05$ was considered statistically significant. The receiver operating characteristic (ROC) curve, or ROC curve, was created, and the maximum value of the area under the ROC curve (AUC) was considered the best threshold (cut-off value).

RESULTS

A total of 50 patients were enrolled, and their MRI, gray-scale ultrasound, and elastography findings were filled out in a predesigned proforma. The age range of the study population varied from 19 to 75 years, with a mean age of 38.46±14.52 years. Among the age distribution, the majority of patients (34%) were in the range of 31–40 years, while the age group from 21 to 30 years was the second most affected (32%). Age groups of 41–50 years, above 60 years, 51–60 years, and <20 years were affected by 14%, 12%, 6%, and 2%, respectively. Males were predominately affected in our study population, i.e., 74%, whereas 26% of females were affected. Right shoulder was affected in majority cases i.e. 68% whereas left was 32% only. After shoulder pain, the most frequent complaint was motion restriction (60%), followed by local tenderness (30%) and swelling (14%).

Based on gray-scale ultrasound findings, thickened tendon was found in 66% of patients, inhomogeneous echotexture in 40%, absent striations in 36%, fluid in the paratenon/tendon sheath in 18%, and calcified tendon in 8% of patients. Table 1 shows the number of patients diagnosed with different pathologies according to gray-scale ultrasound findings.

On SWE, according to the VTIQ color map, blue color was present in 24% of patients, yellow or green color in 56%, and red color in 20% of patients. The maximum SWV was 9.4 m/s and the minimum was 1.9 m/s, with a mean of 6.222 and a standard deviation as 2.2283. Table 1 shows the number of patients with different pathologies according to SWE and MRI.

Table 1: Presentation of Grey scale ultrasound, SWE and MRI diagnosis of study population

Diagnosis	Gray-scale ultrasound		Gray-scale ultrasound+ SWE		MRI	
	No.	%	No.	%	No.	%
Normal	3	6	3	6	2	4
Mild tendinosis	12	24	14	28	17	34
Moderate/Severe	15	30	16	32	13	26
Partial tear	11	22	10	20	11	22
Full thickness	9	18	7	14	7	14
	50	100	50	100	50	100

Figures 1a and b show the SWE and T1 fat-suppressed coronal MRI images of the supraspinatus tendon of a patient with moderate or severe tendinosis. Figures 2a and b show SWE and STIR coronal MRI images of different patients with full-thickness partial-width tears near the insertion site of the supraspinatus tendon.

Table 2 shows the sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), and accuracy of gray-scale ultrasound and SWE on comparison with MRI. For normal cases of mild tendinosis, moderate tendinosis, partial tears, and full-thickness tears, elastography showed greater diagnostic performance as compared to gray-scale ultrasound.

On comparing the SWV between normal and pathological tendon, the mean values of the SWV for mild tendinosis, partial tear, and full thickness tear were observed statistically significant since observed $P<0.05$.

A ROC curve analysis of SWV against MRI in the supraspinatus tendon was done. The optimal cut-off values for normal, mild tendinosis, moderate/severe tendinosis, partial tear, and full-thickness tear were >9.1, >7.45, ≤5.3, ≤4.5 and ≤3.9, respectively. Sensitivity and specificity were also calculated. Sensitivity was >90% in all cases except for moderate/severe tendinosis and full-thickness tears. The value of the AUC was excellent in cases of normal tendon and full-thickness tear; good in cases of mild tendinosis, and fair in cases of partial-thickness tear. The AUC value was lower for moderate/severe tendinosis, which might be due to the small sample size of our study population.

DISCUSSION

The recently launched ultrasound-based technology known as elastography allows for qualitative and quantitative

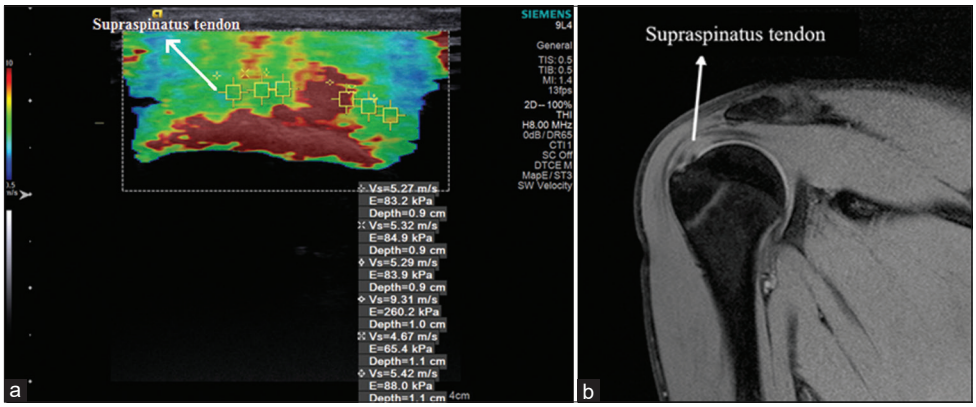

Figure 1: (a) Shear wave elastography of supraspinatus tendon showing reduced shear wave velocity near the footprint in the range of 5.27–5.32 m/s. (b) T1 fat suppressed coronal MRI image of same patient shows bulky supraspinatus tendon with altered signal intensity near the footprint suggestive of moderate/severe tendinosis

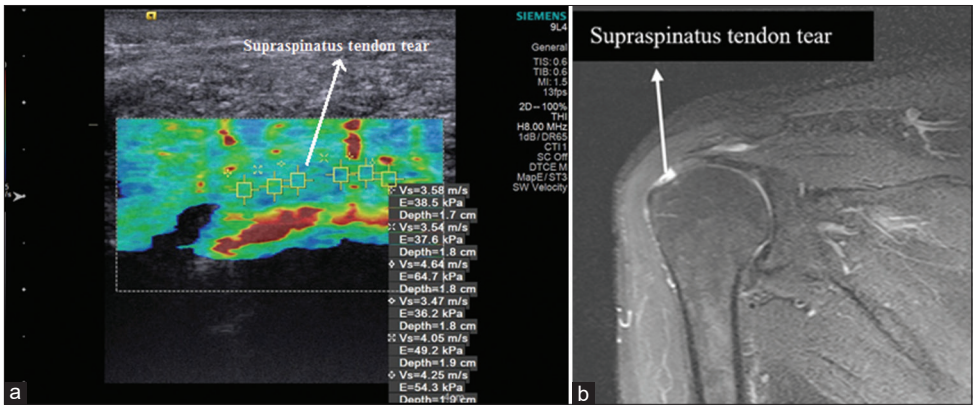

Figure 2: (a) Shear wave elastography shows reduced velocity in range of 3.47–4.64 m/s in and around the region of tear and a color map of near blue scale. (b) STIR coronal MRI image of same patient as (a) shows high fluid signal intensity in the supraspinatus tendon near the insertion site of tendon suggestive of full thickness partial width tear

assessment of mechanical tissue characteristics as well as alterations in tissue stiffness. Given that tendon quality affects the prognosis for rotator cuff surgery, knowledge of tendon stiffness may be helpful to the surgeon.[5]

Also, due to some pitfalls of ultrasound, such as more learning time, high inter-rater variations, and high dependency on the operator, it may show false results. Anisotropy is a significant drawback of ultrasound. Whenever ultrasound beam is at 90° to the long axis of the tendon, it appears echogenic.[14,15] As the pathological tendon has a similar echogenic pattern to the nearby normal tissue, the typical gray scale occasionally fails to detect it, leading to an erroneous hypoechogenicity that might be mistaken for a partial tear or tendinosis. Gray-scale ultrasound frequently fails to detect tendinopathy because of the similar echogenic pattern.[16,17]

Chowdhary et al., also reported that shoulder pain more commonly occurred in older patients, but shoulder instability was more commonly seen in younger patients, with the most common age group affected being 21–30 years and all being males.[18]

Virtual touch tissue imaging and quantification is software used in elastography for the qualitative and quantitative assessment of the stiffness of tissue.[16] In a study by Deng et al., on application of VTIQ SWE in diagnosing supraspinatus tendon tears, a red-yellow color graph was shown by the normal tendon, and the pathological tendon became soft, which was demonstrated by the VTIQ color map. Yellow to green showed tendinopathy, blue to green showed partial tear, and blue to green to full blue demonstrated full thickness tear group.[19] In our study, the VTIQ color map showed blue in 24% of cases, yellow or green in 56%, and red in 20% of cases. It was observed that in cases of tendinopathy, elastography can identify areas of softening in the tendon as regions of color variations within the normal tendon and display a blue color. The minimum and maximum values of SWV were observed at 1.9 m/s and 9.4 m/s in the supraspinatus tendon, respectively. ROC curve analysis of SWV against MRI showed optimum cut-off values for normal, mild tendinosis, moderate/severe tendinosis, partial tear, and full-thickness tear as >9.1, >7.45, ≤5.3, ≤4.5, and ≤3.9, respectively. Deng et al., also observed similar values of

Table 2: Presentation of diagnostic performance of Grey scale ultrasound and elastography in comparison to MRI

Pathology of supraspinatus tendon	Grey scale ultrasound versus MRI	Ultrasound elastography versus MRI
Normal		
Sensitivity	50.00	100.00
Specificity	95.83	100.00
PPV	33.33	40.00
NPV	97.87	106.67
Accuracy	72.73	100.00
Mild tendinosis		
Sensitivity	58.82	82.35
Specificity	93.94	100.00
PPV	83.33	100.00
NPV	81.58	91.67
Accuracy	82.00	94.00
Moderate/severe tendinosis		
Sensitivity	76.92	92.31
Specificity	86.49	89.19
PPV	66.67	75.00
NPV	91.43	97.06
Accuracy	84.00	90.00
Partial tear		
Sensitivity	72.73	81.82
Specificity	92.31	97.44
PPV	72.73	90.00
NPV	92.31	95.00
Accuracy	88.00	94.00
Full thickness tear		
Sensitivity	85.71	85.71
Specificity	93.02	97.67
PPV	66.67	85.71
NPV	97.56	97.67
Accuracy	92.00	96.00

NPV: Negative predictive value, PPV: Positive predictive value

SWV for tear identification.[19] The value of the AUC was excellent in cases of normal tendon and full-thickness tears and good in cases of mild tendinosis.

Few investigations have been conducted on the elasticity of supraspinatus tendon tears. Vasishta et al., employed ultrasonic elastography to evaluate tendon strain in 25 individuals with supraspinatus tendinopathy. Their findings revealed that supraspinatus tendon stiffness was reduced, and substantially linked with the degree of lesion observed by MRI, and demonstrated a good relationship between stiffness findings and tendinopathy on MRI.[2]

In the study by Khodair and Ghieda, who compared MRI, sonoelastography, and conventional ultrasound in healthy and shoulder pain patients, they found that sonoelastography had higher sensitivity and a specificity for detecting rotator cuff disorders than conventional ultrasound, with elastography having a sensitivity of 95% and specificity of 100% compared to conventional ultrasound 85% sensitivity and 95% specificity.[20]

We evaluated the diagnostic performance of gray-scale ultrasound and ultrasound elastography in the supraspinatus tendon against MRI. Accuracy, specificity, NPV, PPV, and sensitivity were observed to be higher when ultrasound is combined with elastography.

Frere et al., utilized sonoelastography, conventional ultrasound, and MRI for the detection of rotator cuff lesions in chronic shoulder pain patients and detected the higher diagnostic performance of elastography for shoulder disease. They compared MRI with ultrasound, and for tendinopathy, sensitivity came out to be 81.3%, accuracy was 88.9%, and specificity was 95%, while for partial tears, accuracy was 88.9%, specificity was 92.3%, and sensitivity was 80%. Its sensitivity for full-thickness rips was 90%, its accuracy was 97.2%, and the specificity was 100%. When elastography was compared to MRI, for tendinopathy sensitivity came out to be 93.8%, accuracy was 94.4%, and specificity was 95%, while for partial tears, accuracy was 91.7%, specificity was 92.3%, and sensitivity was 90%. Its sensitivity for full-thickness rips was 90%, its accuracy was 97.2%, and its specificity was 100%. These findings are in accordance with our study.[21]

Hence based on our results, elastography can be used to differentiate between healthy and pathological tissue, as pathological tissue is softer than normal tissue. Before any change in echogenic pattern or thickness on the gray-scale can be seen; elastography may be utilized as an accurate diagnostic method to identify tendinopathy.[22] The advantage of sonoelastography is that it provides both qualitative and numerical measurements of tissue elasticity, in addition to having greater sensitivity and improved spatial accuracy.

Limitations of the study

The limitation of this study is that this tertiary care hospital-based prospective observational study had a small sample size due to the COVID pandemic. The small sample size may limit the statistical significance of the study. Further studies with a large sample size are needed to validate the study results. Another limitation is that ultrasound elastography is highly operator dependent.

CONCLUSION

Our research concludes that gray-scale ultrasound combined with elastography can be utilized as a preliminary line of investigation for all patients with painful shoulders who are clinically believed to have rotator cuff abnormalities in order to better identify pathological characteristics of the disease and overcome the limitations of gray-scale ultrasonography. The SWV finding can be used as a determining factor for all tears, and its cutoff value can be utilized to differentiate

between different pathological conditions. Thus, it can be used as a cost-effective primary investigation modality. It has demonstrated greater specificity and sensitivity for all types of tears, with relatively good overall accuracy as well.

This study reaffirms that SWE is a useful tool for the evaluation of rotator cuff tendons with reasonably good diagnostic accuracy. It can predict the tendon injury risk as it is based on changes in tissue stiffness, which is not possible with gray-scale ultrasound. Furthermore, it can grade the tendon injury and assess the progression of the tendon disease. Furthermore, compared to MRI, it has the additional benefits of being more portable, easier to use, less expensive, allowing real-time assessment, and can be done in patients for whom MRI is not an option because of conditions such as claustrophobia or metallic implants.

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Authors' Contributions:
VG- Definition of intellectual content, literature survey, prepared first draft of manuscript, implementation of study protocol, data collection, data analysis, manuscript preparation and submission of article; **AM**- Concept, design, manuscript preparation, editing, and manuscript revision; **SC**- Design of study, statistical analysis and interpretation; **DA**- Review manuscript; **AD**- Review manuscript; **SK**- Literature survey and preparation of Figures; **SuK**- Review manuscript.

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