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Role of Sonoelastography in the Evaluation of Supraspinatus Tendinopathy – A Comparative Study with Mri in a Tertiary Care Centre in Chengalpattu District

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KEYWORDS
Sonoelastography, Supraspinatus Tendinopathy

ABSTRACT:
Background: Rotator cuff pathologies are main cause for chronic shoulder pain, among them supraspinatus tendinopathy is more common. Magnetic resonance imaging, which is usually considered as the reference standard. Sono-elastography is noninvasive and reliable ultrasound technique that provides qualitative as well as quantitative assessment of tendon quality through alteration in the tissue composition.
Objectives: To determine if there is a correlation between Sono elastography and MRI for the purpose of early diagnosis of supraspinatus tendinopathy.
Design: Cross-sectional.
Settings: Department of Radio-Diagnosis, Shri Sathya Sai Medical College and Research Institute, Thiruporur.
Patients And Methods: A cross-sectional study included 110 patients with supraspinatus tendinopathy aged 20-70 years, both MRI grades and sonoelastography (Shear Wave Velocity and modulus) parameters were assessed for each grade supraspinatus tendinopathy using a high-frequency linear probe. Data analysis was performed using SPSS 23 software.
Sample Size: 110
Main Outcome Measures: To assess the degree of correlation between MRI grades and sonoelastography measures in cases of supraspinatus tendinopathy.
Patients Results: Over 18 months, 110 cases were studied. Patients experiencing supraspinatus tendinopathy had a significantly decreased tendon stiffness, as shown by a low shear wave velocity (SWV) and high shear wave modulus (kPa) There was an average shear wave velocity of 3.9 m/s for Grade I tendon abnormalities, 3.4 m/s for Grade II abnormalities, and 2.7 m/s for Grade III abnormalities. Classification of tendinopathy was found to be mild in 27.2% of cases, moderate to severe in 31.8%, and severe in 40.9%. which are correlating with MRI grading with P<0.001.
Conclusions: SWE may be used in identification of tendon abnormalities early.Our study found a high association between tendinopathy MRI findings and tendon stiffness values in sonoelastography.It is a method that is simple, fast, and inexpensive helps to diagnose early and start the rehabilitation early so can prevent the tendon tear also reliable diagnostic tool in centers where MRI is not availabe or in patients in whom MRI is contraindicated

INTRODUCTION

During middle age and old age, rotator cuff problems are more prevalent. Most common tendon among them to involve is supraspinatus. Rotator cuff illnesses might be tendinopathy, partial or full thickness tears, or both.[1] Supraspinatus tendinopathy is common cause for shoulder pain and have more predilection for recurrence inspite of treatment.[2] Due to the challenges in clinically distinguishing between different rotator cuff problems, imaging is necessary for diagnosis, evaluation, therapy guidance, and surgical intervention determination. Sonoelastography is a reliable also cost effective technique which has shown loss of tendon elasticity in supraspinatus tendinopathy helping in early With strong correlation with MRI, diagnosis and ease of repeatability for followup scans.3 Softening of tendon that happens in case of supraspinatus tendinopathy has been shown with a strong correlation with MRI using Sonoelastography, an affordable and reliable imaging technique. 4 With a diagnostic accuracy of 91% in cases of partial thickness whereas 100% in cases of tears with full-thickness, ultrasonography is a dependable, low-cost, and noninvasive method for evaluating rotator cuff injuries.5 Ultrasound images of a healthy tendon will reveal a fascicular pattern with many echogenic spots and parallel lines in the transverse and longitudinal

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planes, respectively. When doing an ultrasonic examination, make sure the beam is perpendicular to the fascicles orientation to prevent anisotropy.[6] Tendinopathy is characterized by ultrasound imaging of a thicker tendon with heterogeneous hypoechoic pattern. In contrast to PTT, which shows a hypoechoic deficit, Through FTT, information may be sent all the way from the subacromial/subdeltoid bursa to the glenohumeral joint cavity, over the whole tendon thickness.[7] However in mild to moderate cases, echogenicity of affected tendon may be similar to a healthy tendon, making traditional ultrasonography difficult to diagnose. A relatively recent US method, ultrasound elastography (UE) allows for both quantitative and qualitative evaluation of tissue elastic characteristics, which helps distinguish between healthy and very early tendinopathy before the stage of tear.[8] Using UE to characterize breast, thyroid, and localized hepatic lesions yielded good results.[9] Tendons, muscles, nerves, ligaments, and cartilage are among the musculoskeletal tissues that may undergo UE.[10] Recent studies on muscle and tendon shear wave ultrasound have shown promising outcomes. The majority of these investigations found that tendinopathy causes tendons to soften, prophylactic interventions.[12,13] which slows the propagation of shear waves in comparison to healthy, rigid tendons.[11] Tendon softening may be an early warning indication of tendinopathy and discomfort, according to the research. Elastography may help diagnose tendinopathy before symptoms appear, allowing for prophylactic interventions.[12,13]

METHODS AND MATERIALS: STUDY DESIGN: Cross sectional study

STUDY AREA: Tertiary care centre

STUDY POPULATION: Department of Radiology,Patients of shri sathya sai medical college and research hospital

STUDY SAMPLE: Patients with supraspinatus tendinopathy

STUDY DURATION: 18 months

SAMPLE SIZE CALCULATION: Based on previous study, The prevalence of grade II tendinopathy is 52% N=4PQ/L WHERE P=62% Q=1.52=48 L is percentage error 10% of prevalence N=4x52x48/100 99.84+10% non response error N=109.82=110

INCLUSION CRITERIA: Age:20-70 years Patients with supraspinatus tendinopathy

EXCLUSION CRITERIA: Neuromuscular diseases Labral lesions Shoulder instability Acromioclavicular joint arthritis Humeral head arthritis Rotator cuff tear Cross sectional study done in the Department of Radiology, Patients of shri sathya sai medical college and research hospital in Patients with supraspinatus tendinopathy who are referred for MRI of shoulder for duration 18 months with Sample size of 110.

MRI

The MRI scan was conducted using a standard procedure in 1.5 Tesla Philips MRI to assess rotator cuff/SST pathology. T2/T1 FS, T1/T2 coronal and sagittal images are reviewed. Sein *et al.*[14] provided the criteria that were used to modify the grades of supraspinatus tendinopathy. Based on anterior-to-posterior signal alterations supraspinatus tendinopathy in MRI were graded I–III for abnormal signal intensity. In Grade I - Focal increase in tendon signal - mild tendinopathy (Focal 50% of tendon thickness) Real time sonoelastography evaluation of supraspinatus tendon After explaining the procedure to the patient and getting informed consent shoulder examination was done by Mindray DC 80 ultrasound machine. with a linear array transducer (5-12MHz) to evaluate supraspinatus tendon using shear wave technique of sonoelastography. The patient sitting on chair, with internal rotation of arm and pronation of forearm on patient’s back. Transducer kept perpendicular to supraspinatus tendon so that anisotropy is avoided and SST images in long axis were obtained. Anterior to posterior of the SST examined with shear wave velocity. ROI measuring 0.7 x 0.7 mm, placed over supraspinatus tendon from approximately 5 mm superior to the footprint of an greater tuberosity also 7 mm medial to lateral end of footprint. The values of quantitative stiffness displayed over B-mode ultrasound. Minimum 3 ROIs for each tendon performed and mean for the values was used. Data evaluated by the software SPSS (Statistical Package for social sciences) v. 23.0, and degree of association between two variables measured using the test Spearman rank correlation RESULTS: Mindray DC60 ultrasound machine with linear transducer is used. While the patient was in a neutral shoulder posture, elastography was conducted in the oblique coronal plane. The shear-wave ultrasound elastography (SWE) results were used to calculate the mean, maximum, and lowest velocities as well as the stiffness. Patients experiencing supraspinatus tendinopathy had a significantly decreased tendon stiffness, as shown by a low shear wave velocity (SWV). Shear velocities of grade I tendon anomalies ranged from 3.8 - 5.1 m/s, and

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mean of 3.8 and a standard deviation of 0.4. Shear velocities of grade II tendon anomalies ranged 2.9 - 4.6 m/s, and a mean 3.1 also a standard deviation 0.1. Shear velocities of grade III tendon anomalies are from 2.7 - 3.8 m/s, with average value 2.7 and standard deviation 0.2. This study found that the supraspinatus tendon's shear modulus increases with tendinopathy degree. Shear wave modulus for Grade I tendon Grade III, from 39.5 (±) 6.5 kPa. abnormalities ranged from 26.3 (±) 6.1 kPa, Grade II from 31.7 (±) 6.0 kPa, and In healthy supraspinatus tendons, the red pattern represents homogeneity and stiffness, and the shear wave velocity (SWV) is higher and shear wave modulus was lower; in pathological tendons, the green and blue patterns represent heterogeneity and softness, and the SWV is lower with high shear wave modulus. In our study Elastography of supraspinatus tendon was carried out using Mindray DC60 ultrasound machine. The shear-wave ultrasound elastography (SWE) results

were used to calculate the mean, maximum, and lowest velocities as well as the stiffness. Patients experiencing supraspinatus tendinopathy had a significantly decreased tendon stiffness, as shown by a low shear wave velocity (SWV). The shear wave velocity for Grade I tendon abnormality in MRI was ranging from 3.8 to 5.1 m/s with a mean value of about 3.891 m/s with a standard deviation of 0.47, while the shear wave velocity for Grade II tendon abnormality was ranging from 2.9 to 4.6 m/s with a mean value of about 3.1 m/s and with a standard deviation of 0.1, the shear wave velocity for Grade III was ranging from 2.7 to 3.8 m/s with a mean value of about 2.7 m/s with a standard deviation of 0.19. This study found that the supraspinatus tendon's shear modulus increases with tendinopathy degree. Shear wave modulus for Grade I tendon abnormalities ranged from 26.3 (±) 6.1 kPa, Grade II, from 31.7 (±) 6.0 kPa, and Grade III, from 39.54 (±) 6.5 kPa. In healthy supraspinatus tendons, the red pattern represents homogeneity and stiffness, and the shear wave velocity (SWV) is higher and shear wave modulus was lower; in pathological tendons, the green and blue patterns represent heterogeneity and softness, and the SWV is lower with high shear wave modulus. There was significant statistical correlation between MRI grading and shear wave sonoelastography findings with P value <.0001.

Table 1: DISTRIBUTION OF SONOELASTOGRAPHY FINDINGS

MRI SUPRASPINATUS TENDINOPATHY GRADES	**SHEAR VELOCITY(m/s) Mean +SD**	**SHEAR MODULUS(kPa) Mean +SD**
Grade I	3.891±0.4308	26.38±6.156
Grade II	3.191±0.1100	31.70±6.020
Grade III	2.781±0.1990	39.54±6.560

Table 2: MRI GRADING DISTRIBUTION OF SUPRASPINATUS TENDINOPATHY

Evaluation of anomalies involving the supraspinatus tendon using magnetic resonance imaging	**Number of cases**	**Percentage**
Mild tendinopathy (Grade I),	30	27.2
Moderate tendinopathy (Grade II)	35	31.8
Severe Tendoninopathy (Grade III)	45	40.9
Total	110	99.9%

In the presents study mild tendinopathy (grade I) noted in 27.2% cases,35 moderate tendinopathy (grade II) in 31.8%, and 40.9% shows severe tendinopathy (grade III)

Table 3: Comparison of Sonoelastography Values to MRI in Supraspinatus Tendinopathy

Grde	**Diagnostic Test**	**MRI**	**Positive**	**P value**
Grade I	Sonoelastography	Positive: 56	Negative: 0	<0.0001 ****
		Positive: 0	Negative: 54	
Grade II	Sonoelastography	Positive: 33	Negative: 0	<0.0001 ****

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		Positive: 0	Negative: 77	
Grade III	Sonoelastography	Positive: 21	Negative: 0	<0.0001 ****
		Positive: 0	Negative: 89	

In this study, the comparison of sonoelastography (SE) to MRI for grades I, II, and III supraspinatus tendinopathy shows a significant correlation, with P values all <0.0001. The statistical analysis was performed using Fischer's exact test, where P<0.05 was considered significant (**** indicates highly significant results).

Table 4: Summary of Key Data

Category	Subcategory	Number of Cases	Percentage
Age Distribution	51-60 years (majority)	-	-
Sex Distribution	Males	70	63.6%
	Females	40	36.3%
Presenting Complaints	Pain	110	100%
	Tenderness	60	54.5%
Side Affected	Right Side	70	63.6%
	Left Side	40	36.3%
Aggravation of Symptoms	By Abduction	50	45.4%
	By Elevation	50	45.4%
	By Sustained Overhead Activity	10	9.09%
History of Trauma	Yes	-	27.2%
Previous Surgery on Affected Shoulder	Yes	5	4.5%
	No	105	95.4%

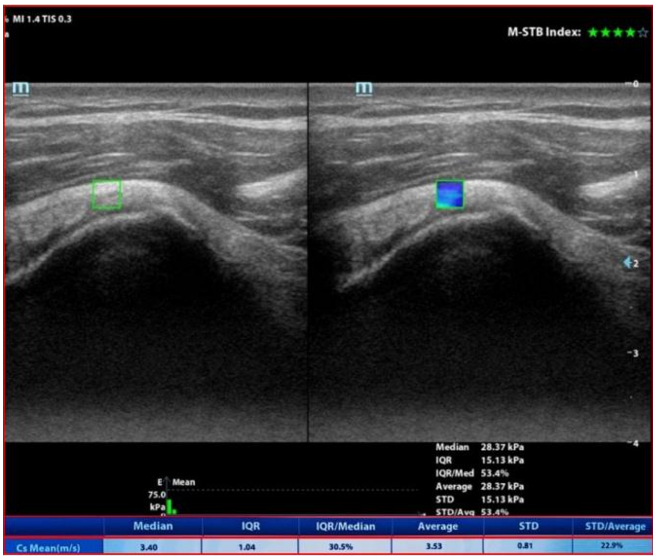

IMAGE 1: SONOELASTOGRAPHY IMAGE OF SUPRASPINATUS TENDON SHOWING MEAN SHEAR WAVE MODULUS OF 28.37 kPa AND SHEAR WAVE VELOCITY MEASURING ~ 3.4 m/s SUGGESTING GRADE I TENDINOPATHY OF SUPRASPINATOUS TENDON

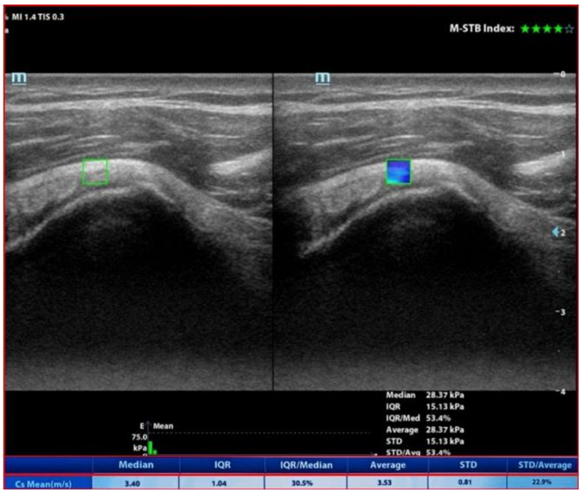

IMAGE 2

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IMAGE 3

GRADE II supraspinatus tendinopathy

IMAGE 4: PDFS SAGITTAL IMAGE OF RIGHT SHOULDER SHOWING GRADE II SIGNAL INTENSITY CHANGES AT SUPRASPINATUS TENDON INSERTION SITE (ARROW)

IMAGE 5: 151x151mm (72 x 72 DPI)

IMAGE 6

DISCUSSION

Rotator cuff tendinopathy, especially the supraspinatus tendon, causes shoulder pain. The correct assessment of rotator cuff problems to direct therapy decisions requires imaging. Ultrasound elastography (UE) helps diagnose tendon issues by identifying composition of tissue, changes in elasticity earlier than changes of echogenicity on the US.[13,14] UE was originally introduced in vitro in the early 1990s. Later SE approaches included strain, shear wave, transient, and acoustic radiation force UE.[15] Because shear wave elastography does not compress tissues, it can quantify tissue elasticity more objectively and reach deeper tissues that strain elastography cannot. The superior rotator cuff tendon (SST) is one of the most damaged and tendinopathy prone tendons in the body. MRI is the most reliable and cutting-edge method for diagnosing rotator cuff tendinopathy because of its sensitivity. Tendinopathy develops when collagen breaks down, weakening and eroding the tendon to the point that it might rip or burst.[16] Ultrasound and MRI can evaluate tendinopathy. Due to its great sensitivity, MRI abnormalities may not match symptoms. Traditional ultrasonography may not be able to distinguish degenerative diseased tissue from healthy tissue since it typically has the same echogenicity. It's generally recognized that inflammation and degradation affect tissue flexibility. To define an intratendinous localized lesion or peritendinous involvement in RC tendinopathy patients, tissue softening estimation may be beneficial. We used MRI for rotator cuff assessment and SWE for supraspinatus tendon abnormalities in this study.

In SWE, the researchers found that healthy supraspinatus tendons seemed uniform and rigid, whereas sick tendons were more flexible and displayed

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intratendinous color alterations. Tendinopathy causes collagen fiber breakdown and lipid infiltration, weakening and softening the tendon and perhaps rupturing it spontaneously.[17] I agree with this. Abdel Razek and Ezzat. 18, Galletti *et al.*[19], and Frere *et al.*[20] studies. Comparative studies related to demographic characteristics The ages of the participants in this research ranged from five to seventy. Notable among those aged 51–60 is the majority, while those aged 20–30 make up the least. The average age was 46.56, and there were more men than women, making up 63.6% and 36.3% of the total, respectively. In Amr *et al.*[21] had considered the 34 number of males and 23 number of females with the average age of the selected person was 37.7 years on total 57 samples were considered in the study. Comparative studies related to Shear wave elastography findings: Present study observed that The red, uniformly rigid pattern of healthy supraspinatus tendons allowed shear waves to propagate more quickly (higher SWV), but the green and blue patterns of pathological tendons were more irregular and softer, and the shear wave propagation was slower (lower SWV).Grade I tendon abnormalities showed shear wave velocities of 3.91 m/s on average, with range of 3.8 - 5.1 m/s, whereas Grade II and III abnormalities had means of 3.45 and 2.9 m/s, respectively. Amr *et al.* study.[21] which showed In cases of grade I tendon abnormalities, the shear wave velocity ranged from 3.8 to 5.1 m/s, with an average of 4.59 m/s. In cases of grade II tendon abnormalities, the shear wave velocity ranged from 2.9 to 4.6 m/s, with an average of 3.678 m/s. In cases of grade III tendon abnormalities, the shear wave velocity ranged from 2.7 to 3.8 m/s, with an average of 3.08 m/s Shear wave velocity (SWV) values were statistically significantly different between cases and volunteers, also cases with different grades of tendon abnormalities. These findings are consistent with previous research showing that tendon softening slows SWV propagation in pathological tendons. Hou *et al.*[22], Coombes *et al.*[23], also Lawrence *et al.*[24] However, study by Hou *et al.*[22] showed SWV values from 8-9 m/s for moderate tendinopathy and lower values like 5-7 for tear, however our study revealed about 6-8 for healthy supraspinatus tendons and for patients with tendinopathy and tear its 2.7 5.1. The SWV differences may be due by the fact that our study utilized mindray SWE technology and theirs Siemens. In a separate investigation conducted by Baumer *et al.*[25] Under the passive condition, there was no discernible difference between the control participants and the RC tendinopathy patients, with the former group showing SWV values of 2.0-4.5 m/s and the latter 2.5-3.9 m/s. Joong-Bae Seo *et al.* 4 shown 45.8%. that changes in SST intratendinous may be detected by SE.MRI revealed that 33.1% of SSP tendons were grade 1C, 29.7% were grade 1B, and 37.3% were grade 1A. Grade 1 SSP tendons were seen in 9.3% of cases, grade 2 in 45.9%, and grade 3 in A good association between the MRI and SE grades was shown by comparing the two sets of results (r = 0.829, P = <.001). It was also noted that there was a good link between US and SE grades (r = 0.723, P = <.001). Brage *et al.*[26] evaluated SE's reliability in the supraspinatus tendon assessment, both between raters and between them. Twenty volunteers without symptoms and twenty patients with verified tendinosis by magnetic resonance imaging were used to quantify strain ratios and raw values in three areas of the supraspinatus tendon. When measuring raw values and ratios using the deltoid muscle, they demonstrated high levels of dependability both within and between raters. A reference tissue of gel pads allowed them to get appropriate ratios. Color scale evaluations and counts of red or yellow lesion showed high to near-perfect reliability. They emphasized how the SE is very pressure dependent and operator-dependent. Because of this, SE's external validity in healthcare contexts could be compromised. Manual compression, reference tissues, and operator training level were among the difficulties they brought up as constraints on this method. Vasishta *et al.*[27] examined 25 patients to investigate the relationship between SE tendon stiffness and supraspinatus tendinopathy MRI grades (normal, mild, moderate, and severe). MRI grade strongly correlated with supraspinatus tendon strain ratio; as tendinopathy severity rose, strain ratio reduced. Predicting whether supraspinatus tendinopathy will improve or worsen may be possible with the use of SE. They were open to the idea that SE may be useful for rehabilitating patient supraspinatus tendinopathy early. Nocera *et al.*[28] used a multimodal imaging technique including MRI, power Doppler, and SWE to ascertain the healing response after RC repairs. In a cohort study, 12 patients with unilateral full-thickness supraspinatus tendon tears were examined using US and MRI before and after surgery, specifically at 3 and 6 months after the procedure. We measured the vascularity in symptomatic and repaired control shoulders using power Doppler and SWE. We also measured the ratio of the MRI signal intensity of the tendon to the delta muscle. Both tendon vascularity and the ratio of tendon to delta muscle went up after repair, but later they went down. Following a decrease, postoperative SWE rose, however there was no statistically significant difference. The results

demonstrated a relationship between MRI and US parameters throughout the healing phases of the RC repair and the total time of the RC operation.

Real time sonoelastography evaluation of supraspinatus tendon using shear wave elastography After explaining the procedure to the patient and getting informed consent shoulder examination was done using Mindray DC 80 ultrasound machine with a linear array transducer L 13-3 Positioning The patient was positioned on a chair, with the arm in the internal rotation position and the forearm positioned in pronation on the patient’s back. The examiner would stand behind the patient. In patients with discomfort, a modified Crass position was adapted, where the patient’s ipsilateral hand is placed on the ipsilateral hip, allowing easy visualization of the rotator interval. Specific bony landmarks were useful in identifying supraspinatus tendon. The acromion (medial) and greater tuberosity footprint (lateral) of the shoulder were the reference points used to identify the plane. supraspinatus tendon in the longitudinal view. The bicipital groove was the reference point in the antero-posterior plane. The area from the most anterior to the most posterior portion of the SST was evaluated in this position. Transducer was maintained perpendicular to the supraspinatus tendon in order to avoid anisotropy and long axis view images of the supraspinatus were obtained which corresponded to the MR image Sonoelastography was performed by using shear wave technique. The supraspinatus tendon resembles a ‘‘bird’s beak’’ configuration with the tendon fibers horizontal to the beam and probe orientation. The fixed-size ROI, a rectangle measuring 0.7 x 0.7 mm, was placed within the supraspinatus tendon at 5 mm superior to the footprint of the greater tuberosity and 7 mm medial to the lateral end of the footprint and the quantitative stiffness value was displayed over a B-mode sonogram.At least three ROIs of each tendon were performed and the mean of the values of the three scans was used as the representative value.

LIMITATIONS: Sonoelastography is operator dependent. Additionally, there are differences in observed SWV across manufacturers due to the lack of standard measurements.

CONFLICT OF INTEREST: None

REFERENCES

1. Tawfik AM. Rotator cuff disorders: How to write a surgically relevant magnetic resonance imaging report. World J Radiol. 2014;6(6):27.
2. Bendale S, Vedpathak S. Sonographic evaluation of rotator cuff pathologies causing restricted movements of shoulder. Int J Contemp Med Surg Radiol. 2019;4(3):C276–80.
3. Boenisch U, Lembcke O, Naumann T. Classification, clinical findings and operative treatment of degenerative and posttraumatic shoulder disease: What do Eur J Radiol. 2000;35(2):103–18. we really need to know from an imaging report to establish a treatment strategy?
4. Seo JB, Yoo JS, Ryu JW. Sonoelastography findings of supraspinatus tendon in rotator cuff tendinopathy without tear: comparison with magnetic resonance images and conventional ultrasonography. J Ultrasound. 2015;18:143–9.
5. Vlychou M, Dailiana Z, Fotiadou A, Papanagiotou M, Fezoulidis IV, Malizos K. Symptomatic partial rotator cuff tears: diagnostic performance of ultrasound and magnetic resonance imaging with surgical correlation. Acta Radiol. 2009;50(1):101–5.
6. Hodgson RJ, O’Connor PJ, Grainger AJ. Tendon and ligament imaging. Br J Radiol. 2012;85(1016):1157–72
7. Venu KM, Howlett DC, Garikipati R, Anderson HJ, Bonnici AV. Evaluation of the symptomatic supraspinatus tendon—a comparison of ultrasound and arthroscopy. Radiography. 2002;8(4):235–40
8. Sein ML, Walton J, Linklater J, Harris C, Dugal T, Appleyard R, *et al.* Reliability of MRI assessment of supraspinatus tendinopathy. Br J Sports Med. 2007;41(8):e9–9.
9. Guibal A, Boularan C, Bruce M, Vallin M, Pilleul F, Walter T, *et al.* Evaluation of shearwave elastography for the characterisation of focal liver lesions on ultrasound. Eur Radiol. 2013;23:1138–49.
10. Cosgrove D, Piscaglia F, Bamber J, Bojunga J, Correas JM, Gilja OA, *et al.* EFSUMB guidelines and recommendations on the clinical use of ultrasound elastography. Part 2: Clinical applications. Ultraschall Med. 2013;34(3):238–53.

11. Winn N, Lalam R, Cassar-Pullicino V. Sonoelastography in the musculoskeletal system: current role and future directions. World J Radiol. 2016;8(11):868.
12. Balaban M, Idilman IS, Ipek A, Ikiz SS, Bektaser B, Gumus M. Elastographic players. J Ultrasound Med. 2016;35(12):2623–8. findings of Achilles tendons in asymptomatic professional male volleyball
13. Ophir J, Alam SK, Garra BS, Kallel F, Konofagou EE, Krouskop T, *et al.* Elastography: Imaging the elastic properties of soft tissues with ultrasound. J Med Ultrason. 2002;29:155–71.
14. Gennisson JL, Deffieux T, Fink M, Tanter M. Ultrasound elastography: principles and techniques. Diagn Interv Imaging. 2013;94(5):487–95.
15. Taylor LS, Porter BC, Rubens DJ, Parker KJ. Three-dimensional sonoelastography: principles and practices. Phys Med Biol. 2000;45(6):1477.
16. Drakonaki E, Allen GM, Wilson DJ. Ultrasound elastography for musculoskeletal applications. Br J Radiol. 2012;85(1019):1435–45.
17. Klauser AS, Faschingbauer R, Jaschke WR. Is sonoelastography of value in assessing tendons? Semin Musculoskelet Radiol. 2010;14(3):323–33.
18. Benson J, Fan L. Understanding ARFI and new elastography quantification technologies. Mountain View (CA): Siemens Medical Solutions; 2014.
19. Hachemi ME, Callé S, Remenieras JP. Transient displacement induced in shear wave elastography: comparison between analytical results and ultrasound measurements. Ultrasonics. 2006;44:e221–5.
20. Kot BCW, Zhang ZJ, Lee AWC, Leung VYF, Fu SN. Elastic modulus of muscle and tendon with shear wave ultrasound elastography: variations with different technical settings. PLoS One. 2012;7(8):e44348.
21. Youk JH, Son EJ, Park AY, Kim JA. Shear-wave elastography for breast masses: local shear wave speed (m/sec) versus Young modulus (kPa). Ultrasonography. 2014;33(1):34.
22. Brum J, Bernal M, Gennisson JL, Tanter M. In vivo evaluation of the elastic Phys Med Biol. 2014;59(3):505. anisotropy of the human Achilles tendon using shear wave dispersion analysis.
23. Woo H, Lee JY, Yoon JH, Kim W, Cho B, Choi BI. Comparison of the reliability of acoustic radiation force impulse imaging and supersonic shear imaging in measurement of liver stiffness. Radiology. 2015;277(3):881–6.
24. Lawrence RL, Ruder MC, Moutzouros V, Makhni EC, Muh SJ, Siegal D, *et al.* Ultrasound shear wave elastography and its association with rotator cuff tear characteristics. JSES Int. 2021;5(3):500–6.
25. Baumer TG, Dischler J, Davis L, Labyed Y, Siegal DS, Van Holsbeeck M, *et al.* Effects of age and pathology on shear wave speed of the human rotator cuff. J Orthop Res. 2018;36(1):282–8.
26. Brage K, Hjarbaek J, Kjaer P, Ingwersen KG, Juul-Kristensen B. Ultrasonic strain elastography for detecting abnormalities in the supraspinatus tendon: an intra-and inter-rater reliability study. BMJ Open. 2019;9(5):e027725.
27. Vasishta A, Kelkar A, Joshi P, Hapse R. The value of sonoelastography in the diagnosis of supraspinatus tendinopathy—a comparison study. Br J Radiol. 2019;92(1096):20180951.
28. Nocera NL, Burke CJ, Gyftopoulos S, Adler RS. Ultrasound□ MRI correlation for healing of rotator cuff repairs using power Doppler, sonographic shear wave elastography and MR signal characteristics: a pilot study. J Ultrasound Med. 2021;40(10):2055–68