Joint Diseases and Related Surgery

Jt Dis Relat Surg
2023;34(1):92-97

ORIGINAL ARTICLE

Evaluation of the anterior shoulder instability using ultrasound shear wave elastography

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ABSTRACT

Objectives: This study aims to evaluate the soft tissue stiffness which has a prominent role in shoulder instability using ultrasound (US) shear wave elastography (SWE) and to compare the results with healthy shoulders.

Patients and methods: Between December 2018 and January 2020, a total of 33 male patients (mean age: 26±4.3 years; range, 18 to 35 years) who underwent arthroscopic repair for traumatic isolated anterior glenohumeral instability were included in this prospective study. The shoulder girdle was evaluated with US SWE in patients with traumatic anterior instability. Deltoid (D), supraspinatus (SS), infraspinatus (IS), subscapularis (SSC), and long head of biceps (LHB) tendons forming the shoulder girdle and anterior labrum (L) were evaluated with SWE. The elasticity and velocity of the tissues were quantitatively measured. The operated shoulders of 33 patients due to isolated traumatic anterior instability were named Group 1, while the healthy shoulders of these patients were named Group 2. Thirty volunteers with healthy shoulders were considered as the control group (Group 3, n=30).

Results: All three groups were compared in terms of SS, D, LHB, and SSC tendon velocity and elasticity; however, no statistically significant difference was observed among the groups ($p<0.05$). The anterior labrum of these three groups did not significantly differ in terms of SWE measurements ($p<0.05$).

Conclusion: The stiffness of shoulder girdle muscle tendons and labrum measured with US SWE does not constitute a risk factor for traumatic anterior shoulder instability.

Keywords: Instability, shear wave elastography, shoulder, ultrasound.

Anterior shoulder instability is the most common form of shoulder instability and is seen in 1.7 to 2% of the general population.[1-3] Traumatic shoulder instability or dislocation is often seen as an avulsion of the anterior inferior labrum and the lesion is called Bankart lesion.[4] Static factors such as the glenoid labrum, capsuloligamentous structures, bone formations forming the joint, dynamic factors such as the muscles forming the shoulder girdle, negative intra-articular pressure, and joint adhesion-cohesion forces stabilize the glenohumeral joint.[5] As the soft tissues play an active role in shoulder stabilization, the deterioration of the balance in these soft tissues plays an important role in the formation of traumatic or atraumatic dislocations.

Shear wave elastography (SWE) is an ultrasound (US) technology that can measure tissue elasticity quantitatively and has also been popularized in the orthopedics field in recent years.[6-9] In SWE technology, acoustic radiation forces are applied to

Received: November 22, 2022
Accepted: December 08, 2022
Published online: January 06, 2023

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Doi: 10.52312/jdrs.2023.956

Citation: Bekin Sarikaya ZP, Sarikaya B, Bozkurt C, Dere O, Balevi Batur E, Duşak A. Evaluation of the anterior shoulder instability using ultrasound shear wave elastography. Jt Dis Relat Surg 2023;34(1):92-97. doi: 10.52312/jdrs.2023.956

tissues by a transducer and this radiation creates "shear waves". The shear waves create deformation in the soft tissues. The degree of this deformation is different in each tissue and varies according to the young modulus value of each tissue. The square of the velocity is indicative of the stiffness of the tissue.[10,11] The velocity of shear waves is measured, as they travel through tissue and, thus, the elasticity of the tissue is calculated. In this technique, no mechanical pressure is applied to the tissues with an US probe as in dynamic methods. Tissues are stimulated from the inside through a strong, focused acoustic impulse.[12] Therefore, more reliable results are obtained compared to dynamic methods.

In the present study, we hypothesized that stiffness of the soft tissues around the shoulder girdle could be a risk factor for anterior shoulder instability. We, therefore, aimed to evaluate the muscles around the shoulder girdle and the glenoid labrum, which play an active role in anterior stability, with SWE, to examine the stiffness of the tissues having an effective role in shoulder stabilization in patients with shoulder instability, and to compare the results with healthy individuals.

PATIENTS AND METHODS

This single-center, prospective study was conducted at Harran University Faculty of Medicine, Department of Radiology and Orthopedics and Traumatology between December 2018 and January 2020. All the patients' data were collected prospectively during the clinical follow-ups. Patients having multidirectional instability, laxity, rotator cuff pathology, and systemic connective tissue diseases were excluded at the beginning of the study. Forty-four patients who underwent arthroscopic repair for traumatic isolated anterior glenohumeral instability were evaluated during the clinical follow-ups. Patients having at least one-year clinical follow-up period, having excellent results (90 to 100 points) according to Rowe shoulder instability score,[13] and having no limitation in shoulder joint movements were included in the study. Patients having Rowe scores other than excellent scores and patients having clinical and US findings of tendinitis were excluded from the study.

According to these criteria, 33 of the 44 patients (33 males; mean age: 26±4.3 years; range, 18 to 35 years) were included in the study. Two patients due to recurrent instability, seven patients due to having good results according to the Rowe score, and two patients due to having clinical and US findings of tendinitis were excluded from the study.

The operated shoulders of 33 patients included in the study were named Group 1. The other shoulders of the same patients were named Group 2. As the control group, 30 patients with the dominant shoulders of healthy volunteers were included in the study and were named Group 3. The same rehabilitation program was applied to all patients postoperatively.

Elastography was performed on all patients and healthy volunteers. Deltoid (D), supraspinatus (SS), infraspinatus (IS), subscapularis (SSC), and long head of biceps (LHB) muscle tendons forming the shoulder girdle and anterior labrum (L) were evaluated with US elastography.

Ultrasound technique

Ultrasound was performed in patients and healthy volunteers in the sitting position. While evaluating the muscles and tendons, the shoulders were in 0 degrees abduction and neutral position.[14,15] First, SS, SSC, D, and LHB fibers were identified by B-mode US. The SWE examination was performed using a 9-Mhz linear transducer (Siemens ACUSON, S3000; Siemens Healthcare GmbH, Erlangen, Germany). The transducer was applied parallel to the muscle fibers. The LHBT was examined in the bicipital groove in a longitudinal plane. While evaluating the labrum, the shoulder was abducted approximately 100 degrees and the transducer was applied to the axillary region, and the procedure was performed by keeping it parallel to the long axis of the glenoid labrum. The tissue elasticity was measured quantitatively with SWE. An elastogram image was acquired. Subsequently, the elasticity and velocity of the tissues were measured by placing a standard measurement box, also named region of interest (ROI), on the place where from 2 to 4 cm of the muscles before their attachment to the bone and from the anteroinferior part of the glenoid labrum and each SWE values were measured three times, the mean values were, then, recorded. We recorded velocity (V) as m/s showing the speed at which the sound wave travels through the tissue and elasticity value (E) as kilopascal (kpa) (Figures 1, 2).

To calculate the intra-observer and inter-observer reliability, the measurements were performed on the all muscles and glenoid labrum of volunteers with healthy shoulders. separately by two radiologists with sufficient experience (five and seven years) in musculoskeletal US. For evaluating intra-observer reliability, the same tests were repeated 10 days later by two radiologists. To measure the inter-observer reliability, two testing sessions were performed with

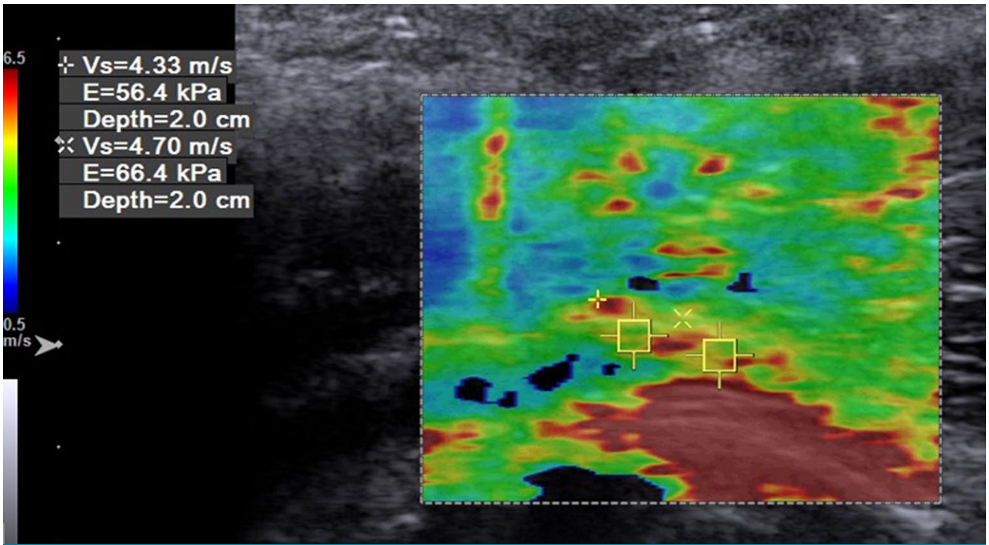

FIGURE 1. Left labrum shear wave elastography values of two measurements.
E: Elasticity; kPa: Kilopascal; V: Velocity; m: Meter; s: Second.

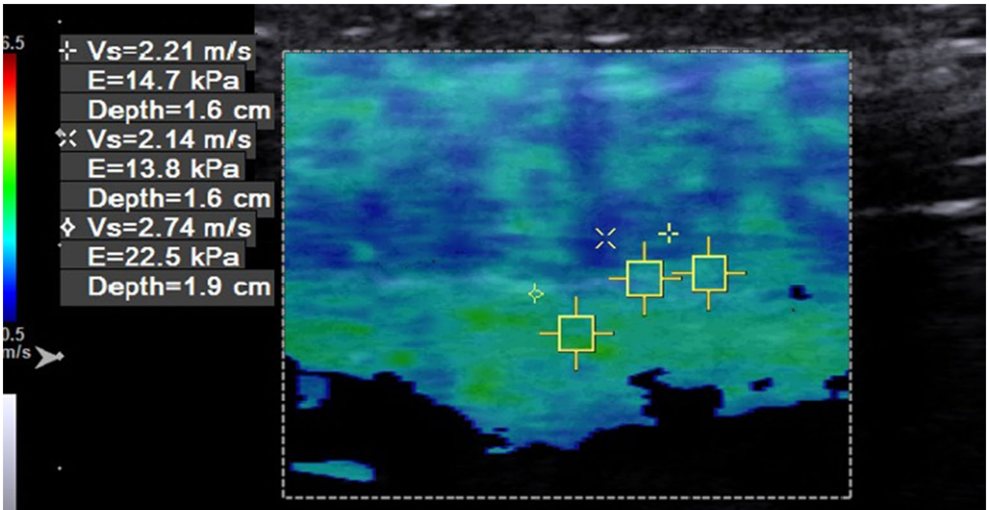

FIGURE 2. Deltoid muscle shear wave elastography measurements.
E: Elasticity; kPa: Kilopascal; V: Velocity; m: Meter; s: Seconds.

a 30-min interval between them to minimize muscle fatigue.

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 24.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. The normality of the distribution of the continuous variables was tested using the Kolmogorov-Smirnov test. We used one-way analysis of variance test (ANOVA) to assess significant differences in elastography measurements. The intra-class correlation coefficients (ICCs) of the elasticity values were used for reliability determination. Based on the 95% confidence interval of the ICC estimate, values of <0.4, 0.4 to 0.59, 0.60 to 0.74, and >0.75 were considered to indicate poor, moderate, good, and excellent reliability, respectively. A p value of <0.05 was considered statistically significant.

TABLE I
Share wave elastography values of the tendons and the labrum

	Group 1	Group 2	Group 3	
	Mean±SD	Mean±SD	Mean±SD	*p*
VSS	3.9±1	3.9±0.8	3.89±1	0.883
ESS	41.6±24.6	46.9±22.6	49.3±26	0.895
VD	3.4±0.6	3.4±0.7	3.5±1	0.965
ED	36.3±14.6	38±16.5	44±27.4	0.390
VB	3.6±1.1	3.7±0.9	3.4±0.9	0.377
EB	38.8±25.1	44.5±23.2	40.4±22.4	0.698
VSSC	3.2±0.9	3.3±0.9	3.5±0.7	0.778
ESSC	32.3±21.1	38.1±22.3	40.1±14.6	0.916
VL	3.6±0.9	3.8±0.9	3.5±0.9	0.534
EL	43.5±20.8	49.1±24.4	42.6±21.1	0.479
Age	26±4.3	26±4.3	24.6±4.5	0.364

V: Velocity; E: Elasticity; SS: Supraspinatus, SSC: Subscapularis, D: Deltoid, B: Long head of biceps tendon, L: Labrum.

RESULTS

The mean follow-up was 23±9.4 (range, 12 to 40) months. Twenty-six of 33 patients were operated from the dominant side. The patients had no limitation in the range of motion of the shoulder. The mean Rowe shoulder score was 92.72±12.85 (90-100; excellent).

Elastography was performed on the dominant side of all patients in the control group. For intra-observer and inter-observer reliabilities, the ICC was >0.85 in all measurements of velocity (V) and elastography (E). When all three groups were compared in terms of elasticity and V, SS, D, LHB, and SSC tendons showed no statistically significant difference among the three groups. The labrum of the three groups also did not significantly differ in terms of SWE measurements ($p<0.05$) (Table I).

DISCUSSION

In this study, we could not find a significant difference among the three groups in terms of SWE values of SS, IS, D, and LHBT structures. Labrums that underwent anatomical repair in patients with a follow-up period of more than one year and no recurrences had similar SWE findings with healthy-sided labrums and labrums of healthy volunteers. Therefore, we conclude that the stiffness values of these structures in our study may not be a risk factor in traumatic anterior instability.

The use of US elastography devices, which emerged with the development of technology, has become widespread. In recent years, there are several studies examining the shoulder region with SWE. In general, pathologies such as rotator cuff tears, frozen shoulder, and fatty degeneration have been investigated in these studies.[16-19] The deltoid muscle has been evaluated in far fewer studies compared to the rotator cuff.[20,21] However, there is no SWE study evaluating shoulder girdle soft tissues related to shoulder instability in the literature.

Soft tissue balance is of utmost importance in shoulder stability. Laxity may be a risk factor for recurrence after previous surgeries to stabilize the shoulder joint. The dynamic and static balance of the supraspinatus and infraspinatus components of the rotator cable, particularly the supraspinatus, is critical for anterior stabilization.[5] The long head of the biceps tendon, which is tightly supported by the supraspinatus and subscapularis tendons, also plays an active role in stabilizing the humeral head. It reflects the objective of this study to examine the role of stiffness of these soft tissues on stabilization in the shoulder joint, which is so well supported by soft tissues.

Review of the literature reveals only one study examining shoulder instability with SWE, in which anterior labrum healing was evaluated with the current elastography. In this study by Fukuyoshi et al.,[22] the labrums of patients with Bankart lesions were compared with the contralateral shoulder labrum, and no significant difference was observed in the labrum SWE values from the third month postoperatively. Again, in the aforementioned study, B-mode echograms of the anteroinferior labrum were found to be Grade 0 in both shoulder labrums starting from the fourth month. In other words, the labrum healing from the fourth month shows similar features with the contralateral shoulder US. All patients in our study had a follow-up period of more than one year, and patients with complete recovery were examined, and our results are similar to this study. Anatomically repaired labrums in patients without recurrence during a follow-up period of more than one year showed similar SWE findings with healthy-sided labrums. The fact that the intact side and the operated side have similar stiffness values suggests that SWE can also be used as an auxiliary method in the evaluation of tissue healing. In our study, we could not detect any significant difference in terms of SWE between the repaired labrums and the labrums of healthy volunteers. According to these findings, labrum stiffness values are not a risk factor for traumatic instability.

There may be changes in the structure of tissues with age. This may affect the SWE values of tissues. In a study, Fontenella et al.[23] analyzed of the supraspinatus tendon in differential age groups and they found a difference between the means of the shear modulus measured by the SSI elastography, indicating a significant decrease of the shear modulus with the chronological age progression. The patients and healthy volunteers in our study were in similar age groups and were all male. Therefore, we believe that age and sex factors did not affect our results.

Furthermore, SWE is a radiological method with high intra-observer and inter-observer capability.[19,22,24,25] We also obtained high intra- and inter-observer reliability results in our study. However, based on studies on SWE are examined, different techniques can be applied. Therefore, the data obtained in similar studies may show differences from each other and the comparison of numerical data in studies may not always yield consistent results. Factors such as patient position, presence of bursal surfaces near tissue, skin thickness, out-of-plane movements of the transducer, and use of different brand devices may cause different results in similar studies.[16,26,27] Creating a standardization in SWE applications may be possible, if future studies show similar features in terms of technology and technique. Further studies are a necessity in this manner.

Nonetheless, there are some limitations to our study. First, it has a relatively small number of patients. Second, we were unable to compare patients with recurrence and patients without. If we could compare these patients, we could evaluate the soft tissue elasticity risk factor much better. In this regard, a further prospective study is in our future plans.

In conclusion, there was no significant difference between the SWE values of patients with traumatic anterior instability and the SWE values of healthy individuals in our study. Therefore, the stiffness values of the structures did not constitute a risk factor in traumatic anterior shoulder instability. Since there are not enough studies on SWE and shoulder instability, we believe that this study, in which we obtained quantitative measurements, would provide an additional contribution to future studies.

Ethics Committee Approval: The study protocol was approved by the Harran University Faculty of Medicine Ethics Committee (date: 05.11.2018, no: 11-01). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Planning, designing, literature survey, writing: P.Z.B.S.; Planning, designing, literature survey, statistical analysis, submission: B.S.; Planning, designing, literature survey: C.B., O.D., E.B.B., A.,D.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

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