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ORIGINAL ARTICLE

Added Value of Ultrasound Shear Wave Elastography in Diagnosis of Frozen Shoulder

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ABSTRACT

Background: : Pain and a progressive lack of shoulder motion are the hallmarks of frozen shoulder (FS). FS usually goes through three phases: Stage I involves pain and limited motion, Stage II is marked by stiffness and Stage III during which symptoms gradually improve. We aimed to evaluate thickness and Share Wave Elastography (SWE) of the coracohumeral ligament (CHL), supraspinatus (SSp) and infraspinatus (ISp) tendons in affected and healthy side in different stages of frozen shoulder. **Methods**: This cross sectional study was carried out on 18 patients clinically identified with unilateral frozen shoulder and divided into three phases based on range of motion and visual analogue score (VAS). SWE and B-mode ultrasound (B-US) of the CHL, SSp and ISp tendons of the affected and healthy side were assessed and compared in different stages of FS. **Results**: The thickness and SWE of the CHL on the affected side were compared to those on the healthy side in stage I, there were no significant differences (P>0.05), but they were greater on the affected side in stages II and III (P =.001). The thickness and SWE of the SSp and ISp tendons on the affected side were compared to those on the healthy side in stage I frozen shoulder, there were significant difference (P>0.05), but they were no significant difference between affected and healthy sides in stages II and III (P > 0.05). **Conclusion**: At different stages of frozen shoulder, the affected side's CHL, SSp, and ISp tendons' thickness and stiffness vary.

Keywords: Stiffness, Shear wave elasticity, Thickness,Frozen Shoulder, Coracohumeral ligament.

INTRODUCTION

Adhesive capsulitis (frozen shoulder) is an idiopathic condition manifesting as restriction of both active and passive glenohumeral joint mobility, accompanied by pain on movement It most commonly affects individuals aged 40-60 **[1,2]**.

The clinical course of frozen shoulder is typically divided into three stages. Stage I, the painful phase, is characterized primarily by shoulder pain. Stage II, the frozen phase, shows decreased pain and a noticeable restriction in shoulder function. Both discomfort and functional limits progressively go away during Stage III, the thawing phase **[3,4]**.

Diagnosing adhesive capsulitis can be difficult due to the overlap of symptoms with other shoulder conditions. Therefore, imaging is essential **[5,6]**.

SWE is a technique that was developed to analyze tissue quality, with a focus on elasticity. SWE provides quantitative and local elastic information on soft tissues in real time, based on viscoelastic properties. The system generates and propagates shear waves into tissues and assesses their elastic modulus as we thought that the soft tissues in patients with frozen shoulder would be variable in morphology on B-mode and stiffness on SWE, and the SWE values of the tissues and B-mode measurements would change depending on the phase [7]. Blue pixels and low velocities indicate a lower modulus, which indicates that the tendon is soft and red pixels and high velocities indicate a higher modulus which indicates that tendon is stiff.

Therefore, our cross-sectional study's goal were to assess the advantages of using shear wave elastography (SWE) with high-resolution ultrasonography in the diagnosis of different stages of frozen shoulder, evaluate thickness and study (SWE) of CHL, SSp and ISp tendons in affected and healthy side in different stages of frozen shoulder.

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METHODS

The Institutional Review Board (I.R.B) approved a cross-sectional study (IRB #11179-26/11-2023) that was conducted from June 2024 to December 2024 at our institute.18 participants who were referred from the outpatient clinics and departments of rheumatology, rehabilitation, and orthopedic surgery gave written consent after being made aware of the nature and goal of the study. The work was conducted in compliance with the World Medical Association's Code of Ethics for research involving human subjects, known as the Declaration of Helsinki.

Inclusion criteria were patient with unilateral frozen shoulder of any age and any sex diagnosed clinically with (shoulder pain for past 6 months and limitation of shoulder joint motion, both active and passive).

Exclusion criteria were shoulder joint dislocation and fracture, tendon disease and rotator cuff damage, TB, rheumatoid arthritis, systemic infections, and disorders of the blood system and the patient feels shoulder pain on both sides.

Operational design:

Every instance that satisfied the requirements for inclusion was put through taking a complete medical history. Before the SWE exam, the shoulder's range of motion and VAS score were assessed. A VAS was used to measure shoulder pain. Shoulder range of motion was evaluated using forward flexion (Ff), external rotation (Er), and internal rotation (Ir) scores. Frozen shoulder stage I was defined as having a VAS score of ≥6 points; stage II was characterized as having a VAS score of less than three, Ff >100°, Er >10°, and Ir score >three points; stage III was characterized as having a VAS score of less than six points, Ff >100°, Er >10°, and Ir score >3 points**.** The research's imaging study included SWE and B-US. A Toshiba Aplio 500US scanner fitted with a multifrequency linear probe that operates between 5 and 18 MHz was used to conduct sonographic tests with a ROI of 1.5 mm² circular approximately 2 cm lateral to coracoid process of CHL SEW and 10 mm² circular ROI, 10 mm medial to greater tuberosity for SSp and ISp tendons SWE .The SWE of three images was measured from the region of interest, and the average value was taken.The B-US and SWE of the CHL were performed when the patient was seated with the elbow flexed 90 degrees With 10 to 30 degree Er of the shoulder joint. The B-US and SWE of the SSp tendon was evaluated with the patient place the arm posteriorly with palmar side of the hand resting on the same iliac wing and the elbow was flexed and directed posteriorly to ensure external rotation “hand-in-back-pocket” position. The B-US and SWE of the ISp tendon was evaluated with the patient sitting and his forearm was placed across the chest and the palm of the hand placed over the contralateral shoulder. The opposite unaffected shoulder was considered as control.

Statistical analysis:

The information was collected, edited, coded, and entered using the Statistical Package for Social Science (IBM SPSS Statistics for Windows, Version 23.0, IBM Corp., Armonk, NY, USA). The t-test was used to assess the parametric data, which was presented as mean and SD. The Mann Whitney test was used to evaluate the non-parametric data, which was presented as the median and interquartile range (IQR). Chi-square or Fisher's exact test was used to examine the qualitative data, which was presented as frequency and percentage. The association between two quantitative variables was evaluated using Pearson's correlation. The relationship between the quantitative variables of more than two groups was evaluated using the ANOVA test

RESULTS

Patients age ranged from 48 to 58 years. (55.6%) of them were males and (44.4%) were females. (50%) of them had a right affected shoulder and (50%) had a left affected shoulder. (33.3%) had stage I injury, (33.3%) had stage II injury and (33.3%) had stage III injury.

Clinical information and frozen shoulder stages were statistically significantly correlated, with patients with stage I frozen shoulder having a greater VAS score and a higher external rotation angle when compared to patients with other stages of frozen shoulder *(P<0.001)*. In contrast, patients with stage III frozen shoulder had a higher forward flexion angle and a higher internal rotation angle when compared to patients with other stages of frozen shoulder *(P<0.001*) (Table1).

The thickness of the affected shoulder's CHL and the stages of frozen shoulder were statistically significantly correlated, as patients with stage II frozen shoulder had a higher CHL thickness (figure1) when compared to patients with other stages of frozen shoulder *(P<0.001)* and among patients with stage II and stage III frozen shoulders only CHL thickness was higher at the affected shoulder *(P<0.001)* (Table 2) (figure 1&2) respectively.

Patients with stage II frozen shoulder had a greater CHL SWE than those with stage I frozen shoulder, indicating a statistically significant correlation between the two variables to patients with other stages of frozen shoulder *(P<0.001)*(figure 1) *and* among patients with stage II and stage III frozen shoulder CHL SWE was higher at the affected shoulder *(P<0.001)* (Table 3) (figure 1&2) respectively.

Patients with stage I frozen shoulder had a higher SSP thickness and a higher ISP thickness when compared to patients with other stages of frozen shoulder (P<0.001) (Table 2) (figure3&4).Furthermore, among patients with stage I frozen shoulder SSP thickness and ISP thickness were higher at the affected shoulder (P<0.001 and P<0.001) respectively (Table 2) (figure3&4).

Patients with stage I frozen shoulder had a higher SSP SWE and a higher ISP SWE when compared to patients with other stages of frozen shoulder (P<0.001).Furthermore, among patients with stage I frozen shoulder SSP SWE and ISP SWE were higher at the affected shoulder (P<0.001 and P<0.001) respectively (Table 3) (figure3&4).

Table 1: Association of the three stages of frozen shoulder and clinical data among the studied patients.

Variables		Stage I (n=6)	Stage II (n=6)	Stage III (n=6)	P Value
VAS score	*Mean ± SD*	6.83 ± 0.75	4.17 ± 1.17	2.5 ± 1.05	**<0.001**
	Range	(6 – 8)	(3 – 6)	(1 – 4)	
Forward flexion angle	*Mean ± SD*	118.8 ± 14.4	71.67 ± 7.37	133.8 ± 18.01	**<0.001**
	Range	(100 – 140)	(65 – 85)	(108 – 155)	
External rotation angle	*Mean ± SD*	5.5 ± 1.38	1.33 ± 0.52	4 ± 0.89	**<0.001**
	Range	(4 – 7)	(1 – 2)	(3 – 5)	
Internal rotation angle	*Mean ± SD*	30.67 ± 7.63	12.3 ± 3.83	52.5 ± 15.41	**<0.001**
	Range	(20 – 42)	(6.8 – 17)	(30 – 70)	

*[1]One way ANOVA test, Non-significant: P >0.05, Significant: P ≤0.05

***VAS**=Visual analogue scale

Table 2: Association of the three stages of frozen shoulder and CHL , SSp and ISp tendons thickness among the studied patients.

Variables		Stage I (n=6)	Stage II (n=6)	Stage III (n=6)	P Value
Affected side CHL thickness	*Mean ± SD*	3.85 ± 0.46	6.38 ± 0.59	4.87 ± 0.22	**<0.001**[1]
	Range	(3.2 – 4.4)	(5.5 – 7.1)	(4.6 – 5.2)	
Non-affected side CHL thickness	*Mean ± SD*	3.28 ± 0.16	3.57 ± 0.4	3.15 ± 0.29	0.19[1]
	Range	(3.1 – 3.5)	(3.1 – 4.2)	(2.8 – 3.6)	
***P value*		0.07[2]	**<0.001**[2]	**<0.001**[2]	
Affected side SSP thickness	*Mean ± SD*	8.02 ± 1.03	4.23 ± 0.18	4.13 ± 0.26	**<0.001**[1]
	Range	(7.1 – 9.9)	(4 – 4.5)	(3.8 – 4.5)	
Non-affected side SSP thickness	*Mean ± SD*	4.02 ± 0.28	3.9 ± 0.37	3.9 ± 0.2	0.71[1]
	Range	(3.5 – 4.2)	(3.2 – 4.2)	(3.6 – 4.2)	
***P value*		**<0.001**[2]	0.07[2]	0.11[2]	

Affected side ISP thickness	*Mean ± SD*	4.98 ± 0.23	2.93 ± 0.39	2.92 ± 0.2	**<0.001[1]**
	Range	(4.7 – 5.3)	(2.4 – 3.5)	(2.6 – 3.2)	
Non-affected side ISP thickness	*Mean ± SD*	2.83 ± 0.46	2.85 ± 0.19	2.85 ± 0.56	0.88[1]
	Range	(2.3 – 3.4)	(2.6 – 3.1)	(2 – 3.4)	
***P value*		**<0.001[2]**	0.65[2]	0.79[2]	

*[1]One way ANOVA test, [2]Student T-test, Non-significant: P >0.05, Significant: P ≤0.05

*P value=Comparison between the three stages, **P value=Comparison between the affected and non-affected side.

***CHL**=Coracohumeral ligament, **SSP**=Supraspinatus, **ISP**=Infraspinatus, **SWE**=Shear wave elastography.

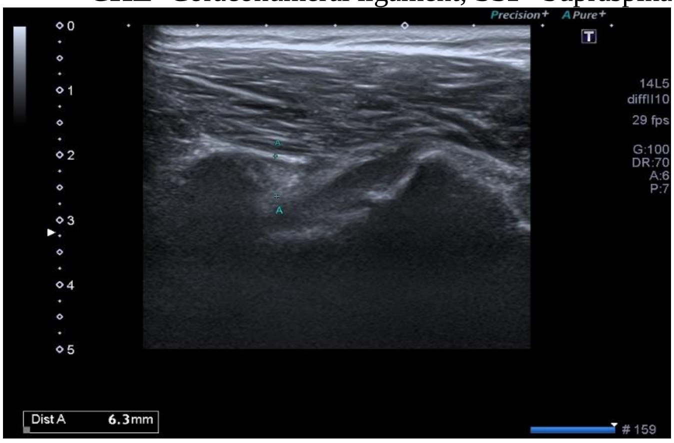
Table 3: Association of the three stages of frozen shoulder and CHL , SSp and ISp SWE among the studied patients

Variables		**Stage I (n=6)**	**Stage II (n=6)**	**Stage III (n=6)**	**P Value**
Affected side CHL SWE	*Mean ± SD*	26.6 ± 7.1	211.3 ± 5.02	91.3 ± 3.37	**<0.001[1]**
	Range	(20.1 – 39.2)	(203.9 – 215.9)	(88 – 97.5)	
Non-affected side CHL SWE	*Mean ± SD*	25.6 ± 4.88	25.5 ± 3.79	28.5 ± 1.05	0.16[1]
	Range	(19.9 – 33.9)	(20.8 – 30.1)	(27 – 30)	
***P value*		0.79[2]	**<0.001[2]**	**<0.001[2]**	
Affected side SSP SWE	*Mean ± SD*	135.4 ± 13.6	29.7 ± 2.19	27.2 ± 4.42	**<0.001[1]**
	Range	(121 – 158.1)	(26.5 – 32.7)	(22 – 35)	
Non-affected side SSP SWE	*Mean ± SD*	24.4 ± 7.03	25.9 ± 3.79	38.7 ± 26.2	0.22[3]
	Range	(15.3 – 34.5)	(20.5 – 30.5)	(25 – 92)	
***P value*		**<0.001[2]**	0.06[2]	0.31[2]	
Affected side ISP SWE	*Mean ± SD*	126.7 ± 13.55	27.6 ± 1.79	27.3 ± 2.07	**<0.001[1]**
	Range	(112.7 – 148.1)	(25.3 – 30)	(24 – 30)	
Non-affected side ISP SWE	*Mean ± SD*	32 ± 5.13	31.1 ± 3.93	24.4 ± 1.57	**0.005[1]**
	Range	(25.3 – 37.1)	(25.3 – 36.9)	(22.1 – 26)	
***P value*		**<0.001[2]**	0.08[2]	0.07[2]	

*[1]One way ANOVA test, [2]Student T-test, Non-significant: P >0.05, Significant: P ≤0.05

*P value=Comparison between the three stages, **P value=Comparison between the affected and non-affected side

***CHL**=Coracohumeral ligament, **SSP**=Supraspinatus, **ISP**=Infraspinatus, **SWE**=Shear wave elastography



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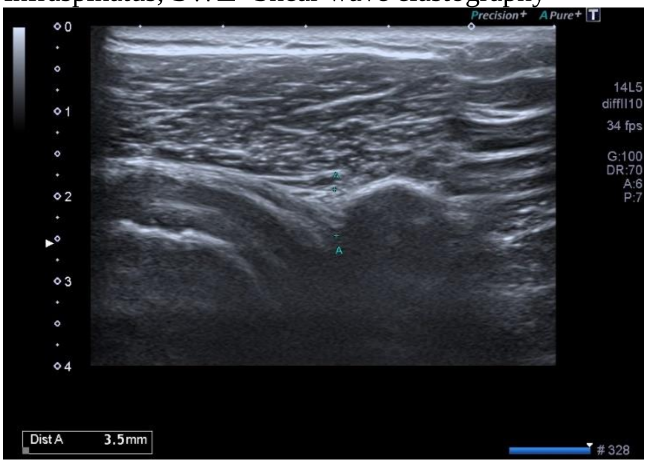

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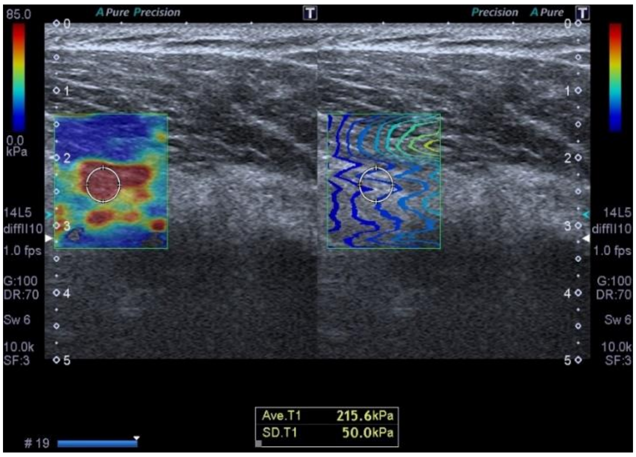
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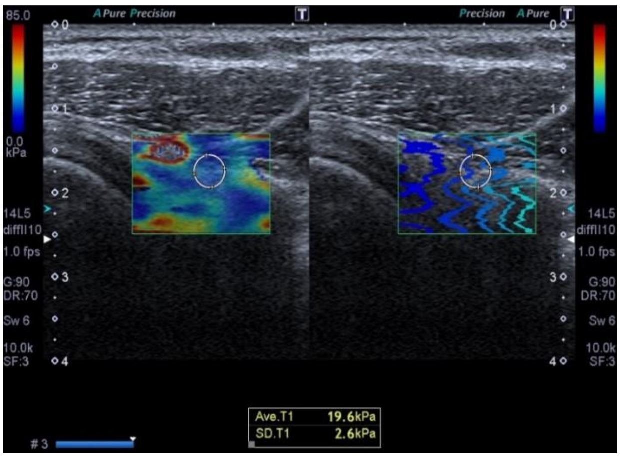
SD.T1 50.0kPa

C


Ave.T1 19.6kPa
SD.T1 2.6kPa

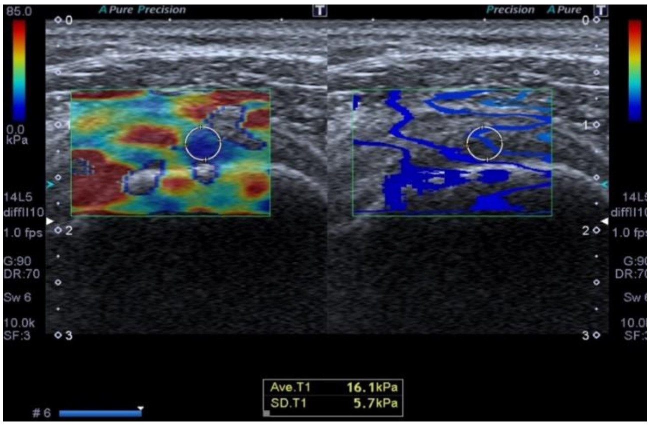
D


Dist A 4.3mm

E


RT SUPRASPI
Dist A 4.2mm

F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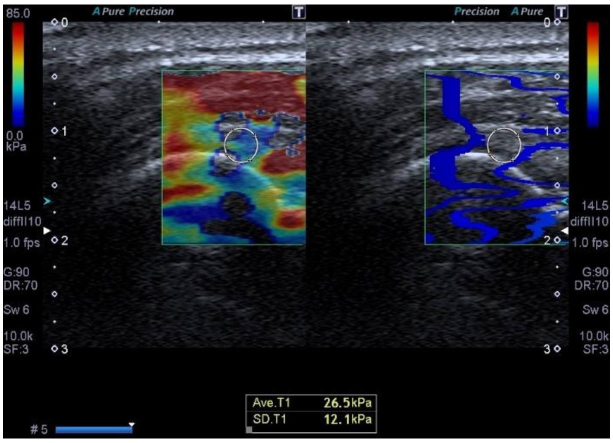
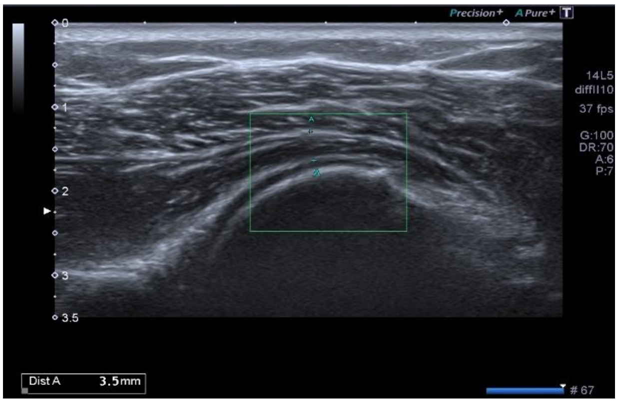
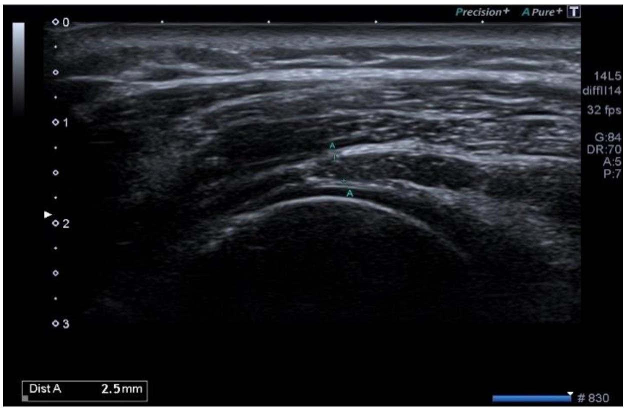
SD.T1 5.7kPa

G


Ave.T1 26.5kPa
SD.T1 12.1kPa

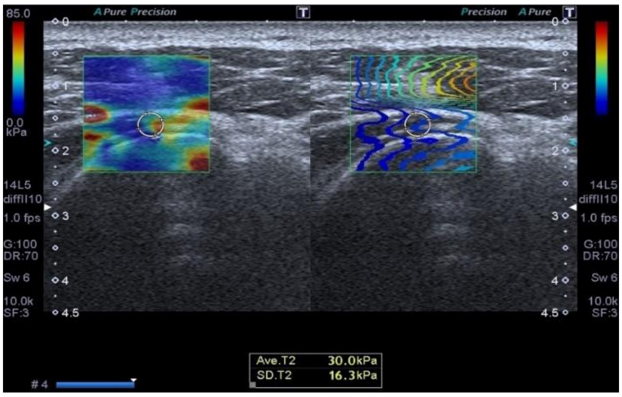
H

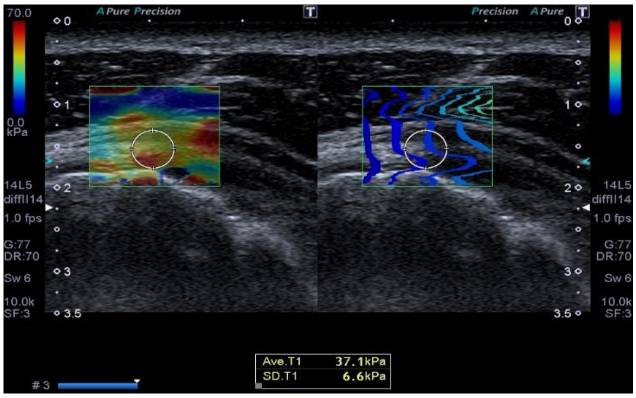




M

N





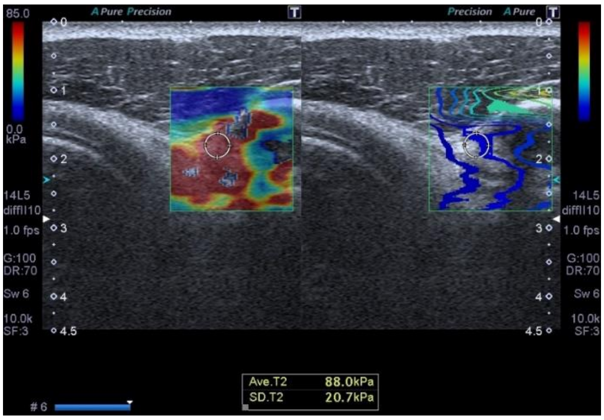
L

O

Figure 1: Ultrasound images of A 57 years old female patient is suffering from left shoulder pain since 1.5 y diagnosed clinically with stage II frozen shoulder. (A) B-US image revealed increased thickness LT CHL. (B) B-US image revealed average thickness of RT CHL. (C) SWE image revealed high value stiffness of LT affected CHL (red and high velocity=stiff). (D) SWE image revealed average value stiffness of RT non-affected CHL(blue and low velocity=soft) with a ROI of 1.5 mm² circular approximately 2 cm lateral to coracoid process.(E) & (F) B-US images revealed average thickness of LT and RT SSp tendons. (G) & (H) SWE images revealed average stiffness values of LT and RT SSp tendons. (M) & (N) B-US images revealed average thickness of LT and RT ISp tendons. (L) & (O) SWE images revealed average stiffness values of LT and RT ISp tendons (blue and low velocity=soft)with 10 mm² circular ROI, 10 mm medial to greater tuberosity for SSp and ISp tendons SWE.

A

B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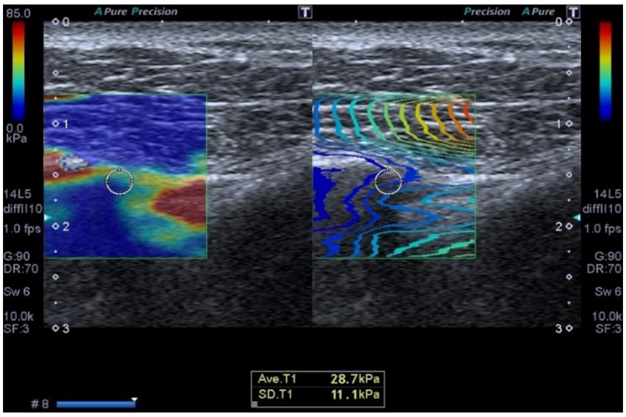
SD.T2 20.7kPa

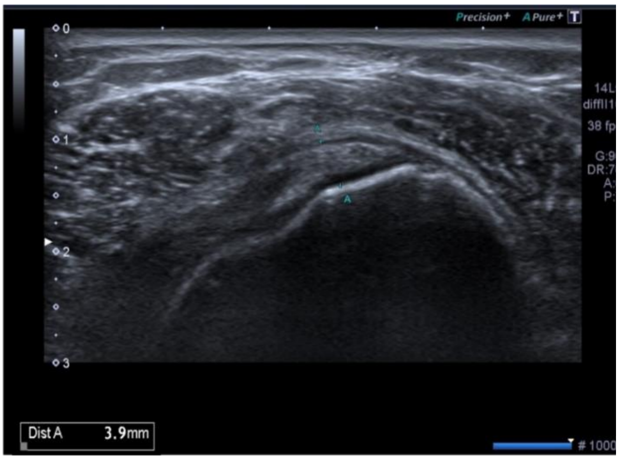
C


Ave.T1 28.7kPa
SD.T1 11.1kPa

D


Dist A 3.8mm

E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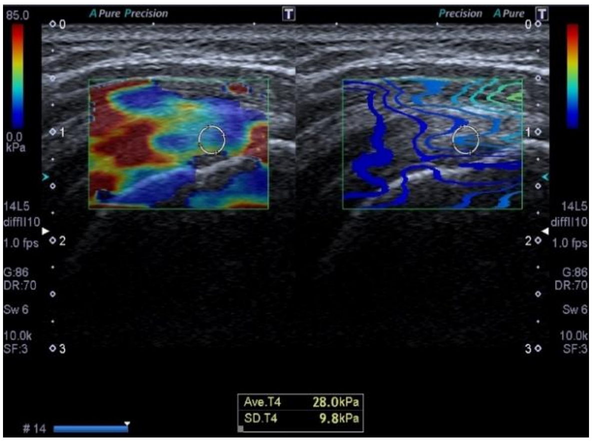
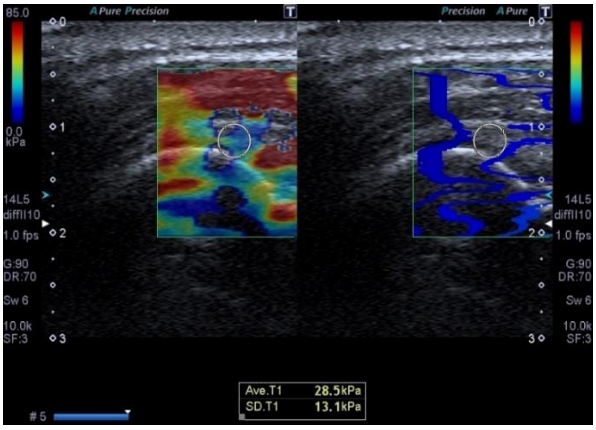
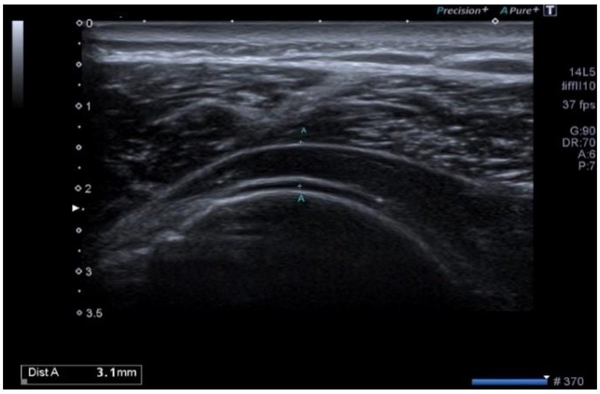
F


Ave.T4 28.0kPa
SD.T4 9.8kPa

G

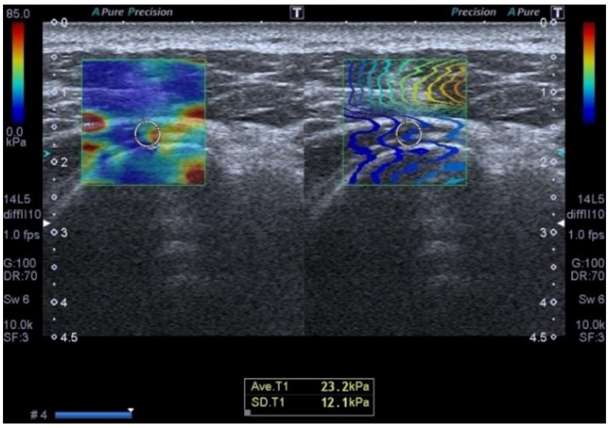

Ave.T1 28.5kPa
SD.T1 13.1kPa

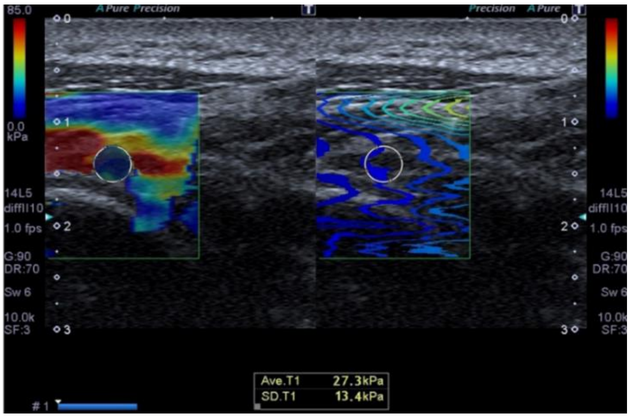
H



M

N





L

O

Figure 2: Ultrasound images of A 54 years old male patient is suffering from right shoulder pain since 2 year diagnosed clinically with stage III frozen shoulder. (A) B-US image revealed moderate increased thickness RT CHL. (B) B-US image revealed average thickness of LT CHL. (C) SWE image revealed high value stiffness of RT affected CHL (red and high velocity=stiff) with a ROI of 1.5 mm² circular approximately 2 cm lateral to coracoid process.(D) SWE image revealed average value stiffness of LT non-affected CHL(blue and low velocity=soft) with a ROI of 1.5 mm² circular approximately 2 cm lateral to coracoid process (E) & (F) B-US images revealed average thickness of RT and LT SSp tendons. (G) & (H) SWE images revealed average stiffness values of RT and LT SSp tendons.(M)&(N) B-US images revealed average thickness of RT and LT ISp tendons. (L) & (O) SWE images revealed average stiffness values of RT and LT ISp tendons(blue and low velocity=soft) with 10 mm² circular ROI, 10 mm medial to greater tuberosity for SSp and ISp tendons SWE.

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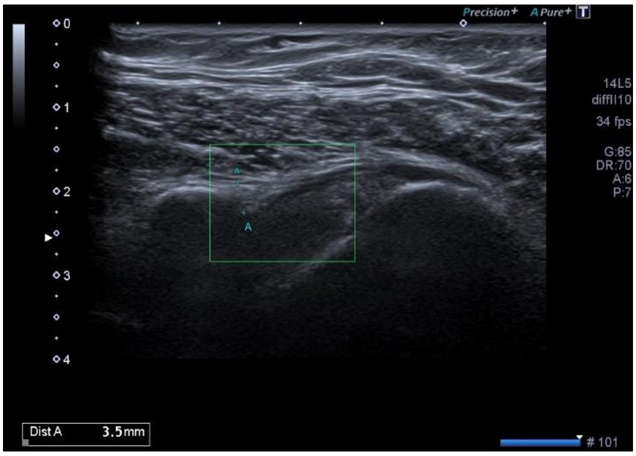
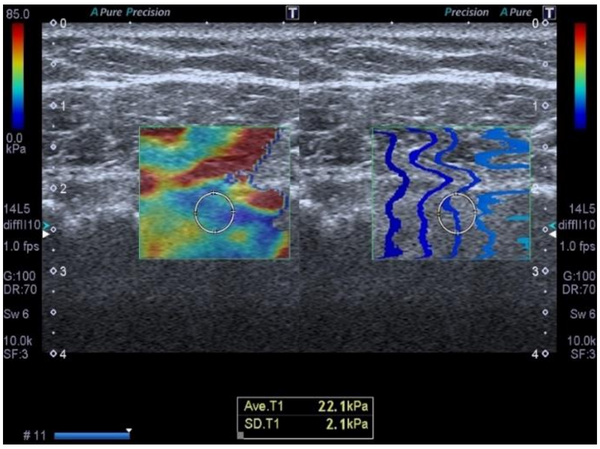
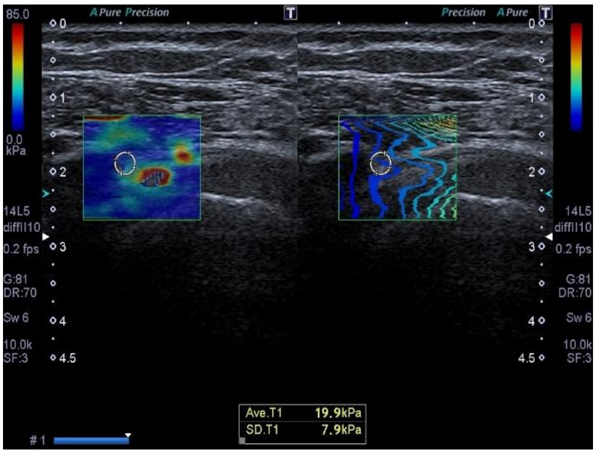


A

B


Ave.T1 22.1kPa
SD.T1 2.1kPa

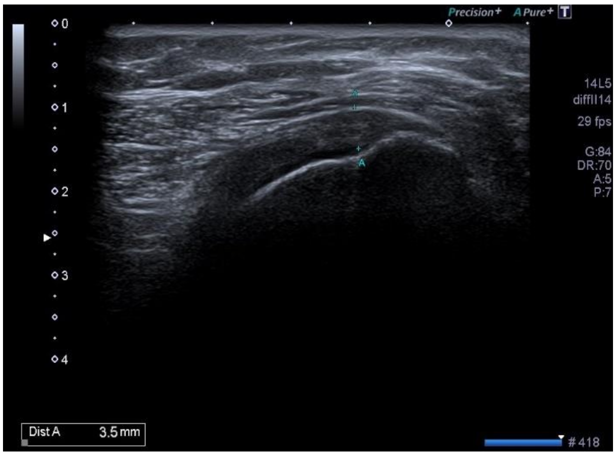
C


Ave.T1 19.9kPa
SD.T1 7.9kPa

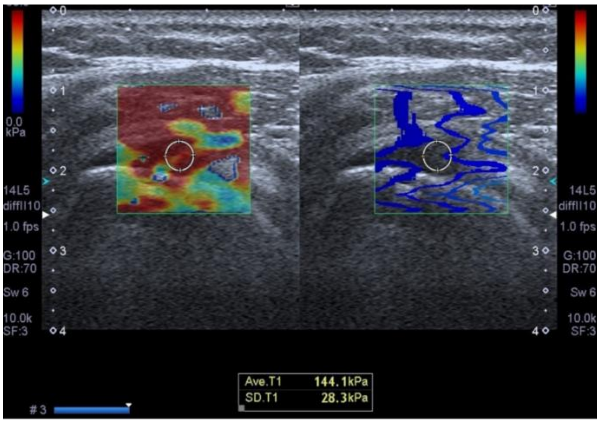
D


Dist A 8.0mm

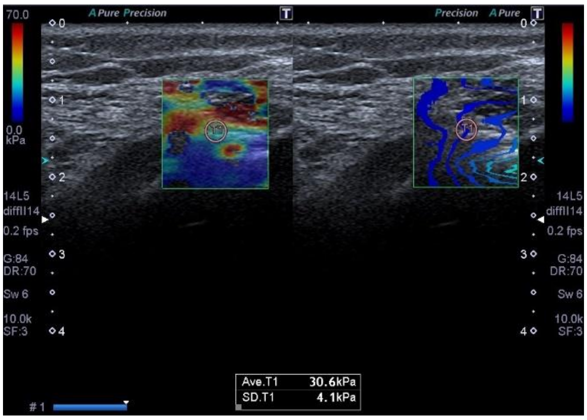
E


Dist A 3.5mm

F

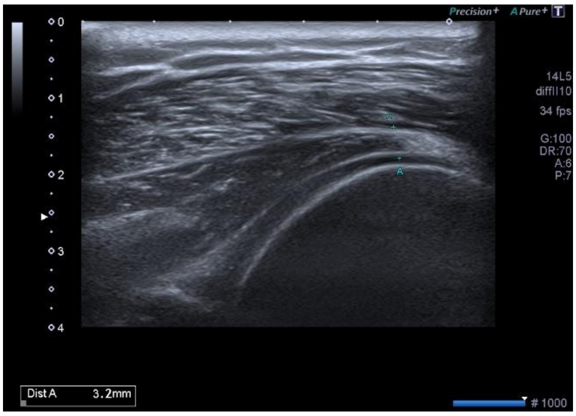

Ave.T1 144.1kPa
SD.T1 28.3kPa

G


Ave.T1 30.6kPa
SD.T1 4.1kPa

H

M



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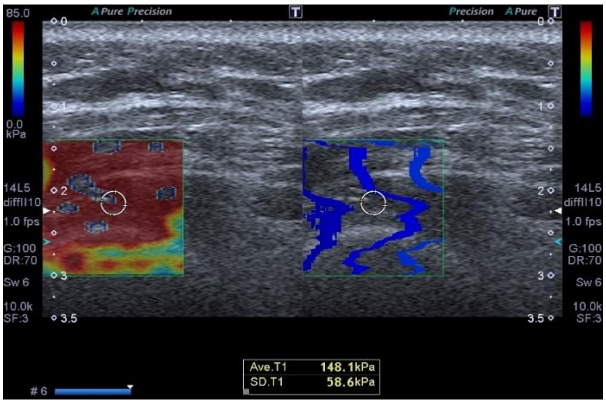

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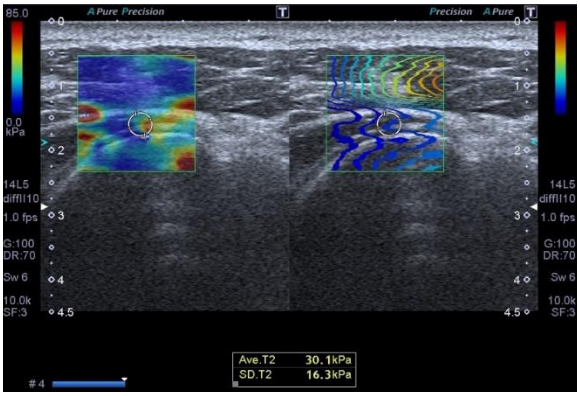
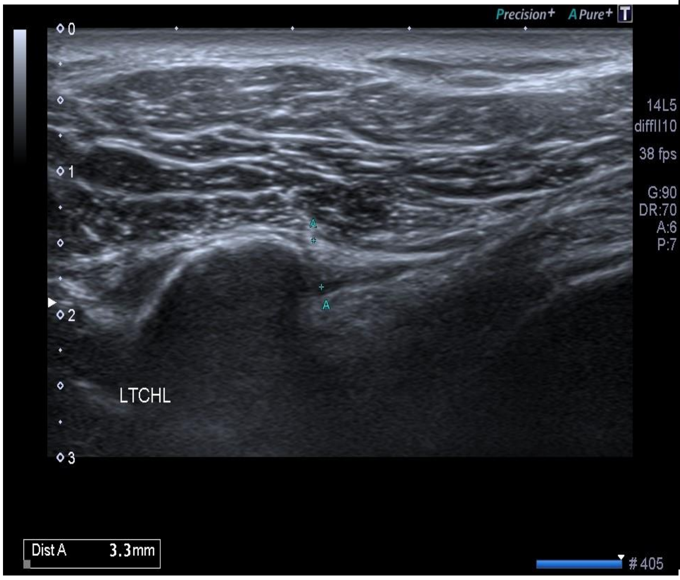


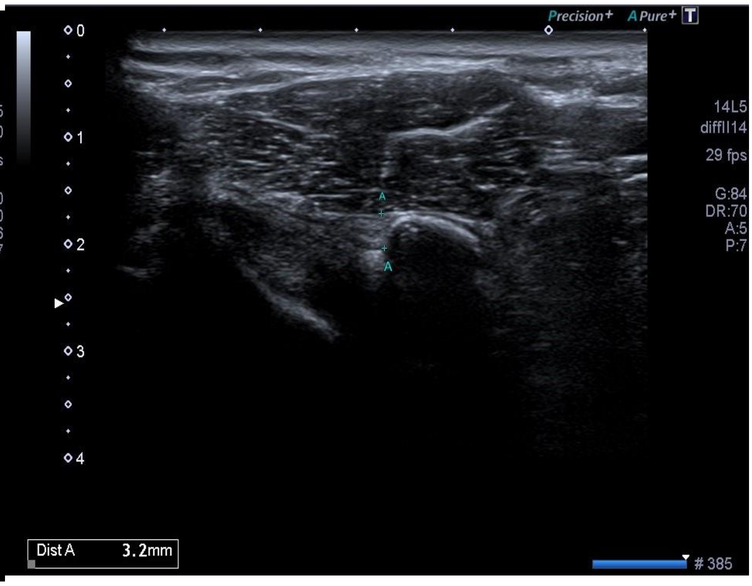
O

Figure 3: Ultrasound images of A 50 years old female patient is suffering from right shoulder pain since 9 months diagnosed clinically with stage I frozen shoulder. (A)& (B) B-US images revealed average thickness RT and LT CHL. (C)&(D) SWE images revealed average value stiffness of RT and LT CHL(blue and low velocity=soft) with a ROI of 1.5 mm² circular approximately 2 cm lateral to coracoid process. (E) B-US image revealed thickened RT SSp tendon .(F) B-US images revealed average thickness of LT SSp tendon.(G) SWE image revealed increased stiffness of RT SSp tendon(red and high velocity=stiff). (H) SWE image revealed average stiffness value of LT SSp tendon(blue and low velocity=soft).(M) B-US image revealed thickened RT ISp tendon.(N) B-US image revealed average thickness of LT ISp tendons.(L) SWE image revealed increased stiffness of RT ISp tendon red and high velocity=stiff .(O)SWE image revealed average stiffness value of LT ISp tendon(blue and low velocity=soft). ROI of 10 mm² circular, approximately 10 mm medial to greater tuberosity for SSp and ISp tendons SWE.

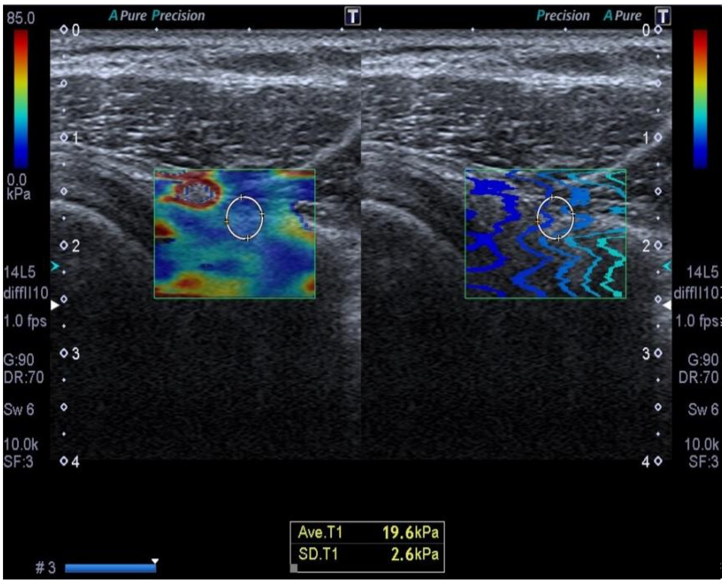
(A)


LTCHL
Dist A 3.3mm

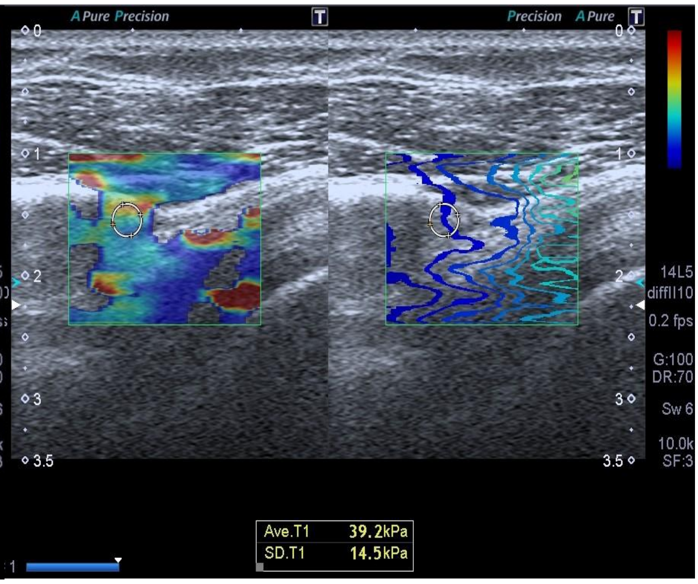
(B)

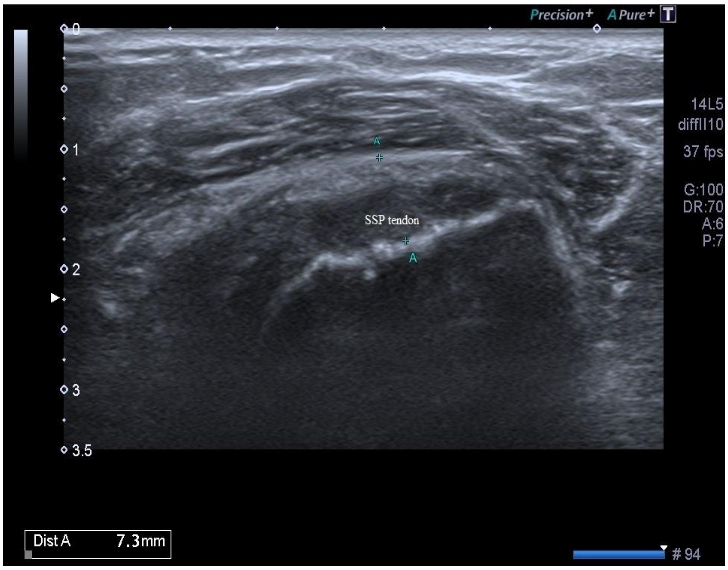

Dist A 3.2mm

(C)

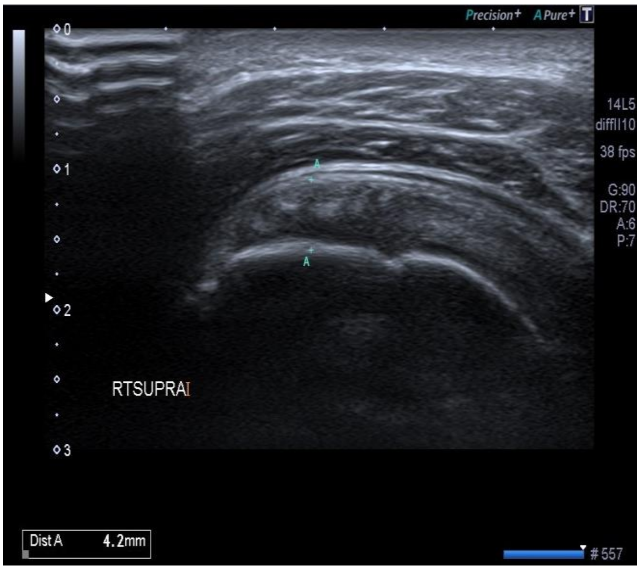

Ave.T1 19.6kPa
SD.T1 2.6kPa

(D)

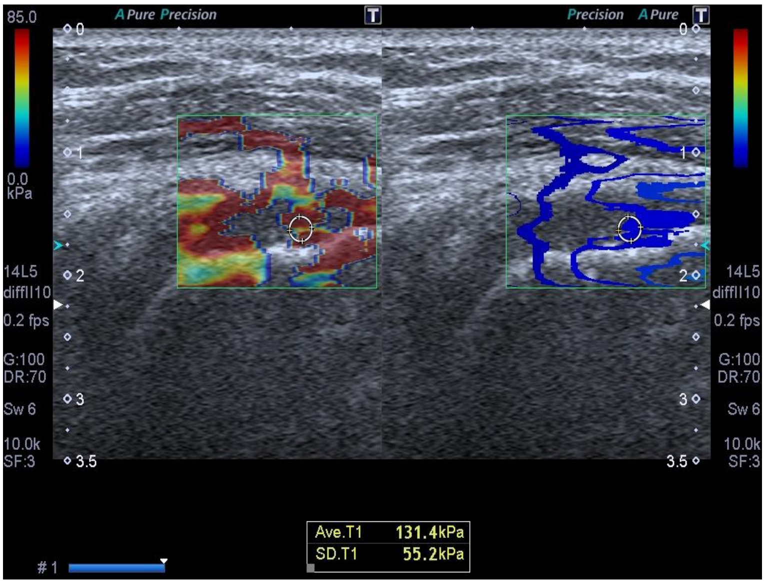

Ave.T1 39.2kPa
SD.T1 14.5kPa


SSP tendon
Dist A 7.3mm

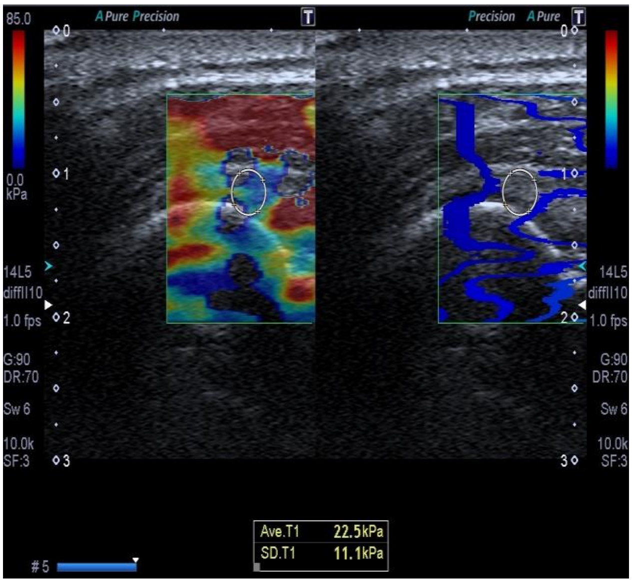
(E)


RTSUPRAI
Dist A 4.2mm

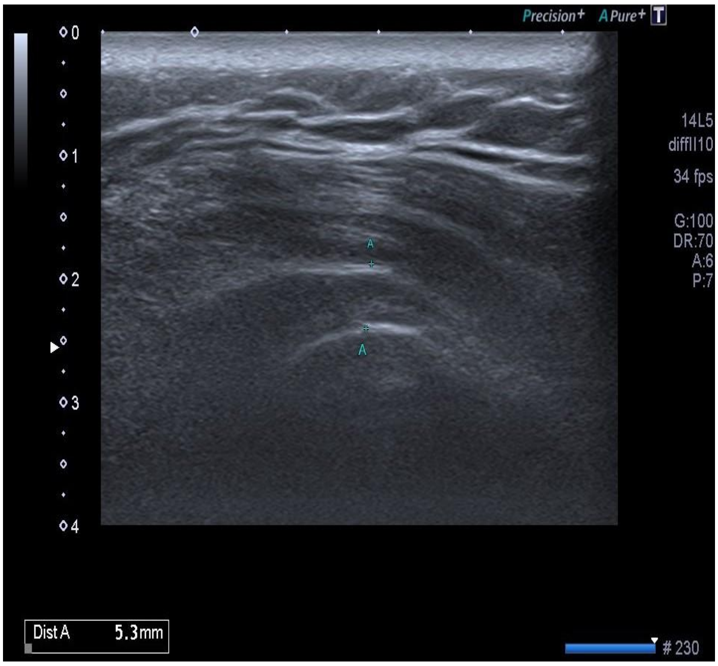
(F)

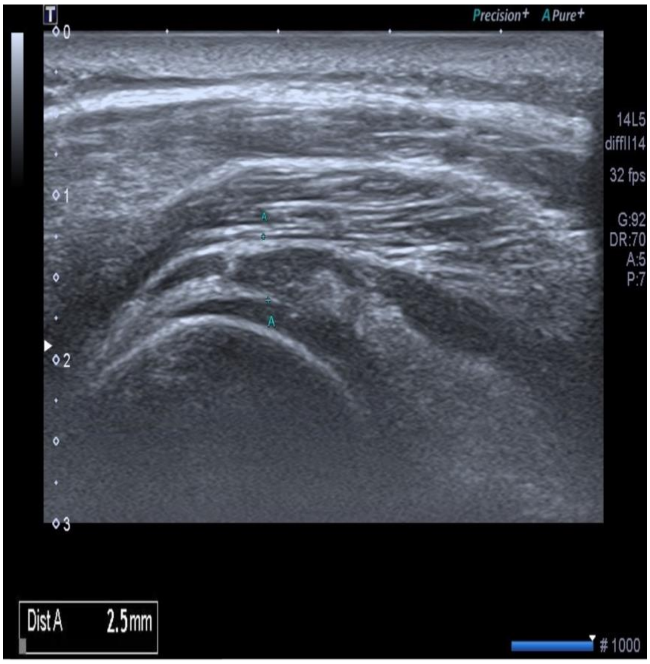

Ave.T1 131.4kPa
SD.T1 55.2kPa

(G)

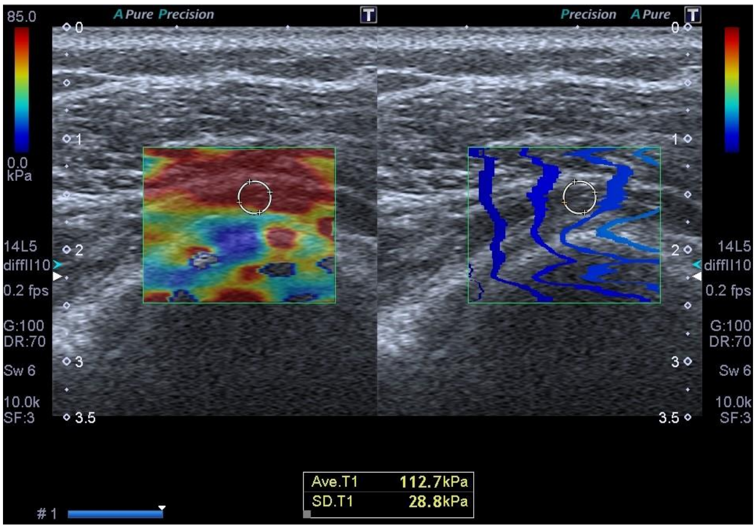

Ave.T1 22.5kPa
SD.T1 11.1kPa

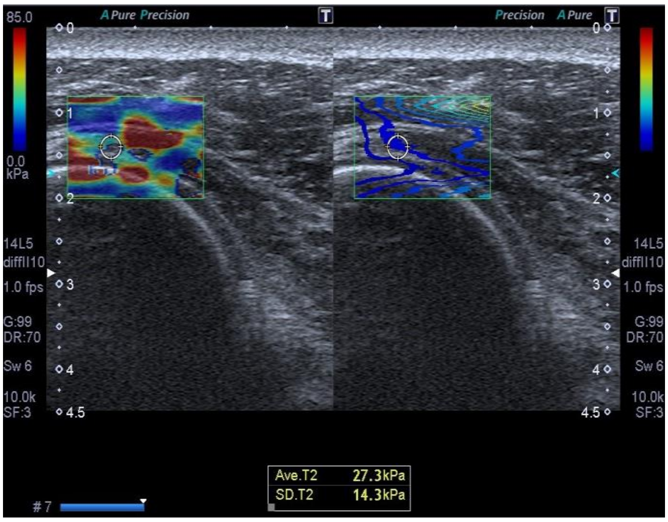
(H)





(M) (N)





(O)

(L)

Figure 4: Ultrasound images of A 50 years old female patient is suffering from left shoulder pain since 8 months diagnosed clinically with stage I frozen shoulder. (A)& (B) B-US images revealed average thickness LT and RT CHL. (C)&(D) SWE images revealed average value stiffness of LT and RT CHL(blue and low velocity=soft) with a ROI of 1.5 mm² circular approximately 2 cm lateral to coracoid process. (E) B-US image revealed thickened LT SSp tendon .(F) B-US images revealed average thickness of RT SSp tendon.(G) SWE image revealed increased stiffness of LT SSp tendon red and high velocity=stiff .(H) SWE image revealed average stiffness value of RT SSp tendon(blue and low velocity=soft).(M) B-US image revealed thickened LT ISp tendon.(N) B-US image revealed average thickness of RT ISp tendon.(L) SWE image revealed increased stiffness of LT ISp tendon red and high velocity=stiff .(O) SWE image revealed average stiffness value of RT ISp tendon(blue and low velocity=soft). ROI of 10 mm² circular, approximately 10 mm medial to greater tuberosity for SSp and ISp tendons SWE.

DISCUSSION

A frozen shoulder was classified as having a VAS score of ≥6 points for stage I, ≤3 for stage II, Ff >100°, Er >10°, and Ir score >3 points for stage III, and <6 points for stage II, Ff >100°, Er >10°, and Ir score >3 points for stage III **[8].**

Eighteen individuals were included in our study (50%) of the patients had a right affected shoulder and (50%) had a left affected shoulder which was not in align with Zhang et al. (124) who had higher number of left sided shoulder affection, In any case, the three stages did not exhibit a substantial age difference, body mass index, sex, or affected shoulder (P >.05), which is comparable to **Zhang et al. [9].**

Our research demonstrates a statistically significant correlation between frozen shoulder phases and clinical data, as patients with stage I frozen shoulder had a higher VAS score and a higher external rotation angle when compared to patients with other stages of frozen shoulder *(P<0.001)*. In contrast, patients with stage III frozen shoulder had a higher forward flexion angle and a higher internal rotation angle when compared to patients with other stages of frozen shoulder *(P<0.001)* which were in consistent with the findings of **Zhang et al [9].**

Lee et al. [10] indicated that the CHL became thicker in patients with frozen shoulder using magnetic resonance arthrography, and **Homsi et al. [11]** showed similar results using B-mode US ,These results are consistent with our findings that there was a significant difference of CHL thickness at the affected shoulder in patient with frozen shoulder in comparison to non-affected shoulder (affected mean 5.03 mm ,non-affected mean 3.33 mm with P < 0.001) .

In our study, the affected side of CHL was substantially thicker than the unaffected side (P<0.001), measuring 6.38 ± 0.59 mm in the frozen phase on the impacted side and 3.57 ± 0.4 mm on the unaffected side. Furthermore there was significant difference in the thickness of CHL in thawing phase (stage III) with the mean thickness of CHL 4.87 ± 0.22 mm (P<0.001) Compared to patients with other stages of frozen shoulder, those with stage Ⅱ had a greater CHL thickness on the affected side. *(P<0.001)*, which align with the findings of **Wada et al. [12]** but stage III was not included in **Wada et al. [12].**

In the three stages of frozen shoulder, we discovered that the affected side's CHL stiffness was not necessarily higher than the healthy side's. McKean et al. found that the CHL on the affected side was thicker and stiffer than the CHL on the healthy side in all of their frozen shoulder patients. However, we discovered that this was only true in stages II (affected CHL mean SWE 211.3 Kpa / non-affected CHL mean SWE 25.5 Kpa, P<0.0012) and stage III (affected CHL mean SWE 91.3 Kpa / non-affected CHL mean SWE 28.5 Kpa, P<0.0012) (figure 2) and the stage II had the higher CHL SWE value among other stages, which were in agreement with **Zhang et al. [9]**.

Our study found no significant difference in the SWE of the CHL between the affected side and the healthy side in stage I (freezing phase) (P > 0.05)**,**which is different from **Zhang et al. [9]**, who reported that the SWE of the CHL on the affected side was lower than that on the healthy side in stage I frozen shoulder. In stage I, there was no discernible difference between the affected side's CHL SWE and the healthy side's (affected CHL SWE 26.6 Kpa / non-affected CHL SWE 25.6 Kpa, P=0.792)**.**

Our study showed statistically significant difference at the thickness of SSP and ISP tendons of the affected shoulder at different stages of frozen shoulder, as patients with stage l frozen shoulder had a higher SSP and ISP tendons thickness when compared to patients with other stages of frozen shoulder (P<0.001) on B-mode US imaging**,** these findings agreed with **Ohya et al. [13]** who found a significant difference at the thickness of SSP tendon in patient with frozen shoulder stage l only (P<0.001) as the study had not include patients in the other stages nor measuring ISP tendon thickness, so our study is considered to be the primary in measuring SSP and ISP tendons thickness in different stages of frozen shoulder .

The SWE values of the SSp and ISp tendons in our study in the freezing phase (stage I) were significantly greater on the affected side than the unaffected side (P <0.0012) which were consistent with the results of **Wada et al. [12]** who found that the SWE values of the SSp and ISp tendons in the freezing phase (stage I) were significantly greater on the affected side than the unaffected side (SSp P <0.05, ISP P <0.05).

In our study ,there were no significant difference in the SWE values of the SSp and ISp tendons between affected and non-affected shoulder in the frozen phase (stage II) and thawing phase (stage III) (SSP P = 0.062, ISP P =0.082, SSP P =0.312 , ISP P=0.072 consequently) which were consistent with the results of **Wada et al. [12]** who found that there were no significant difference in the SWE values of the SSp and ISp tendons between affected and non-affected shoulder in the frozen phase (stage II) ,but **Wada et al. [12]** had not had patients in stage III.

Our study included some limitations; the changes in stiffness with time were unclear as it was a cross-sectional study and the absence of age-based stratification, as previous research [14,15] has indicated that SWE values may increase with age in healthy individual. Future studies should consider a more comprehensive assessment, including multiple measurement points along the mentioned structures.

CONCLUSIONS

At different stages of frozen shoulder, there are differences in the affe cted side's CHL, SSp and ISp tendons thickness and stiffness and its relationship to the shoulder VAS score and range of motion. B-mode ultrasonic shear wave elastography is a simple, cost-effective, and efficient additional technique for diagnosing frozen shoulder. The B-US and SWE can be used to classify patients with frozen shoulder into different stages.

List of abbreviations:

B-US	B mode ultrasound
CHL	coraco-humeral ligament
FS	frozen shoulder
ISp	Infraspinatus
ROI	Region of interest
SSp	Supraspinatous
SWE	shear wave elastography
VAS	visual analogue scale

Conflicts of Interest

The authors report no conflicts of interest.

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