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The Role of Shear Wave Elastography in the Assessment of Lateral Epicondylitis

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ABSTRACT
Background: Lateral epicondylitis (LE) is the most common cause of lateral elbow pain.
Objective: To evaluate the clinical usefulness of shear-wave elastography as an objective method for the assessment of the affected tendons in lateral epicondylitis.
Patients and methods: This cross-sectional study included 35 patients with unilateral lateral epicondylitis for the evaluation of qualitative and quantitative shear-wave elastography (SWE) parameters.
Results: Mean duration of symptoms among the studied group was 7.17±5.6 months. There was a significant difference in hypoechogenicity, swelling, cortical irregularities, and calcification among elbows with LE than those without (97.1 vs 8.6%, 42.9 vs 5.7%, 42.9 vs 0%, and 14.3 vs 0% respectively). The mean velocity and stiffness in affected elbows were (2.3±0.23 and 16.9± 5.7 m/s) compared to the non-affected side (6.1±1.07 kPa and 112.9± 33.4 kPa) (P=0.001). SWE had the highest sensitivity (97.2% vs 97.1%) and specificity (98% vs 98.5) for velocity and stiffness, respectively. There was a highly statistically significant decreased pain severity (VAS) scale after treatment than before (P=0.001).
Conclusion: In patients with lateral epicondylitis, SWE can be utilised as a method with excellent repeatability and appropriate diagnostic accuracy for assessment and monitoring the therapy impact.
Keywords: Shear-Wave Elastography, Lateral Epicondylitis, Grey Scale Ultrasound.

INTRODUCTION

The most typical reason for lateral elbow discomfort is LE. In the general community, it affects 1-3% of people [(1)]. The recurrent microtrauma experienced during supination of the forearm and dorsiflexion of the wrist that causes tendon degeneration and collagen fibre rupture that triggers a reparative reaction is the pathophysiology of LE. The common extensor origin becomes weaker and is at a higher risk of rupture in chronic illness due to a cycle of tendon degeneration and repair [(2)].

The VAS and clinical examination are the main sources of information used to make the LE diagnosis. The use of diagnostic imaging modalities such as real-time sonoelastography, MRI, and conventional US for confirmation is often saved for cases with unusual presentations or those who don't respond to conservative therapy [(3)].

Imaging methods are crucial for determining the severity of LE, measuring the degree of damage, formulating treatment plans, and directing surgery because they give pertinent information on the physiopathology of the disease process. Although grey scale ultrasonography and MRI have always been seen as reliable alternatives for assessing LE, the exorbitant cost of MRI, lengthy examination time, non-dynamic nature of the examination, need for experienced reader, and other known contraindications i.e., claustrophobia and incompatibility with certain metallic prosthesis, greatly limit its feasibility in all cases [(3)].

Currently, advanced US techniques are increasingly being used in the diagnosis of LE due its relatively low cost, non-invasive nature, and added dynamic features. While grey-scale US findings in LE are characterized by edema and decreased echogenicity with or without thickening of the common extensor tendon (CET), epicondylar cortical irregularity or spur formation, and increased Doppler activity; such findings are only based on subjective visual assessment [(4-5)]. However, real-time elastography, was employed to assess the mechanical characteristics of tendons, both qualitatively and quantitative assessments of tendon elasticity can be achieved [(6)].

One of the two primary elastography techniques is shear wave speed (SWS), which can be produced in numerous ways. One such technique calculates the SWS at various depths inside the tissue using numerous focused push beams that produce shear waves and ultra-high frame rate ultrasound imaging of the ensuing shear wave propagation[(7)]. This method yields quantitative maps of elasticity or shear wave velocity in addition to qualitative color-coded elastograms. The SWE of the CET in LE, however, has hardly ever been studied, and the majority of research have only assessed the CET using real-time strain elastography [(8)].

Therefore, in order to determine whether shear elastography can be used to objectively diagnose LE, this study aimed to assess the CET elasticity in patients with unilateral LE by quantitative and qualitative methods and compare findings with the contralateral non affected side.

PATIENTS AND METHODS

This cross-sectional study was conducted over a 6-month period. A total of 35 patients were referred from the orthopedic clinic to the Radiodiagnosis Department for imaging at the Ultrasonography Unit after being evaluated by an orthopedic surgeon with clinical symptoms suggesting unilateral LE at Zagazig University Hospitals.

Inclusion criteria:

Patients with unilateral elbow pain were assessed

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by the orthopedic surgeon. Any age group was included and both sexes. Tenderness on the lateral epicondyle and soreness made worse by extension and twist that spread from the lateral forearm to the palm are signs of LE.

Exclusion criteria:

Patients with known history of bilateral LE, previous elbow fracture and previous elbow surgery.

Clinical assessment:

All patients were subjected to full history taking, complete clinical examination, and imaging including conventional grey scale B-mode sonography and SWE.

(i) Grey scale ultrasound (GSU):

First, to reduce anisotropy, longitudinal pictures of the CET were taken, covering the whole tendon origin from the anterior edge to the posterior edge. We assessed the edema, lateral epicondyle cortical irregularity, hypoechogenicity, calcification, and tendon rupture affecting the CET.

(ii) Shear wave elastography (SWE):

Following GSU, SWE was repeated in the same field of vision. Using a rectangular, color-coded box positioned in the CET at the lateral epicondyle, images were taken from the CET. The shear modules are represented by colour codes, with blue denoting firm consistency and red denoting soft consistency. Several ROIs were drawn and several measurements were obtained followed by calculation of average value of repeated measurements. After the ROI was drawn, SWE parameters [mean area, mean velocity in meters per second (m/s), and stiffness in kilopascals (kPa)] for each ROI were automatically calculated by the ultrasound machine software.

Ethical Consideration:

Zagazig Medical Ethics Committee of the Zagazig Faculty of Medicine gave its approval to this study. All participants gave written consent after receiving all information. The Helsinki Declaration was followed throughout the study's conduct.

Statistical analysis:

Data were first analysed with Microsoft Excel before being loaded into SPSS V. 20.0. Quantitative data are represented by mean±SD, whereas qualitative data are expressed as number and percentage. P value less than 0.05 was regarded as significant.

RESULTS

A total of 35 patients with 70 examined elbows were included in this study. Average age was 44.1± 6.1 years. Of the patient population, female to male ratio was 1.18:1. Regarding patient occupation, lateral epicondylitis was commonly associated with manual work. In our study, 14 cases (40.0%) were housewives, 7 cases (20.0%) were workers, and 5 cases (14.3%) were carpenters **(Table 1)**.

Table (1): Demographic data among the studied cases

Variables		***The studied group No= 35 (%)***
***Age** (years)*	Mean ± SD	44.1± 6.1
	Median	45
	(Range)	(27-55)
Sex	Male	16 (45.7%)
	Female	19 (54.3%)
Occupation	Doctor	1 (2.9%)
	Nurse	2 (5.7%)
	Teacher	1 (2.9%)
	Worker	7 (20.0%)
	Farmer	1 (2.9%)
	Driver	1 (2.9%)
	Housewife	14 (40.0%)
	Waiter	1 (2.9%)
	Carpenter	5 (14.3%)
	Babysitter	1 (2.9%)
	Porter	1 (2.9%)

All patients presented with lateral elbow pain and tenderness induced by pressure on the lateral epicondyle of the affected elbow side. Regarding the pain level on (VAS), a score of 5 was the most common (65.7%). Mean duration of symptoms among the studied group was 7.17± 5.6 months. More than half of patients had less than one-year duration of symptoms (68.6%). Symptoms were more often on the right side. Most patients (94.3%) had right dominant hand **(Table 2)**.

Table (2): Clinical data among the studied cases:

Variables	**The studied group No= 35 (%)**
Symptoms duration	
less than one year	24 (68.6%)
one year	8 (22.9%)
18 months	2 (5.7%)
Two years	1 (2.9%)
Symptom severity (VAS)	
Score 4	5 (14.3%)
Score 5	23 (65.7%)
Score 6	7 (20.0%)
The affected side	
Right	30 (85.7%)
Left	5 (14.3%)
The dominant hand	
Right	33 (94.3%)
Left	2 (5.7%)

On comparison of affected versus healthy CETs, a statistically significant difference was found regarding the laterality of affected side, where the right side was more commonly affected than the left with a 20.2 odds ratio **(Table 3)**. There was a significant difference with increased percentages of hypoechogenicity, swelling, cortical irregularities, and calcification among elbows with LE than those without. Common extensor tears were more frequent among the elbows with LE than without but this difference wasn't statistically significant **(Figure 1)**.

Table (3): Comparison between Elbow with LE and Elbow without pain regarding the affected side

Variables	Elbow with LE No= 35 (%)	Elbow without pain No=35 (%)	Test	P-value	Odds 95% CI
The affected side			χ^2 27.9	**0.001****	20.2 (5.9-69.4)
Right	30 (85.7%)	5 (14.3%)			
Left	5 (14.3%)	30 (85.7%)			

*** Highly statistically significant difference (p<0.001)*

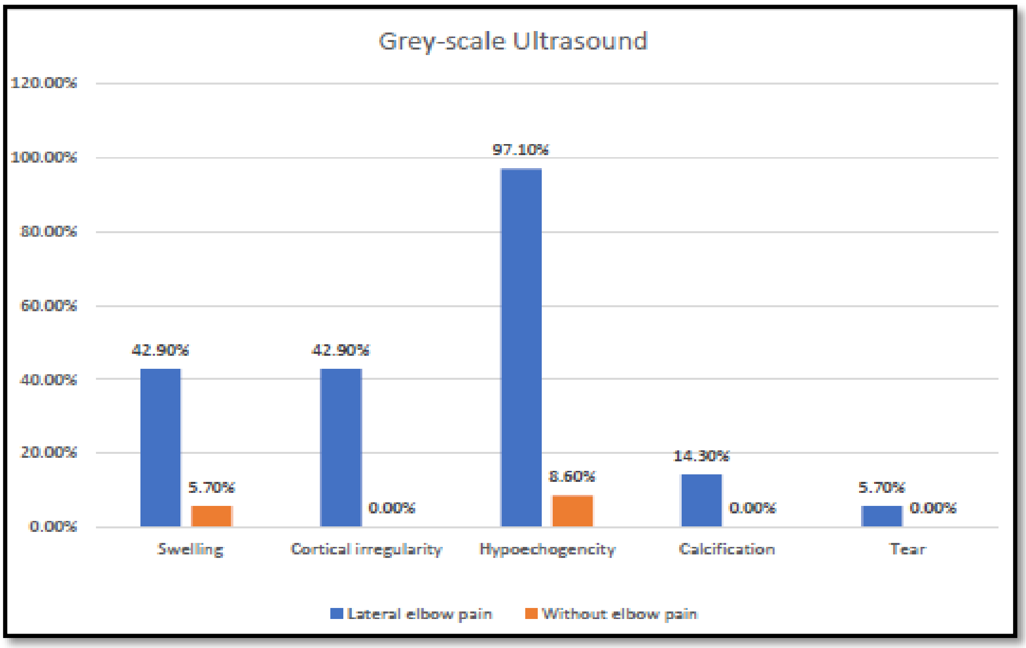

Figure (1): Grey-scale ultrasound characteristics among the studied groups.

There was a statistically significant decrease in velocity and stiffness among the elbows with LE than those without. The mean velocity and stiffness in affected elbows were significantly less than the non-affected side. Regarding color scale, there was a visually noticeable difference, where all elbows with LE had blue and blue to green color while most elbows without pain (80.0%) had a red color **(Table 4)**.

Table (4): Comparison between elbow with LE and elbow without pain regarding Shear wave elastography

Variables	Elbow with LE No= 35 (%) Mean ± SD Median (Range)	Elbow without pain No=35 (%) Mean ± SD Median (Range)	Paired T-test	P-value
Velocity (m/s)	**2.3 ± 0.23 2.4 (1.03-2.95)**	**6.1 ± 1.07 6.1 (3.66-7.77)**	**19.4**	**0.001****
Stiffness (Kilopascal)	**16.9 ± 5.7 17.3 (3.15-26.5)**	**112.9 ± 33.4 114.1 (40.75-170.3)**	**16.7**	**0.001****
Color			**χ^2=4.9**	**0.001****
Blue and blue to green	**35 (100.0%)**	**0 (0.0%)**		
Red	**0 (0.0%)**	**28 (80.0%)**		
Red to yellow	**0 (0.0%)**	**6 (17.1%)**		
Yellow to green	**0 (0.0%)**	**1 (2.9%)**		

*χ^2= Chi-square test, ** Highly statistically significant difference (p<0.001).*

SWE had the highest sensitivity, specificity, positive predictive value, and negative predictive value for velocity and stiffness. These values were higher than grey scale ultrasound, thus more superior was in differentiating LE from contralateral healthy side **(Table 5)**. SWE had the highest diagnostic performance [AUC =0.96, 95% CI (0.91%-1.0%)] followed by stiffness [AUC =0.95, 95% CI (0.89%-1.0%)], then hypoechogenicity [AUC =0.94, 95% CI (0.86%-1.0%)], swelling [AUC =0.81, 95% CI (0.69%-0.91%)], cortical irregularity [AUC =0.69, 95% CI (0.57%-0.82%)], and lastly calcification [AUC =0.57, 95% CI (0.43%-0.71%)] **(Figure 2)**.

Table (5): The diagnostic performance of both grey scale Ultrasound and SWE:

Variables	sensitivity	Specificity	PVP	PVN
Swelling	74.3%	72.0%	72.6%	73.7%
Cortical irregularity	57.1%	68.6%	64.5%	61.5%
Hypoechogenicity	91,8%	96%	97%	91,4%
Calcification	45.7%	62.9%	55.2%	53.7%
Velocity	97.1%	98.0%	97.9%	94.5%
Stiffness	97.2%	98.5%	98.4%	97.3%

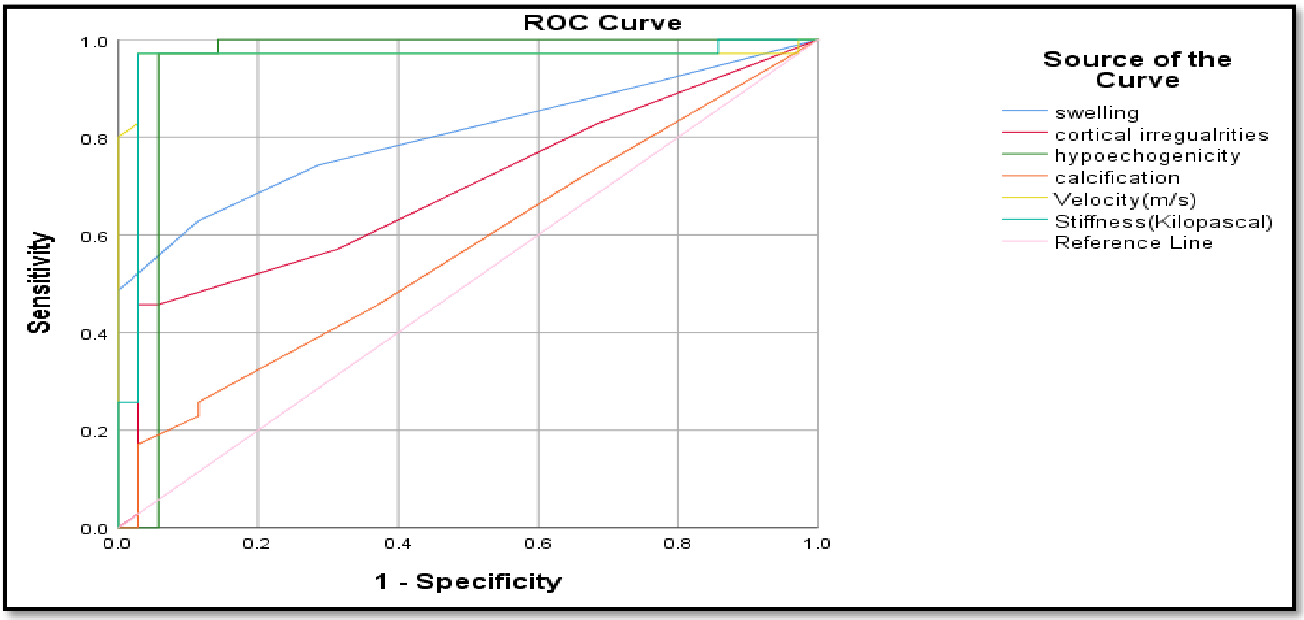

Figure (2): ROC curve for the diagnostic performance of combined grey-scale ultrasound and SWE to discriminate elbow with LE and elbow without pain.

Approximately 15 cases came for follow up after conservative therapy. The mean pain severity (VAS) was reduced after treatment. Regarding velocity and stiffness, there was a highly statistically significant increase after treatment than before. The mean velocity and stiffness increased significantly after treatment, which indicates that these parameters can be used as prognostic factors for the follow up of elbow with LE treatment **(Table 6).**

Table (6): Comparison of SWE and symptoms severity before and after treatment among elbows with LE group

Variables	Elbow With LE Before Treatment Mean ± SD Median (Range)	Elbow With LE After Treatment Mean ± SD Median (Range)	Paired T-Test	P-Value
Pain Severity (VAS)	4.9 ± 0.59 5 (4-6)	1.8 ± 0.86 2 (0-3)	12.3	0.001 **
Velocity (M/S)	2.3 ± 0.23 2.4 (1.03-2.95)	4.8 ± 0.8 4.8 (3.25-6.08)	-11.3	0.001 **
Stiffness (Kilopascal)	16.9 ± 5.1 17.3 (3.15-26.5)	72.8 ± 14.2 114.1 (31.8-113.0)	-9.8	0.001 **

*** Highly statistically significant difference (p<0.001)*

A case of 48 years old male complaining of right lateral elbow pain extending to the dorsum of the forearm for about three months. Pain score according to VAS was 6 and it was reduced after therapy to score 3. Grey scale ultrasound scan for pre-therapy revealed thickening of the CET, associated with area of focal hypoechogenicity. SWE showed pre-therapy quantitative measures with average velocity was 2.45 m/s and average stiffness was 16.45 kPa. Regarding post-therapy; grey scale ultrasound scan revealed decreased in the areas of focal hypoechogenicity with reappearance of normal fibrillar pattern of the CET. SWE showed quantitative measures increased as follows; Average velocity = 3.24 m/s and average stiffness= 31.6 kPa **(Figure 3)**.

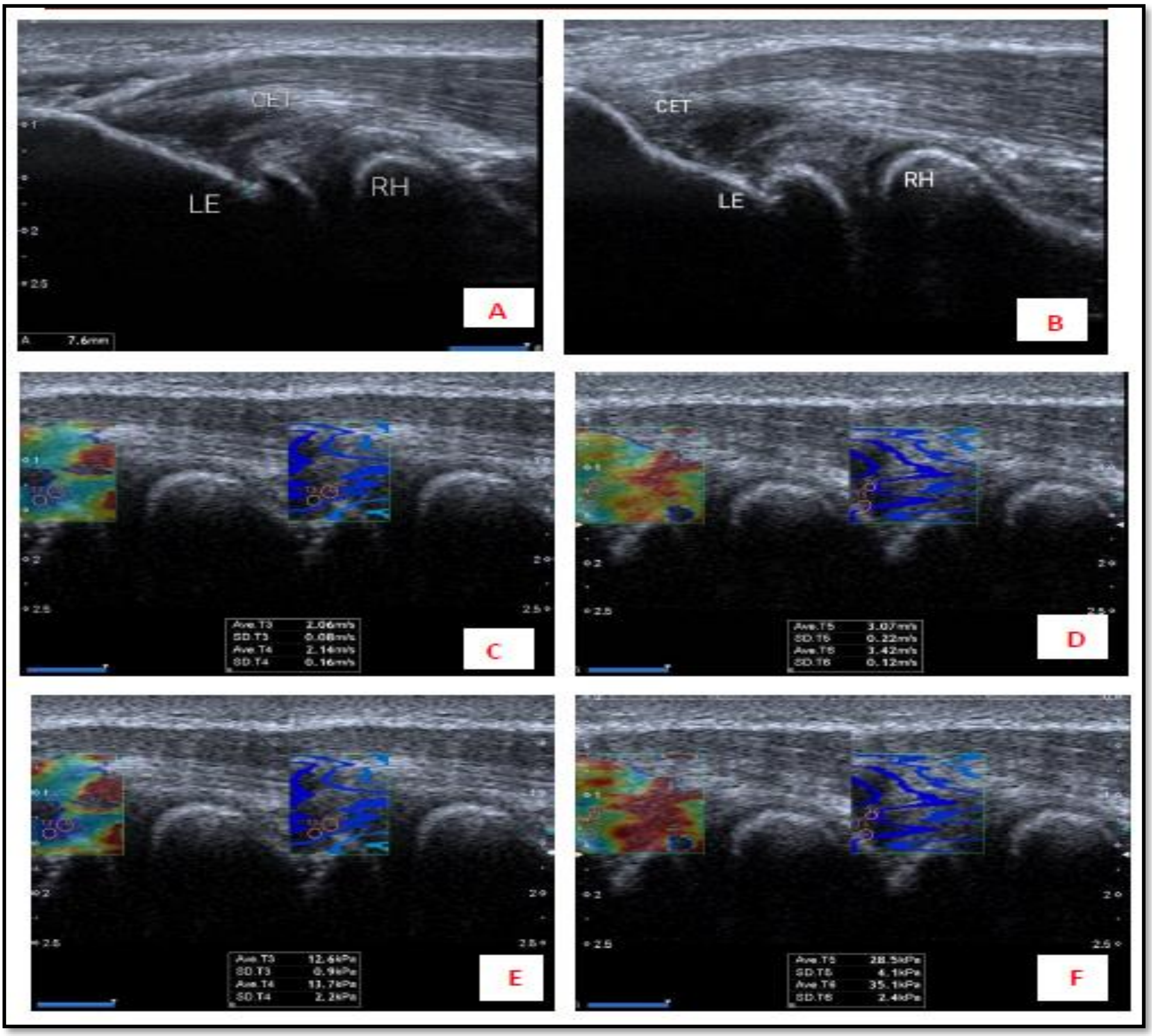

Figure (3): 48 years old male with right lateral elbow pain showing **(A)** Grey scale US scan pre-therapy revealed thickening of the CET, and **(B)** Grey scale US scan post-therapy revealed decreased in the areas of focal hypoechogenicity. SWE color maps displayed a blue to green color indicating soft consistency; **(C)** revealed pre-therapy average velocity was 2.45 m/s, **(D)** pre-therapy average stiffness was 16.45 kPa. SWE showing color maps displayed changing the blue to green colour into yellow to green indicating intermediate consistency revealed **(E)** post-therapy average velocity was 3.24 m/s, and **(F)** post-therapy average stiffness was 31.6 kPa.

DISCUSSION

Men and women are equally affected by LE, which is widespread in adults in their middle years (40–45) and those who work physical labour occupations [(9)]. Less than 10% of patients are tennis players, and only 50% of tennis players experience elbow discomfort, of which 75% is typical of real "tennis elbow" [(1)].

SWE is known to be a more reproductible quantitative technique in the evaluation of lateral epicondylitis [(10)]. In our study, we aimed to evaluate the clinical usefulness of shear wave elastography as an objective method for the assessment of tendons affected by lateral epicondylitis. To achieve this, we compared qualitative parameters of LE on both grey scale shear wave elastography and quantitative parameters of shear wave elastography among diseased versus healthy elbows. Furthermore, we compared the pre and post treatment changes in quantitative SWE parameters in patients who underwent non-surgical management.

In our study, we enrolled 35 patients (16 males and 19 females with age range: 27–55 years, and mean age= 44.1±6.1 SD). After exclusion of bilateral pathologies and elbows with post-surgical changes, a total 70 elbows with suspected clinical diagnosis of unilateral LE were chosen for further imaging. Similar findings were found by **Sanders *et al.*[(11)]** in which lateral epicondylitis was higher in incidence among females and individuals aged 40 to 49 years. Regarding patient occupation, lateral epicondylitis was commonly associated with manual work. 14 cases (40.0%) were housewives, 7 cases (20.0%) were workers, and 5 cases (14.3%) were carpenters.

Clinically, all patients presented with unilateral elbow pain, which was suspected to be LE after evaluation by an orthopedic surgeon. We noted that most patients had right hand dominance (94%) and mostly presented with right elbow pain (86%). Although this is expected, a recent study by **Elsayed *et al.* [(12)]** reported similar findings of right-hand dominance and right sided symptoms (86 and 81%, respectively). All patients in our study were evaluated for initial pain levels using a visual analog scale (VAS). In our study, the most common VAS score was 5 (65.7%). This agreed with findings by **Taljanovic *et al.* [(13)]** in which VAS score of 5 was the most common (32%).

Main shear wave elastography findings in our study were a visually noticeable difference in qualitative findings and a statistically significant difference in quantitative findings among symptomatic versus asymptomatic elbows with excellent diagnostic performance, which was superior to all grey scale parameters. On qualitative color scale, all elbows with LE had a blue or blue to green color, while most elbows without pain (80.0%) had a red color. Similar color map findings were reported by **Hong *et al.* [(10)].**

Quantitative parameters of SWE showed a statistically significant difference in velocity and stiffness among the elbows with LE than those without. Mean velocity and stiffness values were significantly lower in affected elbows compared to the non-affected side (p-value=0.001).

This finding suggests that SWE is an effective approach for identifying LE. In a prior investigation, **Zhu *et al.* [(1)]** found that there were substantial mean differences in stiffness and SWV between the patient's symptomatic and asymptomatic humeral epicondylar tendons. **Hong *et al.*[(10)]** showed a significant decrease in velocity and stiffness among the elbows with LE than those without and between the affected versus contralateral healthy elbow of the same patient (P <0.001).

Additionally, a high diagnostic performance was found for SWE. Quantitative SWE parameters showed the highest sensitivity (97.2% and 97.1%) and specificity (98% and 98.5%), for velocity and stiffness, respectively. In comparison, these values were higher than all GSU parameters, where sensitivities and specificities were 91.8 and 96%, 74.3 and 72.0%, 57.1% and 68.6%, and 45.7% and 62.9% for hypoechogenicity, swelling, cortical irregularity, and calcifications, respectively. Thus, SWE was more superior diagnostic technique in differentiating symptomatic elbows with LE from contralateral healthy side. Similar results were found by **Hong *et al.*[(10)]** and **Bang *et al.*[(14)].** Another study conducted by **Kocyigit *et al.*[(8)]** demonstrated that real-time sono-elastography findings were superior to B-mode US findings in differentiating healthy from diseased elbows.

Area under the curve (AUC) further confirmed this superiority in diagnostic performance. AUC values for quantitative SWE parameters in our study were 0.96 and 0.95 with a 95% CI of 0.91%-1.0% and 0.89%-1.0% for velocity and stiffness, respectively. This agreed with AUC findings by **Zhu *et al.* [(1)]** in which AUC value for shear wave velocity was 0.973 with a 95% CI = 0.949–0.997 and **Elsayed *et al.* [(12)]** revealed that SWE gave the highest diagnostic accuracy with the largest area under the curve measuring 0.973 with a 95% CI = 0.947–1.000.

Furthermore, **Hong *et al.*[(10)]** reported AUC values of 0.995 and 0.996 with a 95% CI = 0.948–1.000 and 0.951–1.000 for velocity and stiffness, respectively, further confirming the consistent finding of higher diagnostic performances for SWE parameters in confirming a diagnosis of LE. Both stiffness and shear wave velocity on SWE showed superior diagnostic performance compared to hypoechogenicity on GSU. In our study AUC values were 0.96 and 0.95 versus 0.94 for SWV and stiffness parameters on SWE versus hypoechogenicity on GSU, respectively.

Bang *et al.*[(14)] recently reported excellent diagnostic performance and AUC values for mean SWV similar to those in our study, however, this study was performed on the medial epicondyle. Nevertheless, the medial epicondyle has similar anatomical structure to the lateral epicondyle with a similar tendon structure, so similar findings can be expected.

In our study the SWV and stiffness were significantly higher in patients following non-operative management of LE (p<0.001). The mean velocity and stiffness increased from 2.3±0.23 m/s and 16.9±5.1 kPa before therapy to 4.8±0.8 m/s and 72.8±14.2 kPa following therapy. However, shear wave velocity and stiffness values did not return to healthy levels. This may be attributed to the individual difference in treatment effect and short treatment duration. To the best of our knowledge, few studies have evaluated the contribution of shear wave elastography in the post therapeutic follow-up of cases with lateral epicondylitis. Nevertheless, our results are in accordance with studies conducted by **Zhu *et al.***[1] and **Elsayed *et al.*** [12], which demonstrated that SWE could not only help establish a diagnosis of the lateral epicondylitis but could also help follow up the response to therapy.

Main grey scale ultrasound findings in our study were statistically significant increase in percentages of hypoechogenicity, swelling, cortical irregularities, and calcification among elbows with LE than those without (p-values = 0.001, 0.001, 0.001, and 0.02, respectively). In our study, the percentage of common extensor tears were higher among elbows with LE (5.7%) than those without (0 %). However, this difference was not statistically significant (p=0.4). These findings agreed with **Hong *et al.***[10] who reported increased percentages of hypoechogenicity, cortical irregularities, and calcification among elbows with LE than those without.

Regarding the diagnostic performance of GSU, sensitivities and specificities were 91.8 and 96% for hypoechogenicity, 74.3 and 72.0% for swelling, 57.1% and 68.6% for cortical irregularity, and 45.7% and 62.9% for calcifications. Mean AUC values in our study were 0.94 for hypoechogenicity, 0.81 for swelling, 0.69 for cortical irregularity, and 0.57 for calcification with 95% CIs of 0.86-1.0%, 0.69-0.91%, 0.57-0.82%, and 0.43-0.71%, respectively. **Hong *et al.***[10] stated similar agreements with our study regarding mean AUC values, which were 0.931 (95% CI: 0.856–0.974) for hypoechogenicity, 0.568 (95% CI: 0.458–0.674) for cortical irregularity, and 0.738 (95% CI: 0.633–0.827) for calcifications.

Another interesting finding was that specific values of SWE were somewhat different among various studies. In our study, the mean velocity and stiffness in affected elbows were 2.3±0.23 m/s and 16.9±5.7 kPa compared to the non-affected side 6.1±1.07 m/s and 112.9±33.4 kPa respectively. That is somewhat different from **Hong *et al.***[10] who showed the mean velocity and stiffness of 1.89±0.38 m/s and 11.69±4.83 kPa in affected elbows when compared to the non-affected side (3.47±0.42 m/s and 37.32±7.94 kPa, respectively). Additionally, **Zhu *et al.***[1] showed that mean velocity in affected elbows were 9.6±1.4 m/s compared to the non-affected side (13.6±1.1 m/s).

We think that the patient's postural irregularities are what caused this disparity due to the possibility of tissue changes and SWV fluctuation brought on by changes in joint position. Also, different settings of ultrasound machines and SWE protocols make cutoff values between what is considered normal versus abnormal vendor specific.

CONCLUSION

In patients with lateral epicondylitis, SWE can be utilised as a method with excellent repeatability and appropriate diagnostic accuracy for assessment and monitoring the therapy impact.

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Competing interests: Nil.

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