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# Assessment of carpal tunnel syndrome by grey scale ultrasound and elastography

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**Abstract**
**Background:** Ultrasound (US) elastography is an innovative imaging technique designed to assess the stiffness of the tissues. Sonoelastography is an US-based technique that quantifies the elasticity of the tissues. The objective of this work was to assess grey scale and elastography US-imaging results in individuals with carpal tunnel syndrome (CTS) relative to nerve conduction investigations and clinical assessments.
**Methods:** This prospective had been conducted on 30 patients aging from 20 to 60 years old, both sexes, with symptoms of CTS, electromyography reveals changes in the median nerve sensory conduction velocities and a distal motor latency prolongation. Each participant underwent elastography ultrasound.
**Results:** Cross-sectional area (CSA), strain ratio, slightly reduced or decreased echogenicity relative to surrounding tissue and mobility had been significantly greater in CTS wrists than normal wrists ($p$<0.001). Carotid artery stenting and strain ratio was significantly reduced in mild CTS wrists than moderate and severe CTS wrists ($p$<0.05). Strain ratio was significantly lower in moderate CTS wrists contrasted to severe CTS wrists ($p$<0.001). CSA and strain ratio is a significant predictor of CTS respectively (area under the curve: 0.882 and 0.928, $p$<0.001). At a cutoff value of >11 and >1.7, it can predict CTS with a sensitivity of 74% and 86% specificity of 88% and 94%.
**Conclusions:** Alongside electrophysiological studies, grey scale ultrasound and elastography ultrasound significantly enhanced diagnostic accuracy in the evaluation of CTS. They are essential instruments for the diagnosis and categorization of CTS.

**Keywords:** Carpal tunnel syndrome, grey scale ultrasound, elastography, central sleep apnea

## Introduction

Carpal tunnel syndrome (CTS) is the most prevalent upper limb compression neuropathy. It constitutes approximately 90% of all entrapment neuropathies. CTS results from the entrapment of the median nerve as it traverses the carpal tunnel at the wrist level [1].

CTS is prevalent as an occupational health issue, particularly among individuals engaged in tasks involving significant pressure or force, or the usage of repetitive vibrating tools. CTS has an ambiguous, complex aetiology. Multiple causal variables may influence the median nerve inside the carpal tunnel [2].

Various clinical exams have been included as elements in the clinical diagnosis of CTS; yet, their accuracy remains contentious. The conventional symptoms of CTS consist of pain, tingling and numbness in the regions innervated by the median nerve, however numbness may extend to involve all fingers. Symptoms often worsen throughout the night and may disturb individuals' sleep. To reduce symptom severity, patients often perform a wrist flick, like the action of shaking a thermometer (flick sign). In instances of CTS, paresthesia and pain may radiate to the shoulder, elbow, and forearm. In instances of significant CTS, thenar muscles atrophy often results in diminished hand grip strength [3].

While electrodiagnostic tests (EDTs) are recognized as appropriate diagnostic tools for CTS, their application is regarded as intrusive and has a false-negative rate of around 20% [4]. Since 1993, US assessment has been a diagnostic modality for individuals with CTS [5]. Ultrasound is regarded as an efficient tool for the diagnosis of CTS, being widely accessible, non-invasive, and requiring a little time for examination [6].

US elastography (USE) is an innovative imaging technique developed to evaluate the stiffness of the tissues.

Sonoelastography is an US-based tool that quantifies elasticity of the tissues. This approach demonstrates the comparative strain of a structure in relation to the adjacent tissue. The foundation of elastography relies on the application of light, repetitive pressure (compression and decompression) via a probe positioned perpendicularly to the lesion. The elastogram quantifies displacement of tissues resulting from the movements of the probe, shown in a color-coded map. Rigid tissues have less displacement relative to the adjacent connective tissue. Currently, it is frequently employed for distinguishing between benign and malignant breast tumors and thyroid nodules [7].

Ultrasound elastography may provide valuable insights into the anatomical characteristics of nerves and tendons [8].

The objective of this work was to assess grey scale and elastography US imaging results in individuals with CTS, in relation to nerve conduction investigations and clinical assessments.

## Patients and Methods

This prospective study had been conducted on 30 subjects aging 20 to 60 years old, both genders, with symptoms of CTS, electromyography (EMG) reveals changes in the median nerve sensory conduction velocities and a distal motor latency prolongation. The work had been performed from 2020 to 2021 following approval from the Ethics Committee Tanta University Hospitals, Tanta, Egypt. Each subject provided well-informed written consent.

Criteria for exclusion had been patients with previous trauma or surgery of the wrist, polyneuropathy, neuropathies owing to diabetes mellitus (DM), chronic renal failure, hypothyroidism, pregnancies, recurrent cases, previous corticosteroid injection and pregnant or 3 months postpartum.

Each subject had been exposed to complete taking of history, clinical examinations, laboratory tests [Blood and urine glucose level to exclude DM] and radiological investigation.

## Imaging techniques

The examinations of each participant consisted of grey scale and elastography US by the same operator. Grey scale and elastography US had been conducted utilising a real time US (Toshiba Aplio500). For each median nerve, grey scale images had been obtained initially. Subsequently, switching the instrument to elastography mode, use the same probe for a further 1-2 minutes for assessing the median nerve at the pisiform by providing mild repeated compression with the portable transducer over the region of interest, while the patient remains in the same posture.

The sonographic diagnostic criteria of CTS include: Flattening of distal nerve and enlargement of proximal nerve relative to the flexor retinaculum, with a CSA $\geq$ 9 mm, are diagnostic for CTS. The median nerve CSA was assessed using ultrasound at the pisiform bone level [9].

Echogenicity is classified as "normal" when numerous fascicles are identifiable, "slightly reduced" when two or fewer fascicles are seen, and "decreased" when no fascicles are observed. The mobility is classified as "normal" if the nerve exhibits deep movement during flexion of finger and wrist, "slightly reduced" if the nerve barely moves side-to-side, and "decreased" if it remains stationary and exclusion of any anatomical variation of the median nerve and other pathological causes.

## Elastography image

Evaluated via visual inspections to ascertain the elastographic pattern shown by the colour map: hard tendon fibers (blue), moderate softening (green and yellow), and significant softening (red). The strain ratio was determined through contrasting the median nerve to the surrounding adipose tissue. The first region of interest (ROI) release of information (strain R) was positioned in adipose tissue as a reference, while the subsequent ROI (strain T) was situated in the median nerve as the target tissue. The strain ratio (strain R/strain T) was computed automatically via the US device. The measures to maintain participant privacy and data confidentiality are as follows: A code number was assigned to each patient, while their name and address were stored in a designated file. The patients' identities were concealed throughout study, and the findings were utilized only for scientific purposes, prohibiting any alternative applications.

## Statistical analysis

Statistical analysis had been performed employing SPSS v26 (IBM Inc., Chicago, IL, USA). Quantitative factors had been displayed as mean and standard deviation (SD) and contrasted among both groups employing unpaired Student's t-test. Qualitative factors had been displayed as frequencies and percentages (%) and analysed employing the Chi-square or Fisher's exact test when appropriate. A two-tailed P value $< 0.05$ was considered statistically significant.

## Results

Demographic data and features of the disease were enumerated in this table. Table 1.

**Table 1:** Demographic data and disease characteristics of the study participants

| | | **N=30** |
|---|---|---|
| **Age (years)** | | 44.13±8.97 |
| Sex | Male | 13 (43.0%) |
| | Female | 17 (57.0%) |
| Predominant hand | Right | 26 (87.0%) |
| | Left | 4 (13.0%) |
| Occupation | Housewives | 9 (30.0%) |
| | Desk jobs | 8 (26.67%) |
| | Factory workers | 10 (33.33%) |
| | Health care workers | 3 (10.0%) |
| Total wrists (n =60) | Right wrist affection | 25 (83.33%) |
| | Left wrist affection | 18 (60.0%) |
| | Normal wrist | 17 (56.67%) |
| Bilateral affection | Right | 13 (43.33%) |
| | Left | 13 (43.33%) |
| Unilateral affection | Right | 12 (40.0%) |
| | Left | 5 (16.67%) |
| Duration of symptoms (months) | | 14.2±13.71 |
| Severity of symptoms | Mild | 9 (30.0%) |
| | Moderate | 20 (67.0%) |
| | Severe | 14 (47.0%) |

**Data are presented as mean ± SD or frequency (%)**

As regards the grey scale and elastography US outcomes in the study participants, CSA, strain ratio. Slightly reduced or decreased echogenicity relative to surrounding tissue and mobility had been significantly greater in CTS wrists than normal wrists ($p<0.001$). Table 2.

**Table 2:** Greyscale US and elastography outcomes in the study participants

| | | Normal wrists (n =17) | CTS wrists (n =43) | P |
|---|---|---|---|---|
| CSA (mm²) | | 8.12±2.9 | 13.48±3.7 | <0.001* |
| Strain ratio | | 1.17±0.47 | 2.73±1.02 | <0.001* |
| Echogenicity | Normal | 17(100%) | 0(0.0%) | <0.001* |
| | Slightly reduced | 0(0.0%) | 25(58.14%) | |
| | Decreased | 0(0.0%) | 18(41.86%) | |
| Mobility | Normal | 14(82.35%) | 0(0.0%) | <0.001* |
| | Slightly reduced | 3(17.65%) | 14(32.56%) | |
| | Decreased | 0(0.0%) | 29(67.44%) | |

Data are presented as mean ± SD or frequency (%). * Significant p value < 0.05. US: Ultrasound, CTS: Carpal tunnel syndrome, CSA: Cross-sectional area

CAS and strain ratio was significantly lower in mild CTS wrists contrasted to moderate and severe CTS wrists ($p<0.05$) but no significant difference in CAS existed among moderate and severe CTS wrists and strain ratio was significantly lower in moderate CTS wrists than severe CTS wrists ($p<0.001$). Table 3.

**Table 3:** Greyscale US and elastography outcomes in CTS wrists

| | Mild CTS (n =9) | Moderate CTS (n =20) | Severe CTS (n =14) | P |
|---|---|---|---|---|
| CSA (mm²) | 10.19±2.88 | 13.52±3.43 | 15.53±3.14 | 0.002* |
| | | | | P1: 0.037* |
| | | | | P2: 0.001* |
| | | | | P3:0.188 |
| Strain ratio | 1.44±0.41 | 2.46±0.34 | 3.94±0.49 | <0.001* |
| | | | | P1: <0.001* |
| | | | | P2: <0.001* |
| | | | | P3: <0.001* |

Data are presented as mean ± SD. * significant p value < 0.05. US: Ultrasound, CTS: Carpal tunnel syndrome, CSA: Cross-sectional area, P1: Significance between mild and moderate CTS, P2: Significance between mild and moderate CTS, P3: Significance between moderate and severe CTS.

CSA and strain ratio is a significant predictor of CTS respectively (AUC: 0.882 and 0.928, $p<0.001$). At a cutoff value of >11 and >1.7, it can predict CTS with a sensitivity of 74% and 86% specificity of 88% and 94%, PPV of 94% and97% and NPV of 58% and 72%. Figure 1.

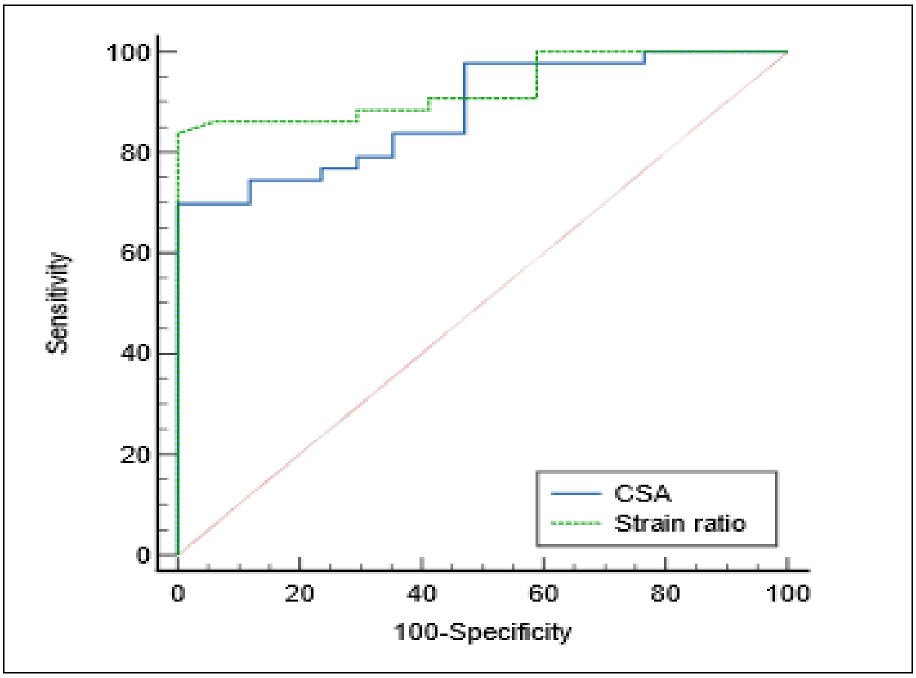
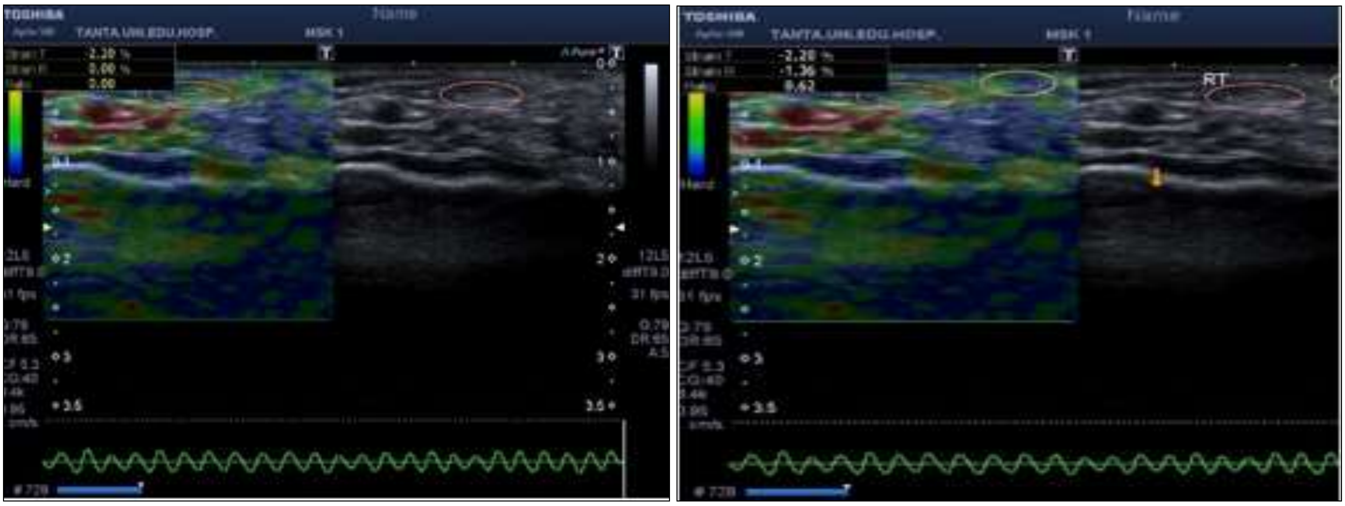



**Fig 1:** ROC curve analysis of cross sectional area and strain ratio for the diagnosis of carpal tunnel syndrome

**Case 1:** Thirty-four-year-old female patient who is a housewife, complaining from pain that increased on daily chores and awakened her at night from her sleep. She had tingling in the right hand and inability to carry or grasp heavy objects. Examination showed: Positive Tenil's test, positive Phalen's test, electrophysiological study of the median and ulnar nerves revealed right severe CTS and grey scale U/S examination show median nerve swelling at the proximal carpal tunnel (CSA = 18 mm²), Decreased echogenicity and elastographic image show hard nerve (blue, green), strain ratio (0.62). Figure 2.

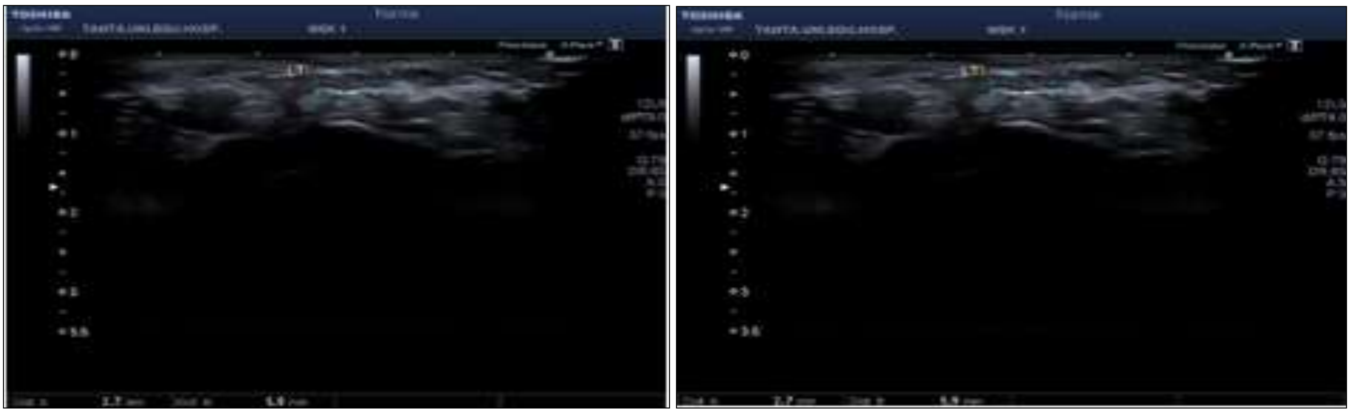
**(A)**



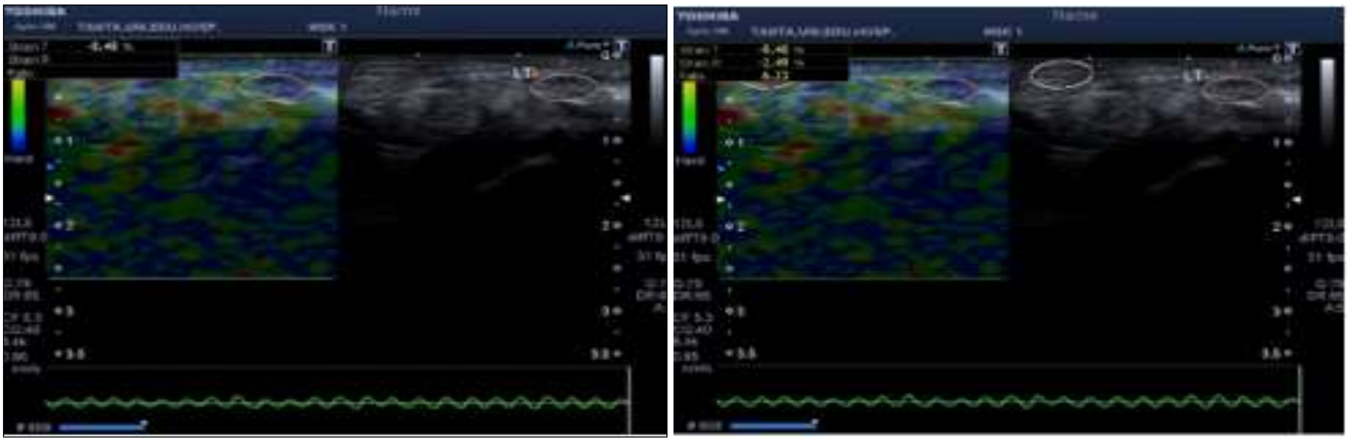
**(B)**

**Fig 2:** (A) Grey scale ultrasound showing right sever carpal tunnel syndrome and (B) Elastography ultrasound showing right sever carpal tunnel syndrome

**Case 2:** Twenty-seven-year-old female patient who is complaining from consistent pain. She had tingling in the left hand and inability to carry or grasp heavy objects. Examination showed: Positive Tenil's test, positive Phalen's test, electrophysiological study of the ulnar and median nerves revealed left severe CTS, grey scale U/S examination shows median nerve swelling at the proximal carpal tunnel (CSA = 13 $mm^2$), decreased echogenicity and elastographic image show hard nerve (blue, green), strain ratio (6.23). Figure 3.



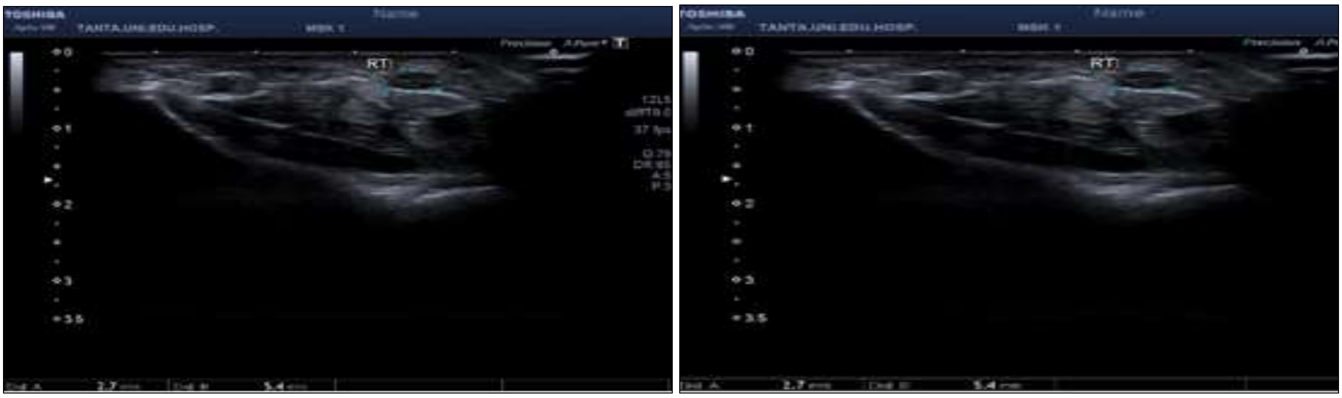
**(A)**



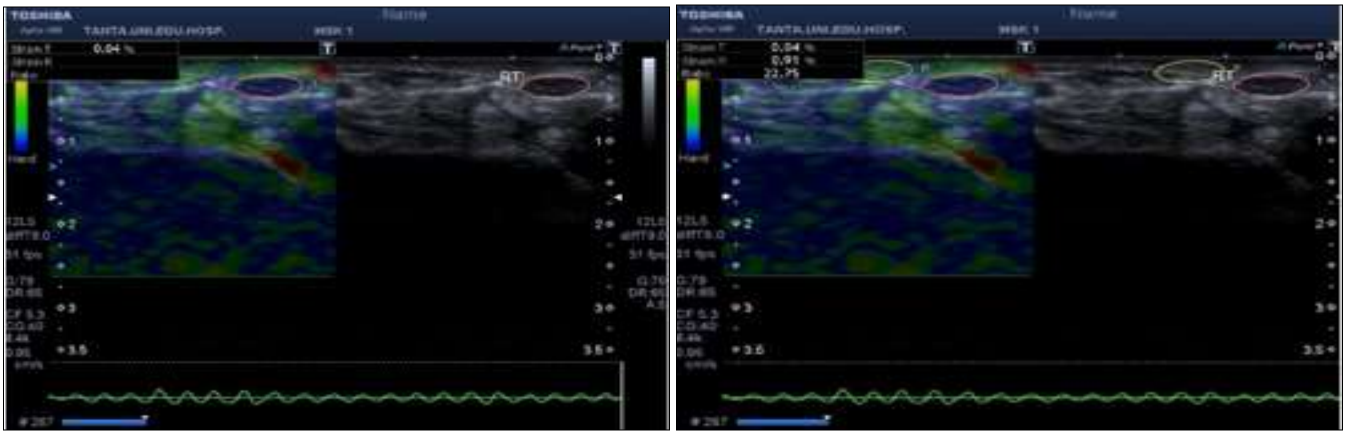
**(B)**

**Fig 3:** (A) Grey scale ultrasound showing right severe carpal tunnel syndrome and (B) Elastography ultrasound showing right severe carpal tunnel syndrome (Color map)

**Case 3:** Forty-three-year-old female patient who is housewife, complaining from pain that increased on daily chores. She had tingling in the right hand and difficulty carrying heavy objects or grasping objects for a long time. Examination showed: Positive Tenil's test, positive Phalen's test, electrophysiological study of the ulnar and median nerves revealed right severe CTS and grey scale U/S examination shows median nerve swelling at the proximal carpal tunnel (CSA = 10 $mm^2$), Decreased echogenicity. Elastographic image show hard nerve (blue, green), strain ratio (22.75). Figure 4.



**(A)**



**(B)**

**Fig 4:** (A) Grey scale ultrasound showing right severe CTS and (B) Elastography ultrasound showing right severe CTS (Color map)

## Discussion

CTS is a prevalent disorder characterized by median nerve neuropathy resulting from compression at the wrist. The patient often exhibits distinct symptoms, involving paresthesia and hypoesthesia in the distribution of the median nerve and thumb opposition weakness [10].

This study showed that regarding the severity of affected wrists, 9(30%) wrists were mild, 20 (67%) were moderate, and 14(47%) were severe. This agrees with Mahmoud *et al.* [11] reported that, concerning the electrophysiological results of the case group, the moderate type of condition was the most prevalent, representing 44% of the assessed wrists. Our findings contradicted those of Emara *et al*. [12], who stated that, based on electrophysiological diagnosis, 44 (44%), 35 (35%), and 21 (21%) individuals with mild, moderate, and severe degrees of CTS existed, correspondingly.

In the present study, regarding the grey scale in the study participants, CSA had been significantly greater in CTS wrists contrasted to normal wrists. Slightly reduced or decreased echogenicity relative to surrounding tissue were significantly higher in CTS wrists than normal wrists also mobility were significantly higher in CTS wrists. Our results are in harmony with another study that assessed the flexibility of the median nerve using compression elastography. Our findings concurred with those of Orman *et al*. [13] revealed a notable disparity between the mean CSA of the case group, which was 11.81 mm², and the control group, which was 7.76 mm². These authors, nevertheless, shown a limited capacity of the CSA to assess the degree of median nerve involvement. This aligns with recent research conducted by Wee *et al*. [14] concluded that it was markedly distinct in people with CTS.

In the present study, regarding elastography US outcomes in the study participants, strain ratio had been significantly greater in CTS wrists than normal wrists. Our findings concurred with Kantarci *et al*. [15], who revealed that the median nerve at the carpal tunnel entrance exhibited considerably greater stiffness in CTS sufferers contrasted to healthy subjects, as assessed by shear-wave elastography. Our results are like Zhang *et al*. [16] found that the Systolic Wave Velocity was 5.24±0.545 m/s in CPS wrists and 3.248±0.410 M/S in the control group, with significant variation. Our results disagreed with Martin *et al*. [17] didn't reveal a significant variation in strain values amongst 17 CTS sufferers and 26 control participants.

In the current study, CSA was significantly lower in mild CTS wrists than moderate and severe CTS wrists but no significant variation existed in CSA among moderate and severe CTS wrists. Our findings agree with Mahmoud *et al*. [11] reported that, a mean value of 10.3 mm² indicated mild CTS, but values of 15.5 mm² and 20.2 mm² corresponded to moderate and severe CTS respectively. Our results disagree with a recent work by Wee *et al*. [18] indicated that the ideal cutoff value for median nerve CSA in diagnosis was 1.45.

In the current study, Strain ratio was significantly lower in mild CTS writs than moderate and severe CTS wrists and was significantly lower in moderate CTS wrists than severe CTS wrists. This agrees with Emara *et al*. [12] found notable variation in strain index among mild, moderate, and severe instances, exhibiting great specificity as well as sensitivity. This is also in harmony with Kantarci *et al*. [15] indicated that individuals with CTS had greater stiffness of median nerve compared to control individuals, with increased severity of CTS correlating with heightened stiffness of median nerve.

In the current work, CSA is a significant predictor of CTS (AUC: 0.882, $p<0.001$). At a cutoff value of >11, it can predict CTS with a specificity of 88%, sensitivity of 74%, PPV of 94% and NPV of 58%. Our results agreed with Miyamoto *et al*. [19] and Gunes *et al*. [13] revealed that The cutoff value for the median nerve CSA to distinguish various stages of median nerve involvement is 11 mm², and that is comparable to our findings of 12 mm².

In the current study, Strain ratio is a significant predictor of CTS (AUC: 0.928, $p<0.001$). At a cut-off value of >1.7, it can predict CTS with a sensitivity of 86%, specificity of 94%, PPV of 97% and NPV of 72%. Also, Tatar *et al*. [20] determined that evaluating the ratio of strain at the carpal tunnel is more precise for detecting instances of CTS compared to assessing it in the proximal forearm. A cutoff value of 2.3 was suggested. Moran *et al*. [21] performed research including 105 wrists with varying degrees of CTS, with the objective of determining a cutoff threshold to differentiate those who have moderate and severe CTS from those with mild instances. A cutoff value of 57 kPa effectively differentiated moderate and severe instances of CTS from mild and normal instances, with a sensitivity of 46.5% and a specificity of 89.6%. When paired with a CSA cutoff value of 14 mm², specificity reached 100%.

Limitations of the work involved the relatively small sample size. It was single-center study. Lack of patient follow up.

## Conclusions

Alongside electrophysiological studies, grey scale ultrasound and elastography ultrasound significantly enhanced diagnostic accuracy in evaluating carpal tunnel syndrome. They are essential instruments for the diagnosis and categorization of CTS.

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**Conflict of Interest:** Nil.

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