Contribution of power Doppler and gray-scale ultrasound of the median nerve in evaluation of carpal tunnel syndrome

Rania E. Mohamed a,*, Mohamed A. Amina a, Ashraf A. Aboelsafa b, Salwa E. Elsayed c

a Radiodiagnosis Department, Tanta University, Egypt
b Neurology Department, Tanta University, Egypt
c Physical Medicine, Rheumatology and Rehabilitation Department, Tanta University, Egypt

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Abstract Aim of the work: To assess the role of gray-scale and power Doppler ultrasound (US) of the median nerve at the wrist in evaluating carpal tunnel syndrome (CTS).

Materials and methods: Seventy-one wrists in 51 patients with CTS in addition to 50 healthy volunteers that served as the control group were enrolled in this study. The following sonographic parameters were evaluated in both patients and controls: cross sectional area of the median nerve just proximal to the tunnel inlet (CSA1), at the pisiform bone level (CSA2), the CSA difference (ΔCSA), flattening ratio of the median nerve and bowing of the flexor retinaculum. The power Doppler US was used to assess the number of nerve vessels with estimation of the vascularity score.

Results: The ΔCSA revealed an excellent discriminative ability (AUC = 0.988) in differentiating patients with CTS at an optimal cut-off value of 3.9 mm². Intraneural hypervascularization was significantly correlated with the ΔCSA of the median nerve (P < 0.001), while not significantly correlated with the age of patients, median nerve flattening ratio and bowing of flexor retinaculum. The power Doppler US was used to assess the number of nerve vessels with estimation of the vascularity score.

Conclusion: The ΔCSA and vascularity score of the median nerve are important and useful sonographic parameters in evaluation of CTS.

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1. Introduction

The carpal tunnel is an anatomical passage way compartment located at the middle third of the base of the palm. Nine flexor tendons and the median nerve pass through it. It is surrounded on three sides by the carpal bones that form an arch and restrict the tunnel dorsally, while the flexor retinaculum restricts it ventrally. The proximal boundary is the distal wrist skin crease, and the distal boundary is approximated by a line known as Kaplan’s cardinal line (1). This line uses surface landmarks, and is drawn between the apex of the skin fold between the thumb and index finger to the palpatled hamate hook along the axis of the ring finger (2).

Carpal tunnel syndrome (CTS) occurs when the median nerve becomes pressed at the wrist in the carpal tunnel. In fact, women are three times more likely than men to develop CTS, which usually occurs only in adults. Most cases are idiopathic (3). However, CTS is often the result of a combination of factors that increase pressure on the median nerve and tendons in the carpal tunnel (4). Although painful sensations may indicate other conditions, CTS is the most common and widely known of the entrapment neuropathies in which the peripheral nerves are compressed (5).

Early diagnosis and treatment are important to avoid permanent damage to the median nerve. Symptoms usually start gradually in one or both hands during the night, with tingling or numbness in the palm and fingers, especially the thumb, index and middle fingers. Some feel swollen hands. Typical times include while holding a phone or a newspaper, gripping a steering wheel, or waking up during the night. As symptoms worsen, people might feel tingling during the day with difficulty to form a fist, grasp small objects, or perform other manual tasks. Long-standing CTS leads to permanent nerve damage with constant numbness, atrophy of the thenar muscles and weakness of palmar abduction (6,7). Pressure on the median nerve at the wrist, produced by either bending the wrist to 90° (Phalen or wrist-flexion test), tapping the skin over the flexor retinaculum (Tinel test), or firmly pressing the palm over the nerve (Durkan or carpal compression test), can bring on the symptoms within 1 min (8–10).

Electrodiagnostic studies are useful in making the decision for surgical decompression and in differentiating less typical cases such as entrapment of other nerves, cervical radiculopathy, demyelinating disease, diabetes or peripheral neuritis which could be confused with CTS. Although they are highly specific, they have a substantial false-negative rate of 10–20% (11).

Ultrasonography (US) is a simple, non-invasive and valuable tool for confirming the diagnosis of CTS because it can detect the median nerve compression characteristics and space-occupying lesions such as ganglia, neural tumors and tenosynovitis (12). Moreover, the power Doppler US might be a useful imaging method for evaluating the degree of severity of CTS especially before surgical decompression is warranted (7).

The aim of the present study was to assess the role of grayscale and power Doppler US of the median nerve at the wrist in evaluating CTS.

2. Materials and methods

This study was performed in the period between January, 2012 and March, 2013 on 71 wrists from 51 patients (34 females and 17 males), referred from the Neurology department of our institution, with clinically characterized idiopathic CTS lasting for at least one month. Symptoms were unilateral in 31 patients and bilateral in 20 patients. Clinical diagnosis of CTS was confirmed by the electrodiagnostic tests that were performed within 5 days before the imaging examination was done. The control group included 50 normal healthy volunteers (32 females and 18 males) with no clinical signs or symptoms suggestive of CTS. One wrist from every individual in the control group was chosen for imaging tests while electrodiagnostic testing was not done in this group. Exclusion criteria included pregnancy, previous wrist surgery or injury, clinical suspicion of any other neuropathies e.g., cervical spondylisis, and bifid median nerve on US. All patients and controls were investigated to exclude disorders that might be associated with neuropathy as diabetes mellitus, thyroid disease, connective tissue disorders, renal and hepatic disease. All patients were educated about the study design and procedures. Written consent was obtained from all study participants and approval from the local ethics committee was obtained.

The diagnosis of CTS was reached through the characteristic clinical history (nocturnal hand discomfort and sensory impairment in the median nerve distribution), clinical examination (positive Tinel, Phalen and/or Durkan tests), and then confirmed by the electrodiagnostic tests.

2.1. Electrodiagnostic tests

Electrodiagnostic tests were done by Neuropack X1/EMG/EP measuring system, MEB-2300 in the Physical medicine, Rheumatology and Rehabilitation department of our institution. The median nerve sensory action potential amplitude, latency, and sensory conduction velocity (CV) were measured. The median nerve motor amplitude, distal motor latency (DML), and motor conduction velocity were measured using standard techniques of supramaximal cutaneous stimulation and surface recording electrodes. F-response latency of the median nerve was also obtained to exclude proximal affection of the median nerve roots. Additional ulnar nerve sensory and motor conduction studies were also performed using similar standard techniques. Needle EMG was done in the abductor pollicis brevis muscle to determine the severity of CTS and additional muscles in the upper limb to exclude proximal median neuropathy, brachial plexopathy or radiculopathy.

The diagnostic criteria of electrodiagnostic tests for CTS were reduction in the median nerve sensory CV of less than 50 m/s across the carpal tunnel, prolongation of median nerve DML more than 4 ms, no abnormalities in the ulnar nerve, and no abnormalities in the proximal median nerve. The absence of any electrical diagnostic criterion resulted in defining the wrist as normal. Mild CTS was considered when reduction of the sensory CV with normal motor responses and EMG results. Moderate CTS was considered when sensory abnormalities were combined with prolonged DML but normal EMG. Severe CTS was considered when absence of sensory responses was associated with motor nerve changes and abnormal EMG (13).

2.2. Imaging

All imaging examinations were performed by using a linear array transducer of 12 mega-Hertz (MHz) frequency connected to a real-time ultrasound machine (Biomedical P-K, Denmark).
with pulsed and color Doppler options. The patient was seated supine with the forearm extended and the fingers semi extended on a flat surface facing the examiner. Undue excess pressure of the transducer over the wrist was avoided to minimize sampling errors. The median nerve was examined axially and longitudinally along the carpal tunnel by gray-scale and power Doppler US. The gray-scale was used to detect compression criteria of the median nerve including median nerve edema, swelling, and flattening as well as increased bowing of the flexor retinaculum. The power Doppler was used to detect intraneural hypervascularization of the median nerve.

The normal median nerve is formed of hypoechoic bundle of fascicles surrounded by hypoechoic epineural connective tissue; all are enclosed in a hypoechoic nerve sheath (14). Nerve edema causes altered signals of the nerve structures resulting in an increase in the hypoechoic nerve signal. Nerve swelling was defined as an enlargement of the cross-sectional area (CSA) of the median nerve to 11 mm² or more within the carpal tunnel. The CSA of the nerve was defined as the area of the nerve bundles in the perineural fibrous tissue. Axial images of the median nerve were taken at three levels. Level (1) located just proximal to the tunnel inlet where the nerve was more circular (CSA1). Level (2) located at the pisiform bone level where the nerve was small in antero-posterior diameter (CSA2). Level (3) located at the hamate bone level where the nerve size was reduced and became smaller in antero-posterior diameter. A cross-sectional area of the median nerve was measured by means of direct tracing with electronic calipers around the margin of the nerve on sonograms at the first and second levels. The cross-sectional area difference (ΔCSA) was obtained by subtracting CSA1 from CSA2. Level (3) was used to calculate the flattening degree by calculating the ratio (the flattening ratio) between the largest diameter and the diameter perpendicular to this finding. The presence of increased palmar bowing of the flexor retinaculum was detected when the palmar apex of the retinaculum was displaced 2 mm or more from the straight line between the trapezium tubercle and the hamate bone.

Power Doppler US was done after the gray-scale US to calculate the number of vessels in the median nerve along the carpal tunnel. Standardized machine settings were selected to reach the highest degree of sensitivity of detection of low-velocity and low blood flow volume. These settings were fixed throughout the study. Noise suppression was achieved by optimizing the power gain through reduction of the gain to the extent just adequate to suppress the noise (75–85% gain). The color box of the power Doppler was limited to the region of interest. The pulsed wave spectral Doppler imaging was performed after visualization of power-flow signals (PFS), using the lowest filter setting (125 Hz) and smallest existing scale that would exhibit the Doppler waveforms as large as possible without aliasing. Moreover, to confirm the power Doppler signals that represented true arterial or venous flow, a spectral Doppler tracing was acquired. Also, to evaluate the intensity of vascularity in the nerve, the number of PFS was counted by using the scores established in a modification of Klausler and Shio’s method used in the quantification of vessels in the metacarpophalangeal joints of patients with rheumatoid arthritis (15–17). **Score 0**: no PFS; **score 1**: 1 PFS; **score 2**: 2–3 PFS; **score 3**: 4 or more PFS. The illustrated vessels were counted while the transducer was swept very slowly from the tunnel inlet to its outlet. The CSA2 was calculated for each score. Additionally, the pulsatility index (PI) of the vessels related to PFS was calculated automatically using a computer by tracking the velocity wave developed by spectral Doppler sonography according to the following formula:

\[ \text{PI} = \frac{\text{peak systolic velocity (PSV)}}{- \text{end diastolic velocity (EDV)/mean velocity (mean V)}} \]

### 2.3. Statistical analysis

The mean values of the age, and the different sonographic parameters along the carpal tunnel were determined. Quantitative data were expressed in the mean values ± standard deviation (SD). The Receiver Operating Characteristic (ROC) curves for the sonographic measurements of the median nerve were obtained and plotted by using a maximum likelihood curve-fitting algorithm. Relative diagnostic accuracy was estimated for each single sonographic feature by using the individual area under the ROC curve to identify the optimal cut-off values. The student t-test and chi-square were used for comparison between two groups and the analysis of variance (ANOVA) test was used for correlation of the data. The SPSS for Windows version 18.0 software package (SPSS Inc, Chicago, IL) was used for statistical data analysis. *P*-value < 0.05 was considered statistically significant.

### 3. Results

Fifty-one patients (34 females and 17 males) with carpal tunnel syndrome (unilateral in 31 and bilateral in 20 patients) were included in this study. Their ages ranged from 19 to 78 years (mean 42.4 ± 12.5 years). Additional 50 normal healthy volunteers (32 females and 18 males) served as the control group. Their ages ranged from 21 to 70 years with a mean of 41.9 ± 15.4 years (Table 1). The electrodiagnostic tests revealed 11 (15.5%) wrists with mild CTS, 24 (33.8%) with moderate CTS and 36 (50.7%) with severe CTS. Increased hypoechoic signal of the median nerve was reported in 60 (84.5%) wrists with CTS.

The mean CSA1 was not significantly different in the patients with CTS when compared to normal controls (*P* = 0.423), while each of the mean CSA2, ΔCSA, flattening ratio, and bowing of flexor retinaculum was significantly increased in the patients when compared to normal controls (*P* < 0.001 in each), (Table 1). The power Doppler US did not detect PFS in any of the normal control. But in patients with CTS, the mean number of vessels in the median nerve was 1.7 ± 0.8 (Table 1). We detected vessels in only 35 (49.29%) CTS-affected wrists. Score 0 was present in 36 (50.71%) median nerves, score 1 in 18 (25.35%), score 2 in 10 (14.08%), and score 3 in 7 (9.86%) median nerves (Table 2). The mean CSA2 in patients with score 0 was 14.4 ± 3.1 mm², and in patients with score 1 was 14.6 ± 4.7 mm²; while it was 16.3 ± 2.9 mm² in patients with score 2 and 18.7 ± 1.7 mm² in patients with score 3, (Table 2). Also, the mean PI value in vessels of the median nerve was 5.0 ± 1.1.

The ROC curve analyses revealed an excellent discriminative ability with use of the ΔCSA (AUC = 0.988) in differentiating patients with CTS from normal control. Furthermore, this discriminative ability of the ΔCSA was significantly higher...
when compared to that of CSA2 ($P < 0.001$) and the flattening ratio ($P < 0.001$), (Table 3 and Fig. 1). The sensitivity, specificity, PPV, NPV, and accuracy of the sonographic features revealed a higher accuracy (98.8%) for $D_{CSA}$ at an optimal cut-off value of 3.9 mm$^2$ in differentiating cases with CTS from normal control, (Table 3).

Each of the $D_{CSA}$ of the median nerve, its flattening ratio, flexor retinaculum bowing and intraneural hypervascularization was significantly correlated with the severity degree of CTS ($P < 0.001$), (Table 4 and Fig. 2).

Intraneural hypervascularization was significantly correlated with the $D_{CSA}$ of the median nerve (correlation coefficient = 0.785, $P < 0.001$), while no significant correlation was found with the age of patients (correlation coefficient = 0.245, $P = 0.098$), the median nerve flattening ratio (correlation coefficient = 0.354, $P = 0.098$), and bowing of the flexor retinaculum (correlation coefficient = 0.405, $P = 0.055$), (Table 5).

3.1. Cases

The figures (from Figs. 3–6) demonstrate a sample of selected cases of our study, each figure outlines one case.
A 37 year old female patient with moderate CTS. A transverse section of the median nerve proximal to the carpal tunnel (A) and at the carpal tunnel (B) show the CSA 1 = 8 mm² and CSA 2 = 15 mm² with ΔCSA = 7 mm². The estimated flattening ratio (C) is 2.3. The nerve swelling is obviously seen. The longitudinal images of power Doppler (D) and duplex Doppler ultrasound (E) images reveal intra-neural vascularization with arterial waveform (Fig. 5).

A 43 year old male patient with severe CTS. A transverse section of the median nerve proximal to the carpal tunnel (A) and at the carpal tunnel (B) show the CSA 1 = 9 cm² and CSA 2 = 19 cm² with ΔCSA = 10 cm². The estimated flattening ratio (C) is 2.5. The nerve swelling is obviously seen. The power Doppler (D) and duplex Doppler ultrasound (E) images reveal intra-neural vascularization with arterial waveform (Fig. 6).

4. Discussion

The diagnosis of CTS usually depends upon the typical clinical symptoms and signs and can be confirmed with the electrodiagnostic testing in most cases (18). Furthermore, US has been used as an additional approach for evaluating patients with CTS during the past two decades (19). While electrodiagnostic tests are based on physiologic malfunctions of the median nerve in this condition, US examination depicts structural abnormalities of nerve swelling. (20) Buchberger et al. (21), who were the first to quantify the anatomic changes in CTS using sonography, showed that an increase in the proximal or middle CSA of median nerve to 10 mm², a distal flattening ratio above 3, or a displacement of the flexor retinaculum above 4 mm are sonographic signs suggestive of CTS. Previous US studies have proposed a range of median nerve CSA cut-off values at the carpal tunnel (19,22,23). In our study, we investigated the use of an additional measurement, the proximal CSA, to calculate a new parameter, the ΔCSA.

It is known that there is a sudden change in the diameter of the median nerve in the longitudinal view, especially at the entry of the tunnel in cases of CTS. Therefore, the measurement of the nerve diameter just before the tunnel inlet in addition to measurement at the carpal tunnel might contribute to sonographic diagnosis of CTS (19). So, we measured the CSA at two levels and obtained CSA1 and CSA2 values. The median nerve cross sectional area indicating CTS ranged from 9 to 15 mm², and the sensitivity and specificity of nerve swelling ranged from 57% to 97% and from 65% to 97%, respectively (12,19,21,24,25). Our study revealed a significantly larger mean CSA2 in patients with CTS when compared with that of normal controls (P < 0.001). In the healthy volunteers, CSA1 and CSA2 were relatively similar, with a difference of less than 1 mm². Receiver-operating characteristic analysis of CSA2 revealed a value of 11.2 mm² as the threshold level, with 67.6% sensitivity, and 98% specificity. These data agree with the findings reported by Sarria et al. (26) and Mallouhi et al. (27). Measurement just before tunnel inlet (CSA1) was not a clinically important predictor in our study with a mean value of 8.7 mm² in CTS-affected wrists versus 8.4 mm² in healthy volunteers (P = 0.423).

If the degree of nerve swelling in the carpal tunnel is compared with the proximal CSA of the nerve, a ΔCSA measurement (area difference between CSA1 and CSA2) will compensate for the interindividual variability in the CSA of the median nerve and yield a more accurate diagnosis of CTS (12) and provide additional confirmatory criterion for the diagnosis of CTS. We found 97.2% sensitivity and 100% specificity for the cut-off value for ΔCSA of 3.9 mm². But, in the study of Klauser et al. (12), they reported 95% sensitivity and 100% specificity for ΔCSA of 2 mm². The ROC curve analysis revealed a significant diagnostic advantage to use the ΔCSA parameter rather than the CSA2 to diagnose CTS. Therefore, the ΔCSA seems to be a good parameter for the detection of CTS.
It has been reported that the flattening ratio was highly variable and thus poorly predictive (28–30). The mean flattening ratios for patients and the control group were 3.3 and 2.1, respectively (69.6% sensitivity and 96% specificity). According to Buchberger et al. (21) criteria, the flattening ratio was little high in patients with CTS. The results of this study indicate that the inclusion of patients in advanced phase of the disease probably led to such findings related to CTS. Actually, it has been reported that the role of nerve flattening varied among studies, with sensitivities of 38–65% (21).

Increased palmar bowing of the flexor retinaculum was seen less frequently. (26) Determination of its degree was seldom done in the previous studies due to its too low sensitivity and specificity of sonographic diagnosis. (7) However, in the present study, we found a significant difference in the mean of palmar bowing of the flexor retinaculum between patients and controls ($P < 0.001$). Also, it was significantly correlated with the degree of severity of CTS by electrodiagnostic tests ($P < 0.001$), however not significantly correlated with the intraneural hypervascularization of the median nerve. This

Fig. 3 (A–E) A 45 year old healthy control female subject. Transverse images (A, B and D) at gray-scale US show a transverse section of the median nerve with its normal fasicular or speckled pattern, proximal to the carpal tunnel (A) and at the carpal tunnel (B) demonstrating the CSA1 of 6 mm$^2$ and the CSA2 of 7 mm$^2$ with the ΔCSA = 1 mm$^2$. The estimated flattening ratio (D) is 1.6. The longitudinal image (C) at gray-scale US shows absent bowing of the flexor retinaculum. Additionally, the power Doppler (E) image shows no intra-neural vascularization.
might be attributed to the relatively low incidence (49.29%) of intramural hypervascularization in patients of our study.

With respect to CTS severity at electrodiagnostic examination, each of the mean ΔCSA, flattening ratio, bowing of flexor retinaculum and intraneural hypervascularization was significantly correlated with the severity of CTS ($P < 0.001$ in each). Previous studies to evaluate US imaging of CTS, with electrodiagnostic tests as the reference standard, have revealed sensitivities ranging from 82% to 94% and specificities ranging from 65% to 97% (28,31,32). The relatively wide range of sensitivity and specificity values in these studies contributes to the variety of opinions regarding the utility of US for the diagnosis of CTS. Seror (33) stated that US appears to be of little use in the diagnosis of CTS. In contrast, Wong et al. (19) proposed an algorithm involving initial US examination of patients suspected of having CTS and secondary electrodiagnostic tests performed only when US results were negative. Given the non-invasive nature of US as compared with electrodiagnostic tests, clinical examination combined with US may be the best approach in the future.

It is interesting that in patients with CTS, paresthesia has been shown to occur before conduction failure in myelinated axons. This phenomenon has been attributed to the delay in nerve conduction due to intraneural edema and increased intraneural pressure.

Fig. 4  (A–E) A 48 year old female patient with mild CTS. A transverse section of the median nerve proximal to the carpal tunnel (A) and at the carpal tunnel (B) show the CSA1 = 12 cm$^2$ and CSA2 = 16 cm$^2$ with the ΔCSA = 4 cm$^2$. The estimated flattening ratio (C) is 2.2. The nerve swelling is obviously seen. The power Doppler (D) and duplex Doppler ultrasound (E) images demonstrate intraneural vascularization with arterial waveform.
sensory fibers, as measured with nerve conduction tests (34). A study by Koyuncuoglu et al. (23) revealed positive US findings in patients who had CTS positive clinical results, with negative electrodagnostic findings in 30.5% of these patients, suggesting an advantage to using US especially during the early stages of CTS, when the median nerve shows no functional impairment at electrodagnostic examination.

It is postulated that both intermittent mechanical compression and vascular compromise due to a rise in intracanal pressure can result in the neuropathy of CTS and are responsible for the clinical progression of this condition. The median nerve is supplied by surface epineural, interfascicular and intrafascicular vascular plexuses that are linked to one another to form a free vascular network. Vascular compromise seems to occur in three stages: (1) venous congestion, (2) nerve edema, and (3) impairment of the venous-arterial blood supplies. Therefore, there is an increase in expression of the vascular endothelial growth factor in a synovial tissue biopsy, thus denoting a particular activity in disease progression, which might explain the hypervascularization of the median nerve in CTS (27,35).

Power Doppler US is the most sensitive to flow and is used to document diminished blood flow in the median nerve as a

Fig. 5 (A–E) A 37 year old female patient with moderate CTS. A transverse section of the median nerve proximal to the carpal tunnel (A) and at the carpal tunnel (B) show the CSA 1 = 8 mm² and CSA 2 = 15 mm² with ΔCSA = 7 mm². The estimated flattening ratio (C) is 2.3. The nerve swelling is obviously seen. The longitudinal images of power Doppler (D) and duplex Doppler ultrasound (E) images reveal intra-neural vascularization with arterial waveform.
result of high sensitivity to slow flow, no angle dependency, and no aliasing (36,37). In the current work, by using power Doppler US, we quantitatively studied the vascularization of the median nerve at the carpal tunnel that was a very limited signal, not seen in the control group and only seen in patients with very large nerves. We detected vessels in only 35 (49.29%) CTS-affected wrists. We then evaluated the mean CSA2 for each score, which increased as the score increased (Table 2). El Miedany et al. (38) recommended US cut-off points for CSA2 of the median nerve that discriminate between different grades of CTS severity (10–13 mm² for mild, 13–15 mm² for moderate and > 15 mm² for severe patients in relation to electrodagnostic tests grades). Because increased vascularization was the characteristic of a nerve with larger CSA2, this indicating a more severe degree of CTS, grading is important in the management of patients especially when deciding for surgical decompression. Our results are parallel to those obtained by Evans et al. (39), who concluded that an inverse relationship might exist between intraneural vascular flow in the median nerve and an increasing severity of carpal tunnel syndrome based on nerve conduction results. We also evaluated the PI values of vessels in the median nerve and found a mean value

Fig. 6 (A–E) A 43 year old male patient with severe CTS. A transverse section of the median nerve proximal to the carpal tunnel (A) and at the carpal tunnel (B) show the CSA1 = 9 cm² and CSA2 = 19 cm² with ACSA = 10 cm². The estimated flattening ratio (C) is 2.5. The nerve swelling is obviously seen. The power Doppler (D) and duplex Doppler ultrasound (E) images represent intra-neural vascularization with arterial waveform.
of 5.0. It has been suggested that nerve hyper-vascularization and nerve swelling yielded the best detectability of CTS (27).

The limitation of this study is that we included only patients diagnosed by electrodiagnostic tests. It is known that having a typical clinical picture of CTS with negative electrophysiological studies does not preclude the diagnosis of CTS, as a threshold of nerve injury must be reached before study results become abnormal and cut-off values for abnormality are variable (11). The number of patients in this study is another limitation. Future studies with a larger number of patients are required to develop a better scoring system by Doppler ultrasonography to evaluate the grade of CTS in correlation of the electrodagnostic test results.

A strengthening point of our study design was the inclusion of the disease severities. The results demonstrate that the CSA is useful in patients with both mild and severe CTS. Use of the ACSA improves the US-based diagnostic discrimination of CTS by reducing the overlap of measurements obtained in healthy volunteers with those obtained in CTS-affected patients.

In conclusion, the present study reveals a high degree of sensitivity and specificity level in the diagnosis of CTS when the ACSA is evaluated. Also, the power Doppler US is useful when the number of vessels in median nerve is scored.

Conflict of interest

The authors have no conflict of interest to declare.

References

Contribution of power Doppler and gray-scale ultrasound of the median nerve in evaluation


