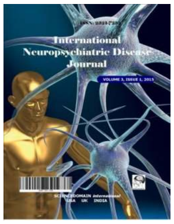

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Can Sonography Replace Electromyography and Nerve Conduction Velocity in Carpal Tunnel Syndrome?

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Authors' contributions

This work was carried out in collaboration between all authors. All authors designed the study and wrote the protocol. Author AEB preformed the statistical analysis, managed the literature search and wrote the first draft of the manuscript with assistance from author MES. All authors read and approved the final manuscript.

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ABSTRACT

Purpose of the Study: To justify the efficacy of the ultrasonography (US) in the diagnosis of carpal tunnel syndrome (CTS) in the postoperative follow-up in comparison to electrodiagnostic tests [electromyography (EMG) and nerve conduction velocity (NCV)].
Patients and Methods: One hundred CTS patients were documented through clinically, electrophysiologically, and intraoperatively grading by using the Tuncali grading system (TGS), in Mansoura University Hospital, Insurance Hospital, and EL Ahrar, during the period of April 2014 till March 2015. All patients were evaluated pre and postoperatively by both the gold standard invasive electrodiagnostic (EMG, NCV) and the new noninvasive US tests.
Results: All of the 100 CTS cases (24 men, 76 women) showed improvement in pain after releasing incisions (TGS grades 2 and 3). The CTS diagnosis by electrodiagnostic (EMG and NCV) were 90 positive and 10 negative. However, by the US were 86 positive and 14 negative. Six months after surgery, electrodiagnostic tests (EMG and NCV) had improved in 74% of cases, but

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with US, it showed improvement in the cross-sectional area (CSA) swelling of median nerve after three weeks in 64 CTS cases (64%). The sensitivity and the specificities were 90% and 79.2% for NCV respectively while for the US were 86% and 77.4% respectively.

Conclusion: US showed improvement of morphological criteria (within 3 weeks) than the betterment of the function by electrodiagnostic (after 6 months) in the postoperative follow-up of CTS cases. Therefore, US examination for CTS can possibly be done without the need for other invasive investigations.

Keywords: Carpal tunnel syndrome; electromyography; median nerve; ultrasonography; nerve conduction velocity.

1. INTRODUCTION

Since it was first described by Sir James Paget in 1854, carpal tunnel syndrome (CTS) has been understood as the most common of peripheral compression neuropathies [1]. CTS is caused by the compression of the median nerve under the transverse carpal ligament (TCL) at the wrist [2,3]. The main reasons for CTS are idiopathic; however, medical reasons can also be responsible in some cases such as gout, endocrine disorders (like acromegaly and myxedema), rheumatoid arthritis, and flexor tenosynovitis [1,2,3].

Its prevalence is ranging between 0.6 and 3.4% [4,5] that increased in certain occupations while the incidence is 330 to 346 per 100,000 person-years [6]. The CTS may cause several symptoms including asymptomatic (subclinical like during pregnancy and with endocrine disorders), pain, numbness in the hand or fingers, and burning or tingling in the fingers, that, radiates to the forearm especially during the night. We can find the flick sign defined as pain relief by shaking the hand. Other signs include hypoesthesia or hyperesthesia in the distribution of the median nerve and thenar muscle atrophy. Some of the other clinical tests that can enhance the diagnosis are the Phalen's maneuver and the Tinel's sign [4,5,7]. The early diagnosis is important to prevent nerve injury, which may be irreversible if treated late [8].

The CTS can often be diagnosed clinically [9], but the beneficial effect of electrodiagnostic [electromyography (EMG) and nerve conduction velocity (NCV)] testing can enhance the accuracy [10]. That reached 53 to 98% of CTS patients [11,12,13,14]. While, thermography [15], ultrasound (US) [16], and computed tomography [17] were helpfully used as diagnostic tools. The decompression surgery works to reduce symptoms in CTS cases [3,4,5].

The electrodiagnostic (EMG and NCV) method is the most commonly used diagnostic test for CTS, and US may also be used for its diagnosis [9,18,19]. The US as a technique is extensively applicable, cheap, short time and non-invasive. The US evaluation demonstrated an increased cross-sectional area (CSA) of the median nerve in the CTS patients [16].

2. AIM OF THE STUDY

The aim of this study was first to compare the accuracy of the electrodiagnostic (EMG, NCV) and the US for the diagnosis and re-evaluation of CTS with the use of the clinical findings.

3. PATIENTS AND METHODS

3.1 Patients

This prospective study included 100 CTS patients recruited from the outpatient clinic in Mansoura University Hospital (MUH), Insurance Hospital, and EL Ahrar, Egypt since April 2014 till March 2015. All enrolled patients had approved to participate in the study.

3.1.1 Inclusion criteria

All patients involved in this study were diagnosed clinically as CTS, based on the signs and typical history of CTS as assessed by the neurologist and confirmed by electrodiagnostic (EMG & NCS). Also, all cases must be positive intraoperatively and had CTS grades 2 or 3 by Tuncali grading system (TGS) [20].

3.1.2 Exclusion criteria

Any patient with a previous history of diabetes mellitus or other coexisting disorders, such as polyneuropathy, radiculopathy, gout, endocrine disorders (like acromegaly and myxedema), rheumatoid arthritis, and flexor tenosynovitis or thoracic outlet obstruction were excluded from this study. Also, the CTS patients with abnormalities in ulnar nerve motor conduction or sensory conduction were excluded. Pregnant female patient or history of trauma to the upper limbs were also excluded.

3.2 Methods

3.2.1 Baseline data

Demographic characteristics, age, sex, dominant hand, occupation, complaints, family history, past history, medical history, and duration of symptoms were recorded. The routine laboratory investigations including complete blood count (CBC), blood glucose level, serum uric acid, renal, and liver functions were normal. X-ray studies were performed to exclude rheumatoid arthritis, cervical radiculopathy, and thoracic outlet syndrome. All patients who were diagnosed clinically were also diagnosed by the invasive electrodiagnostic method (EMG, NCV), and the non-invasive US method to assure the diagnosis. All patients with positive CTS underwent decompressive surgery and re-evaluated again by both methods.

3.2.2 Clinical evaluation

Clinical monitoring to assess the CTS by visual analog score, flick sign, Tinel's sign, Phalen's sign, reverse Phalen's sign, median hypoesthesia, presence of weakness or atrophy of the opponens pollicis, and/or the abductor pollicis brevis muscles. Also, neurological and physical examination were performed.

3.2.3 The studied patients were examined using the following scales

1. Visual analog pain scale (VAS) to estimate the severity of pain reported by the patient ranging from grade 0 (no pain) to grade 10 (maximum pain) [21].
2. Intraoperative Tuncali grading system (TGS) [20]: It is a clinical scale that gives a dependable, objective method of estimating the degree of CTS intraoperatively. The patient is evaluated by the scale criteria, and the patient score lies between grade 1 (denoting normal-mild) to grade 3 (denoting severe) depending on the degree of the affection of vascularity and fibrosis (Table 1).

3.3 Decompressive Surgical Operation

In this study, the operation was performed in an operating room with local anesthetic and with the hand extended 30 degrees without a tourniquet. Magnification glasses (4x) were used. A 2 cm long palmar longitudinal skin incision was made distal to the wrist flexion crease along the axis of the radial side of the fourth digit, and then divided the TCL with the scalpel along the ulnar side 1 mm from the edge. The division was extended subcutaneously with fine scissors under direct vision proximally and distally until the complete release of the nerve. To confirm the complete release of the proximal fibers of the TCL, we applied the little finger pulp sign [5,19]. The TGS grades for CTS was applied (intraoperative grades 2 and 3) [20]. The skin has approximated with interrupted 5–0 monofilament sutures, and an antebrachial plaster cast was applied with the wrist in slight extension. Finger exercises were encouraged after the surgery. The plaster and sutures were removed two weeks after the surgery (Fig. 1).

3.4 Electrodiagnostic Studies

3.4.1 Device and tests

The Medelec-Oxford EMG equipment (Oxford Instruments Medical, Surrey, UK) was used for all of the tests. All studies were performed by one electrophysiologist. All patients were re-examined 6 months postoperatively. EMG for diagnosing CTS was based on the practice parameters for electrodiagnostic studies established by the American Academy of Neurology [22]. Nerve conduction study data related to sensory conduction velocity; median distal motor latency; median motor conduction velocity; and nerve conduction from the thumb (M1), index (M2), and middle (M3) and M4 (ring) fingers to the wrist of the patients were measured. During the Nerve conduction studies, surface electrodes were used.

3.4.2 Scale for the abnormalities

The patients were evaluated on a 5-stage scale:

Stage 1, abnormal segmental or comparative study results.

Stage 2, abnormal finger/wrist sensory conduction velocities.

Stage 3, abnormal finger/wrist sensory conduction velocities, and abnormal distal motor latencies.

Stage 4, the absence of a sensory response and abnormal distal motor latency.

Stage 5, absence of sensory and motor responses [23,24,25].

Fig. 1. Intraoperative releasing incision of carpal tunnel syndrome (A, B, C)

Table 1. Tuncali grading scale for the intraoperative assessment [20]

Grade 1	Normal–Mild	Thickening and flattening of the nerve but normal vascular structures of epineurium, no fibrosis
Grade 2	Moderate	Moderate decrease in vascularity, mild to moderate fibrosis in any part of the nerve, hourglass or pseudo neuroma appearance
Grade 3	Severe	Loss of vascularity, diffuse fibrosis, rounding off the nerve, hourglass or pseudo neuroma appearance

All wrists belonging to any of these stages were categorized in the electromyographically CTS-positive group.

3.4.3 The cut-off value

A cut-off value was set as follows:

1- More than 0.5 ms between the median and ulnar sensory peak latencies or
2- Prolonged median distal motor latency of more than 5 ms was defined as NCV-positive case for CTS.

3.5 The US Imaging Studies

3.5.1 Time and the device

US examinations were performed within a week after the electrodiagnostic study by a radiologist by using a 13–5 MHz linear array transducer (Multi-D; Sonoline Elegra Advanced; Siemens, Munich, Germany).

3.5.2 Technique

Patients were seated in front of the examiner. The arms were extended, wrists were rested on a hard flat surface, forearms were supinated, and the fingers were in relaxed position. The images of the median nerve were obtained at two levels (proximal and distal). At each level, the CSA of the median nerve was measured by means of direct tracking with electronic calipers around the margin of the nerve on sonograms. The margin of the nerve referred to the margin outside the hypoechoic nerve fascicles and inside the hyperechoic nerve sheath [26] (Figs. 2 and 3).

3.5.3 Cut off value

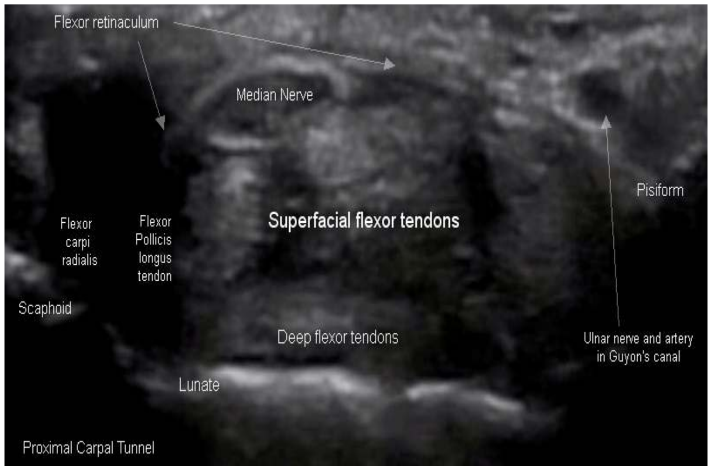
The swelling of the distal median nerve 1.3 mm^2 as the proximal median nerve across the flexor retinaculum (FR) is the positive-CTS case because our belief that body builds may change the cross section of the median nerve. Therefore, bringing up normal value will have a limited success and the most accurate standard is the patient himself (Figs. 2 and 3).

3.6 Statistical Analysis

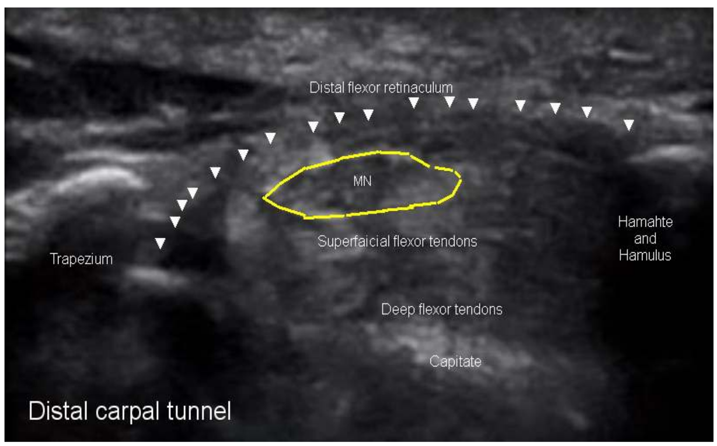
Collected data were presented as percentages. Receiver operating characteristic (ROC) curves were used to detect optimal possible cut-off values of the ultrasonographic and electrodiagnostic data, and specificity and sensitivity were obtained.

4. RESULTS

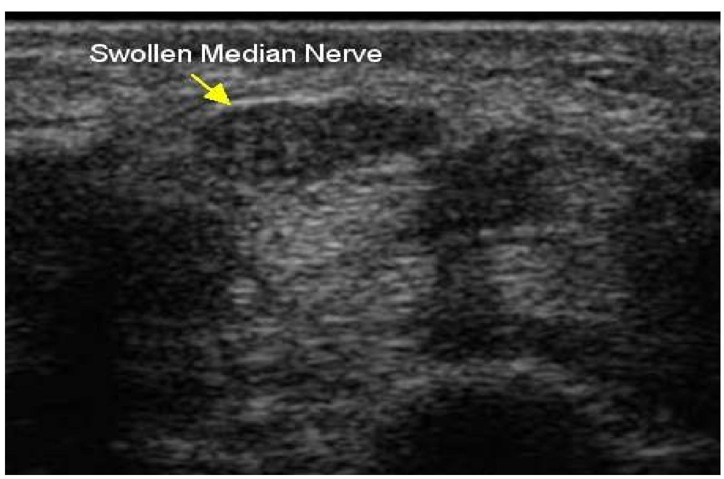
A total of 100 patients (24 men, 76 women) who have CTS on presentation to the outpatient clinic in in Mansoura University Hospital, Insurance Hospital, and EL Ahrar, during the period of April 2014 till March 2015. The mean age was 41.3 years. Also, their CTS manifestations were evaluated pre, intra and postoperatively, which showed postoperative improvement of pain in the patients. As, The VAS was high in preoperative (mean 72.03) compare with the low levels in postoperative patients (mean 20.7).



A-Anatomical landmarks of the left proximal carpal tunnel



B- Anatomical landmarks of the left distal carpal tunnel



C-A case of CTS showing swollen left median nerve

Fig. 2. Ultrasonography pictures of cross section views (A, B, C)

The surgical complications after one month were pillar pain, scar tenderness, and wound infection (24%, 12%, 4% respectively), which improved after 3 months (only pillar pain that was present in 2%).

The number of CTS clinically positive cases was as follows: NCV, 90 positive/10 negative; the US, 86 positive/14 negative. The patients on whom both tests positive were 82. Diagnostic efficacies of electrodiagnostic (EMG and NCV) and the US were found to have practical value. The cornerstone was the measurement of CSA by the US. The sensitivity and the specificities were 90% and 79.2% for NCV respectively, 86% and 77.4% for the US respectively (Table 2).

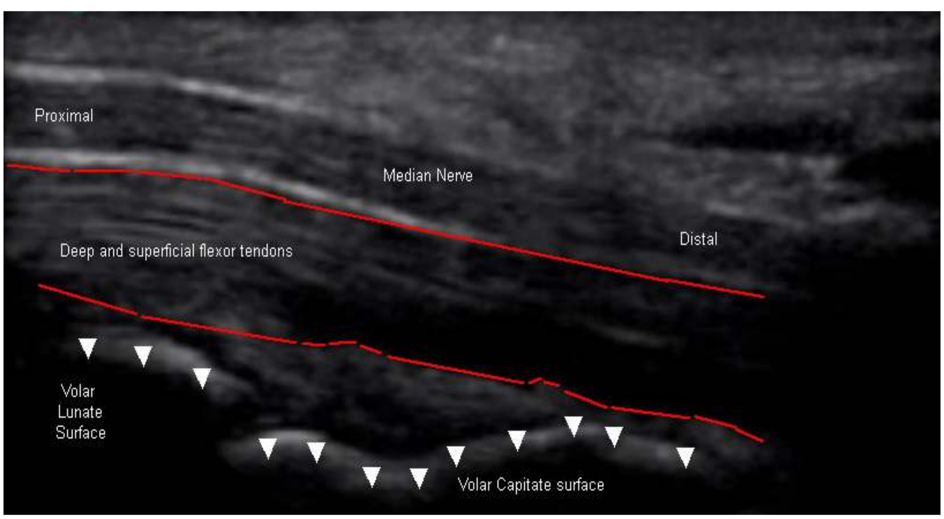
When comparing NCV results, before surgery there was decreasing speed of sensory conduction velocity (SCV) of the median nerve in all CTS cases; however, distal motor latency (DML) showed decreasing speed in 90 (90%) CTS cases and no significant changes in 10 (10%) CTS cases. Six months after surgery, SCV and DML had improved in almost all CTS cases. Before surgery, M3 and M4 sensory action potentials (SAPs) were absent in 40 (40%) cases and 54 (54%) cases respectively. After surgery, conduction velocities returned to normal in 74 (74%) cases. However, after surgery, M3 and M4 SAPs remained absent in only 4 (4%) cases (improved in 96%) (Table 2).

By using US initial swelling diminished was revealed in the CSA of the median nerve after CTS incision release in all of the cases. But, reassessment after 3 weeks showed improvement in 64 (64%) cases (Table 2).

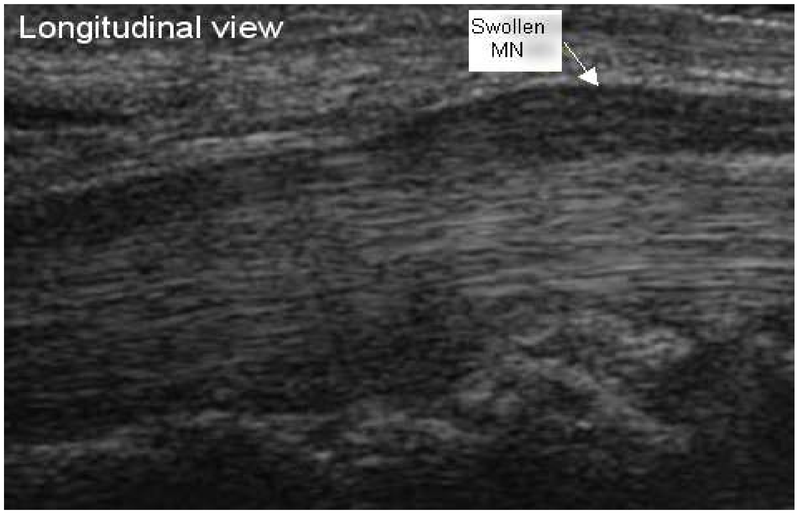
5. DISCUSSION

The exact pathophysiological manifestations of CTS are not clear. Several theories have been put forward to explain the symptoms and impaired nerve conduction. The most popular ones are mechanical compression, microvascular insufficiency, and vibration theories. Compression of a nerve affects intraneural blood flow [15,16]. Normally, the pressure is around 2 mm Hg. While, at 20 mm Hg the venular blood flow retarded, at 30 mm Hg the axonal transport impaired, at 40 mm Hg sensory and motor dysfunctions presented, and at 60–80 mm Hg complete cessation of intraneural blood flow occurred [27,28]. In addition to pressure, traction and elongation had been demonstrated to produce alterations in intraneural circulation. The pathophysiology of CTS is typically demyelination. In more severe cases, the secondary axonal loss may be present [29].

Okutsu et al. [30], were able to measure a significant drop in pressure after decompression of the carpal tunnel, which explains improvement of signs and symptoms using physiological and structural tools (EMG, NCV, and US). In spite of the diagnosis of CTS, which is based mainly on clinical symptoms and signs and nerve conduction studies, 13–27% of patients will have a normal NCV. However, no tool gave 100% accuracy [31].



A- Anatomical landmarks of the left longitudinal view of carpal tunnel



B- A case of CTS showing swollen left median nerve (MN) in distal part

Fig. 3. Ultrasonography pictures of longitudinal views (A, B)

Table 2. Comparison between electrodiagnostic and US tests in the studied CTS patients

Variables	Test	Electrodiagnostic				US
		SCV	**M3**	**M4**	**DML**	
Preoperative CTS diagnosis	Positive	100%	40%	54%	90%	86%
	Negative	0	60%	46%	10%	14%
	Positive in both tests	82%				
Postoperative improvement	After incision release	NA				100%
	Within 3 weeks	NA				64%
	After 6 months	74%				NA
Sensitivity		90%				86%
Specificity		79%				77.4%

NA=Not applicable, Sensory Conduction Velocity (SCV), M3 (third) and M4 (ring) fingers sensory action potentials, Distal Motor Latency (DML), Ultrasonography (US), Carpal Tunnel Syndrome (CTS)

During our review of articles, we found, Keles examined the role of US in 35 patients with an NCV confirmed the diagnosis of CTS and compared it to 40 normal wrists [32]. The CSA of the median nerve and bowing of the FR were significantly increased in patients with NCV-positive CTS when compared to controls. Because of similar results with us, especially, we made the intraoperative confirmation as one of the inclusion criteria. Koyuncuoglu studied the role of US in 59 patients with clinical diagnosis of CTS with negative NCV findings by comparing their results with US findings in 30 normal wrists. He found a CSA of larger than 10.5 mm in 18 patients compared to one wrist in the control group, but we did not take normal value as cut-off for diagnosis of CTS as we believe it changes according to body build and limit the success of this article. Therefore, we chose to put our patient against its own values by comparing CSA of median nerve distal end swelling more than 1.3 mm^2 of the proximal end as cut-off the diagnostic edge of CTS [33]. The results from El Miedany et al., confirmed our result also when it compared the results of US with NCV in a group of patients with CTS against a control group and observed a high degree of correlation between the US findings and NCV in diagnosing and in assessing the severity of CTS [34]. Few studies have used clinical parameters as the gold standard [6,7,35]. The specificity of the electrodiagnostic test has been reported to be 90% or better; the sensitivity has been reported to range between 49 and 90% [35]. Using clinical gold standards, Visser et al. [18], prospectively investigated 207 patients with possible CTS based on clinical signs and symptoms with the high-resolution US and electrodiagnostic tests. They concluded that the accuracy of US is similar to that of EMG. The US is probably preferable because it is painless and easily accessible and the patients preferred it in our study. We also found most of the patients (88%) preferred the US than electrodiagnostic tests if we let them choose to repeat after doing both tests in our study. We found that the CSA of the distal median nerve had the highest sensitivity and specificity for radiological tests [36,37].

US measures the structural and pathological abnormalities while electrodiagnostic tests measure the physiological malfunction [23]. Both electrodiagnostic tests and US data should be interpreted by a well-trained specialist. NCV becomes positive when nerve damage occurs, but nerve conduction may be slowed if demyelination neuropathies are established, which can explain false-positive and false negative results which may due to the presence of few nerve fibers that were still functioning [7].

The role of electrodiagnostic (EMG and NCV) in predicting the outcome of CTS decompressive surgery by assessing the relief of symptoms is not clear. In a randomized controlled trial, Schrijver et al. [38] found that NCV improved significantly at 12 months, while in our study, 6 months after surgery, SCV and DML had improved in almost all CTS cases which may be due to the strict follow-up or due to learning curves and good decompression of the median nerve. While US revealed improvement in cross section of the median nerve after CTS incision release in all of the cases which began to diminish the median nerve swelling 3 weeks later in 32 (64%) cases. However, we did not find many papers denoting the use of US for follow-up cases postoperatively and most authorities depend on questionnaire and improvement in clinical pictures.

In this study, the inclusion criteria were a combination of symptoms and neurological findings and surgical confirmation besides electrodiagnostic tests and the US which limited our study and made the results not expressed the same in the general population. The US has the advantage of low cost and easy accessibility in comparison to electrodiagnostic tests but needs a high-resolution machine which is an operator-dependent test. In the past, the electrodiagnostic study has had other roles in the treatment of CTS.

Kang et al. [39] stated that ultrasonography is a useful complementary tool for the evaluation of CTS. Both wrist-to-forearm median nerve area ratio and cross sectional area of median nerve at the wrist are highly correlated with severity grade of CTS. This is in agreement with our findings.

This study indicates that these both tests (electrodiagnostic and the US) were comparable for efficacy for the diagnosis of CTS and postoperative follow-up. But the preference of the patient to US examination as noninvasive technique may spread its usage more than electrodiagnostic tests. Another advantage of US is revealing early postoperative improvement as a morphological criterion before electrodiagnostic tests which may need time to resolve demyelination if it was in the early phase of CTS.

6. CONCLUSION

Both the tests, electrodiagnostic (EMG and NCV) and US, have nearly similar accuracy for the diagnosis of CTS and for the postoperative follow-up of the cases. But early postoperative improvement appeared by US than by EMG. We recommend that all patients who are suspected of having CTS can do ultrasonographic examination first. So if it test is positive by US no other tests will be needed; however, if the results are negative EMG and NCV can be performed, and US can be performed as a postoperative follow-up test because US is noninvasive, low-cost, and can be widespread by taking learning curve and the equipment with the preference of patients.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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