

Electrophysiological assessment of hand elevation test in the diagnosis of carpal tunnel syndrome

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Background

Provided that the hand elevation test can reproduce the symptoms of carpal tunnel syndrome (CTS), this phenomenon prompted the idea of developing a simple test to diagnose CTS.

Aim

The aim of this study was assess the electrophysiological values of the hand elevation test in the diagnosis of CTS syndrome.

Patients and methods

Thirty patients with initial symptoms and clinical signs of CTS in 49 hands were included. Special provocative tests for CTS were carried out before the hand elevation tests and the electrophysiological studies at least 5 min to avoid their effect on the intended test. The hand elevation test was performed and the test result was considered positive if symptoms occurred within 2 min. Nerve conduction study, including motor and sensory nerve conduction studies with F-wave study for both median nerves, was performed twice immediately before and after the hand elevation provocative test.

Results

This study was carried out on 60 hands; however, the initial complaint was in 49 hands, where the results showed a highly significant difference in parasthesia and hand pain, values of nerve conduction study (distal motor and sensory latencies) both before and after the hand elevation test, and a nonsignificant difference in the F-wave latencies. The posthand elevation distal motor and sensory latencies showed a sensitivity of 100 versus 78.6%, a specificity of 75 versus 81.2%, a positive predictive value of 77.8 versus 78.6%, and a negative predictive value of 100 versus 81.2%, respectively.

Conclusion

Hand elevation is a simple provocative test that could be the physical examination of choice and can be used as a first-order provocative test instead of other tests for the diagnosis of CTS. Its significant provocative value was documented electrophysiologically.

Keywords:

carpal tunnel syndrome, distal motor latencies, distal sensory latencies, electrodiagnosis, hand elevation test, Phalen's test, Tinel's test

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Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy of the upper limb. The median nerve is compressed between the transverse carpal ligament (flexor retinaculum) superiorly and the flexor tendons (flexor digitorum superficialis, flexor digitorum profundus, flexor pollicis longus) and carpal bones (scaphoid and trapezium) inferiorly [1].

The prevalence of CTS is 9.2% in women and 0.6% in men [2]. The severity of CTS ranges from mild to severe; in mild CTS, focal disturbance to myelin is the dominant factor and indeed paranodal demyelination has been documented [3].

The clinical manifestations of CTS are variable among patient populations with predominance of sensory manifestations, including paroxysmal nocturnal pain, paresthesia or hyposthesia, and tingling sensation

primarily in the finger tips, not the entire hand, in the thumb, index finger, and middle finger, together with nocturnal paresthesia in the affected digits. Nocturnal pain, weakness and atrophy of thenar muscles are late findings [4,5].

The diagnosis of CTS is made on the basis of clinical criteria such as assessment of history, physical examination, and clinical provocative tests, followed by electrodiagnostic evaluation such as nerve conduction study (NCS), electromyography (EMG), sonography of carpal tunnel, and MRI to confirm the diagnosis [6].

Clinical provocative tests such as Tinel's test, Phalen's test and reversed Phalen's test, and carpal compression test need a skillful examiner to reproduce CTS symptoms. Sonography and electrodiagnostic evaluation are expensive, invasive initial tools for the diagnosis for CTS. Therefore, there is a need for another clinical provocative test that is easy to perform,

does not need a skillful examiner, is not invasive, and has high sensitivity and specificity.

Provided that the hand elevation test can reproduce the symptoms of CTS, this phenomenon prompted the idea of developing a simple hand elevation provocative test to diagnose CTS. The sensitivity and specificity of the elevation test were higher than those of Phalen's test and Tinel's test; the sensitivity and specificity of the hand elevation test is 86.7 and 88.9%, respectively. Tinel's test has a sensitivity of 82.2% and a specificity of 88.9%. Phalen's test had a sensitivity of 84.4% and a specificity of 86.7%. Carpal compression test has been used to diagnose CTS; it has a sensitivity of 84.4% a specificity of 82.2% [7].

Aim of the work

To assess objectively, by electrodiagnosis, the hand elevation test as a clinical tool in the diagnosis of CTS.

Patients and methods

This is a prospective cohort randomized study that was carried out on 60 hands (30 patients) with symptoms and clinical signs of idiopathic CTS. They were primarily diagnosed on a clinical basis according to the American Academy of Neurology [8]. Patients were chosen from Physical Medicine, Rheumatology and Rehabilitation, and Neurology Departments of Ain Shams University Hospitals. Patients were informed about the nature of the study and their consent was obtained.

Exclusion criteria included patients with traumatic nerve lesions, peripheral neuropathies, a history of previous neurological disorders (multiple sclerosis, stroke, motor neuron disease, a known case of cervical radiculopathy, crush syndrome), a history of systemic diseases (diabetes, thyroid disorders, alcohol abuse, gout and renal disorders, pregnancy, intake of oral contraceptive pills), different rheumatic arthritidis, and recurrent or postoperative CTS.

All patients were subjected to the following

- (1) Full assessment of medical history with particular attention to disease duration, nocturnal pain and parasthesia in the affected digits, and wasting in thenar muscles.
- (2) Thorough clinical examination including sensory and motor examination of the hand.
- (3) Plain radiograph films, anteroposterior and lateral views.
- (4) Clinical assessment scales were evaluated before and after the hand elevation test such as: Pain

was evaluated using the visual analogue scale (VAS) [9], the symptom severity scale (SSS) according to Levine *et al.* [10], and the functional status scale (FSS) according to David *et al.* [11].

- (5) Special tests for CTS (Tinel's sign, Phalen's test, and reverse Phalen's test [1] with a 2-min interval between each test) were carried out before the hand elevation tests and the electrophysiological studies after at least 5 min to avoid their effect on the new attended test (which are the hand elevation test and NCS).
- (6) The hand elevation test was performed by just elevating both hands above the head and maintaining in position until the patient felt parasthesia, numbness, and dull pain in the median nerve distribution in the hand; the test result was considered positive if symptoms occurred within 2 min [12].
- (7) Electrophysiological assessment: NCS studies were used for the absolute diagnosis of CTS and they were carried out twice immediately before and after the hand elevation provocative test. They were performed in a quiet room with a constant temperature set at 27°C using a thermostat of an air conditioner. The EMG apparatus used was Toennies version 1.59 ur/pri/emg, Germany 1993 (Ain Shams University Hospitals). Bipolar surface recording electrodes were used in the NCS.

Motor NCS of the median nerve

The active electrode was placed on the motor point of the abductor pollicis brevis muscle about two-thirds proximally on the line from the metacarpophalangeal joint to the carpometacarpal joint of the thumb. The reference electrode was placed on the metacarpophalangeal joint of the thumb. Stimulating sites are at the wrist (8 cm from the active recording electrode) and at the elbow in the antecubital fossa. The stimulus intensity should be increased up to the maximal compound muscle action potential amplitude reflecting stimulation of the whole motor nerve fibers. The conduction velocity was calculated by dividing the distance between proximal and distal stimulation over the difference between the proximal and distal latencies. Mild to moderate CTS was classified according to Chang *et al.* [13].

F-wave latencies of the median nerve were obtained by stimulating the median nerve at the wrist and recording from the abductor pollicis brevis muscle. F-wave minimal and maximal latencies were obtained using 10 stimulations at a rate of once every 2 s. F-wave chronodispersion was also measured, which basically refers to the difference of maximal and minimal latencies in a series of F-waves. F-wave latencies were measured to exclude proximal root affection.

Sensory NCS of median nerves: the median sensory nerve action potential (SNAP) was obtained by applying a pulse current of 0.2 ms duration with the intensity increased gradually until SNAP reached the maximal amplitude. The sweep speed velocity was set at 1 ms/division and the gain was 20 μ V/division. The sensory conduction studies were performed using the antidromic technique. Two ring recording electrodes were placed on the index finger 4 cm apart, with the active electrode proximal at the base of the digit. Stimulation was applied 14 cm proximal to the active ring electrode and over the median nerve between the tendon of palmaris longus and flexor carpiradialis; the distal latency was recorded from take-off of the recorded SNAP [14].

Statistical methods

Analysis of data was carried out with an IBM compatible computer using statistical package for the social sciences 10 for windows (SAS Software and Services, North Carolina, USA). Descriptive statistics were calculated for continuous variables as mean, \pm SD, minimum, maximum, and range; for qualitative data of number and %, analytic statistics were calculated using Student's *t*-test to compare two independent means. The χ^2 -test was used to compare quantitative variables between the mean values of some parameters (for continuous variables). The Mann-Whitney *U*-test was used for comparison between groups of nonparametric values. A receiver-operating character (ROC) curve was constructed using Medcalc program 3.5 (MedCalc Software, Ostend, Belgium). *P* value less than 0.001 was considered highly significant (HS), whereas less than 0.05 was considered significant (S).

Results

This study was carried out on 30 patients, 23 (76.66%) women and seven (23.33%) men. They were initially presented with symptoms and signs of CTS in 49 hands out of the examined 60 hand of the over all 30 patients, with a mean complaint duration of 8.12 months \pm 2.50 SD; their age ranged from 32 to 55 years, with a mean of 42.15 \pm 6.78 SD. These descriptive and demographic data are shown in Table 1.

Did all patients have bilateral CTS to get 60 hands? (49 hands only).

Table 2 showed that there was a HS and significant statistical difference in the increase in percentage of occurrence of clinical symptoms in the form of parasthesia and hand pain specifically following the hand elevation test.

The hand elevation test was positive in 54 hands (90%) of our patients; however, the initial complaint

was only in 49 hands. Tinel's sign was positive in 29 hands (48.33%), whereas the Phalen test was positive in 25 hands (41.66%), and the reversed Phalen's test was positive in 22 hands (33.66%) as shown in Table 3.

Clinical scales were used and their values were recorded as follows

Table 4 shows that both the VAS showed a highly statistically significant difference; their values were affected by the posthand elevation test.

Table 1 Descriptive and demographic data of the 30 patients included in the study

Variant	Range	Mean \pm SD
Age (years)	32-55	42.15 \pm 6.78
Sex	Female/ male	23 (76.66%)/7 (23.33%)
Duration of complaint (months)	4.5-12	8.12 \pm 2.50
BMI (%)	28-33	28.512 \pm 3.48

Table 2 Comparison between the percentage of occurrence of clinical symptoms before and after the hand elevation test

Variant	Prehand elevation test (N=30 patients) [n (%)]	Posthand elevation test (N=30 patients) [n (%)]	κ test	Significance
Parasthesia	9 (30)	27 (90)	<0.001*	HS
Hand pain	18 (60)	27 (90)	0.007	S
Parasthesia and Hand pain	3 (10)	27 (90)	<0.001*	HS

Table 3 Percentage of data of variable clinical tests among our 30 patients in 60 examined hands

Variant	Positive test/N=60 hands	%
Hand elevation test	54/60	90
Tinel's sign	29/60	48.33
Phalen's test	25/60	41.66
Reversed Phalen's test	22/60	36.66

Table 4 Different clinical scales data obtained before and after the hand elevation test for the median nerve in our 30 patients

Variant	Prehand elevation test (N=30 patients) (mean \pm SD)	Posthand elevation test (N=30 patients) (mean \pm SD)	<i>T</i> -test	<i>P</i> value	Significance
Visual analog scale (VAS)	5.321 \pm 1.833	6.555 \pm 1.737	6.638	0.000	HS
Symptom severity scale (SSS)	1.890 \pm 1.123	2.213 \pm 0.731	8.705	0.573	NS
Functional status scale (FSS)	2.130 \pm 1.213	2.531 \pm 0.831	0.241	0.815	NS

HS, highly significant.

The electrophysiological data of the median nerves examined show a HS statistical delay in the values of the distal motor latencies (DML) and distal sensory latencies when the posthand elevation test was performed compared with the values recorded before the hand elevation test, whereas the F-wave latencies responses as well as the values of motor and sensory amplitudes were nonsignificantly affected by the hand elevation test as shown in Table 5.

In order to compare the diagnostic accuracies of each test, the area under the nonparametric ROC curve was applied to DML and distal sensory latency (DSL) variables as shown in Tables 6 and 7.

The ROC analysis curve is a method to compare the results of various tests and to evaluate the diagnostic accuracy of a test for the same outcome. An ROC curve is a plot of the sensitivity (true-positive) against false-negative specificity to calculate the sensitivity of all values available. Thus, it can evaluate the balance between sensitivity and specificity of a diagnostic test over a variety of cutpoints. An ROC analysis curve was constructed for both DML and DSL variables as shown in Figs 1 and 2.

The positive predictive value was calculated as

$$\frac{\text{True positive value}}{\text{True positive value} + \text{false positive}} \times 100\%$$

The negative predictive value was calculated as

$$\frac{\text{True negative value}}{\text{True negative value} + \text{false negative}} \times 100\%$$

Discussion

CTS is the most common peripheral compressive entrapment neuropathy that occurs with the compression of the median nerve in the carpal tunnel

at the wrist and its incidence is 1% of the population. CTS is considered a sensory disorder mainly because the sensory fibers may be affected more than the motor fibers [15]. Therefore, patients with CTS complain of sensory symptoms such as dull pain and tingling sensation in the thumb, index, and middle finger or parasthesia and stiffness of the hand at night [16].

The pathophysiology of CTS is not clear; yet, there is a hypothesis that entrapped carpal tunnel increases nerve compression pressure and may cause ischemia of microcirculation of the nerve by compressing the vessel in perineurium [17].

The diagnosis of CTS is very difficult and can be controversial. CTS can be diagnosed by assessment of history, clinical physical examination, and confirmatory studies. Confirmatory studies such as nerve conduction velocities studies and EMG can be very helpful in the diagnosis of CTS as they remain gold standard diagnostic and reliable tools with sensitivity greater than 90% [18] and specificity greater than 95% [19]. Yet, electrodiagnostic tests are expensive, invasive, and cannot be used in all local medical centers.

To date, Phalen's test and Tinel's sign have been used as diagnostic criteria in the physical examination. However, the results of each test depend on the physician's examination skills, with variable sensitivity and specificity [20,21]. Therefore, there is a need for a simple clinical provocative test that is cost effective, sensitive, and specifically for the diagnosis of CTS.

As the ischemic attack to the median nerve is related to the pathophysiology of CTS, and as hypothesized, hand elevation above the shoulder may be the cause of ischemia of the median nerve [22], this raises the idea beyond the importance of the study of the

Table 5 Electrophysiological values before and after the hand elevation test of the median nerve in DML, DSL, and F-wave latencies

Variant	Prehand elevation test (N=30 patients)	Posthand elevation test (N=30 patients)	T-test		Significance
			T	P value	
DML (ms)					
Range	4.1–7.8	4.5–9.2	–6.638	0.000	HS
Mean ± SD	5.871 ± 1.063	6.848 ± 1.352			
Motor amplitude (mV)					
Mean ± SD	7.651 ± 3.045	8.431 ± 2.341	2.951	0.071	NS
DSL (ms)					
Range	3.1–4.8	4.3–6.1	–5.790	0.000	HS
Mean ± SD	4.294 ± 0.398	5.10 ± 0.603			
Sensory amplitude (µV)					
Mean ± SD	4.951 ± 3.243	5.431 ± 2.379	1.895	0.096	NS
F-wave(ms)					
Range	24.2–31.1	25–29.2	–0.126	0.901	NS
Mean ± SD	26.1755 ± 1.21	26.23 ± 1.873			

DML, distal motor latency; DSL, distal sensory latency; HS, highly significant.

HS: P value < 0.001.

NS: P value > 0.05.

electrophysiological value of the hand elevation test in the diagnosis of the CTS. The hand elevation test does not need a skillful examiner, it is a very simple test to perform, just elevating the hand above the shoulder in the air freely and waiting for the occurrence of symptoms of CTS, it is cost effective, and can be performed within 2 min.

The aim of our study was to evaluate the electrophysiological diagnostic value of before and half hand elevation test in the diagnosis of CTS as an attempt to document the importance of the hand elevation test as a bedside diagnostic test.

We carried out our study on 30 patients, with 60 hands examined. Two-three (76.66%) women and seven (23.33%) men presented with symptoms and signs of

Table 6 Sensitivity, specificity, PPV, NPV, and accuracy of the value of DML of the hand elevation test

ROC curve DML values of the hand elevation test					
Cutoff	Sensitivity	Specificity	PPV	NPV	Accuracy
>4.96	100.0	75.0	77.8	100.0	0.931

DML, distal motor latency; NPV, negative predictive value; PPV, positive predictive value; ROC, receiver-operating characteristic.

Table 7 Sensitivity, specificity, PPV, NPV, and accuracy of the value of DSL of the hand elevation test

ROC curve DSL values of the hand elevation test					
Cutoff	Sensitivity	Specificity	PPV	NPV	Accuracy
>4.4	78.6	81.2	78.6	81.2	0.801

DSL, distal sensory latency; NPV, negative predictive value; PPV, positive predictive value; ROC, receiver-operating characteristic.

CTS and were diagnosed according to the American Academy of Neurology Clinical Diagnosis Criteria [8].

Their mean complaint duration was 8.12 months ± 2.50 SD and their age ranged from 32 to 55 years, with a mean of 42.15 ± 6.78 SD.

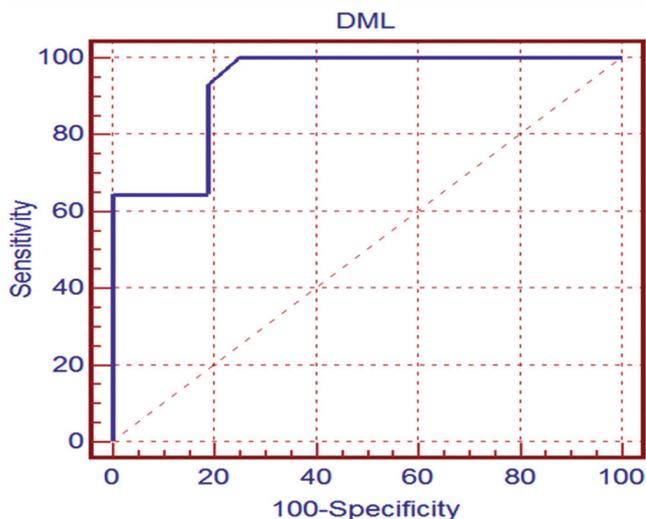
The hand elevation test performed was positive in 54 hands (90%); however, Tinel’s sign was positive in 29 hands (48.33%), the Phalen test was positive in 25 hands (41.66%), and the reversed Phalen’s test was positive in 22 hands (33.66%).

Our demographic data were in agreement with those of Ma and Kim [7], who studied 45 hands of 38 patients diagnosed with CTS according to the American Academy Criteria; the hand elevation test showed a sensitivity and a specificity of 86.7 and 88.9% as a clinical test.

The hand elevation test is a new provocative test for the diagnosis of CTS; in a study by Amirefeyz *et al.* [23], who investigated 48 patients clinically diagnosed with CTS with the hand elevation test and compared it with Tinel’s and Phalen’s tests, the sensitivity and specificity were found to be 88 and 98%, respectively, indicating that this test is a reproducible, easy-to-use test for CTS.

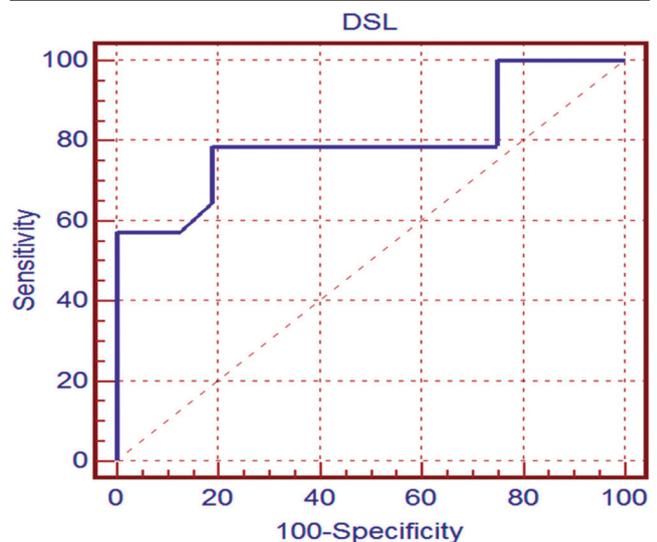
On comparing the occurrence of clinical symptoms in the form of paresthesia and hand pain, there was a HS ($P < 0.001$) and a significant statistical ($P > 0.05$) difference, respectively, comparing these complaints both before and after the hand elevation test. This increased percentage of occurrence of the clinical symptoms in the examined hand supports the hypothesis of

Figure 1



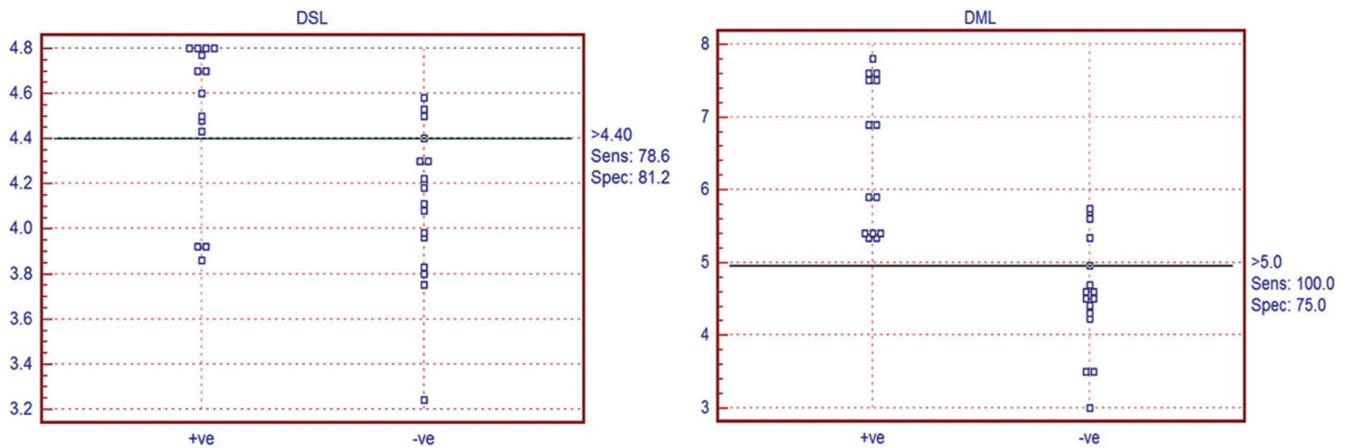
The receiver-operating characteristic curve for the hand elevation test for distal motor latency (DML) values after the hand elevation test.

Figure 2



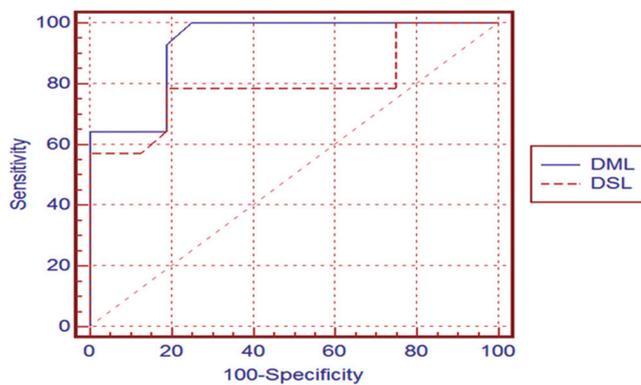
The receiver-operating characteristic curve for the hand elevation test for distal sensory latency (DSL) latency of after the hand elevation test.

Figure 3



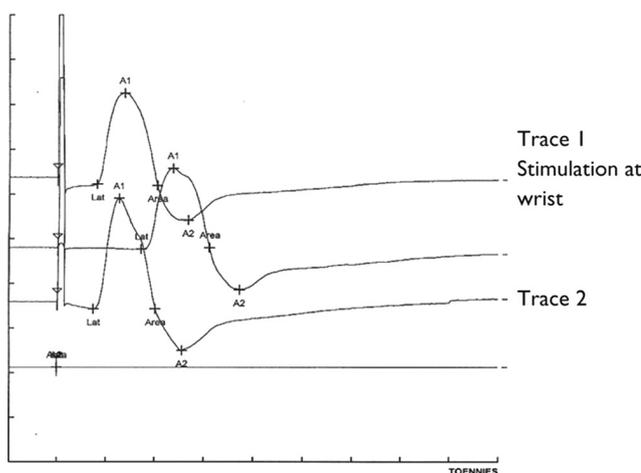
Cut-off values of the distal sensory latency (DSL) and distal motor latency (DML) after the hand elevation test, which were 4.40 and 5.0 ms, respectively.

Figure 4



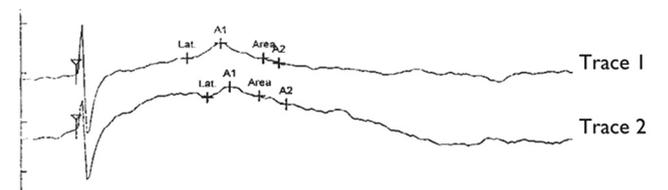
The presence of a larger area under receiver-operating characteristic curve (as regards DML and DSL) that indicates high accuracy of the hand elevation test that yielded the following statistical values including difference between areas ($=0.129$) with SE ($=0.067$), 95% confidence interval ($=-0.003$ to 0.262), and significance level ($P = 0.055$). DML, distal motor latency; DSL, distal sensory latency.

Figure 6



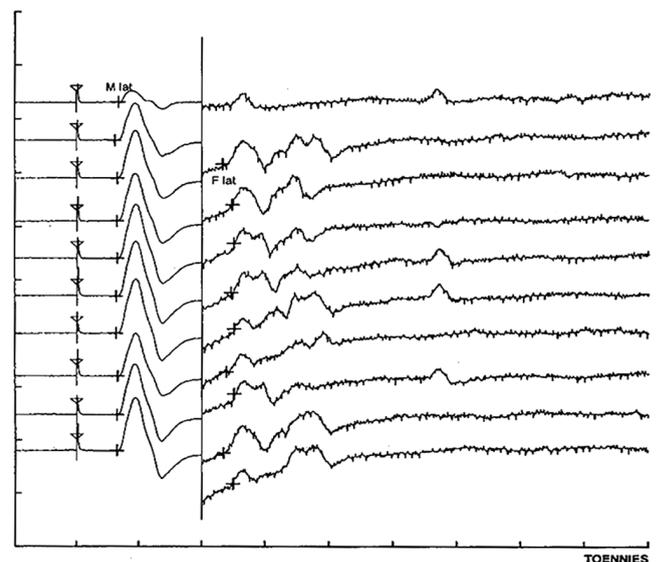
MUAP. Trace 1 DML (before hand elevation) 3.7 ms amplitude of 11.9 mV. Trace 2 DML (after hand elevation) 4.2 ms amplitude of 11.9 mV. DML, distal motor latency.

Figure 5



SAP. Trace 1 (before hand elevation) DSL: 4.0 ms amplitude of 7.8 mV). Trace 2 (after hand elevation) DSL: 4.7 ms amplitude of 7.8 mV. DSL, distal sensory latency.

Figure 7



F wave. Mean of proximal latency: 24.6 ms. 90% persistence. $F_{max} - F_{min} = 1.8$ ms.

provocation of tingling and numbness and hand pain by the performance of the hand elevation test. This is in agreement with the hypothesis of an ischemic attack to the median nerve being related to the pathophysiology

of CTS; hand elevation above the shoulder may be the cause of ischemia of the median nerve [24].

On comparing our results of clinical assessment scales (VAS, SSS, and FSS) before and after the performance of the hand elevation test, there was a highly statistically significant difference ($P > 0.001$) in VAS that could have been because of the affection of VAS by pain and parasthesia; yet, there was no significant difference ($P > 0.05$) in the SSS and FSS, which is in agreement with Karatay *et al.* [25] and El Sheshtawy *et al.* [26], who concluded that the use of local corticosteroids in idiopathic carpal tunnel would result in a significant reduction in VAS and SSS as well as a significant decrease in both distal motor and sensory latencies because of decreased compression on the median nerve owing to a reduction in inflammatory response.

Our electrophysiological data of the median nerve examined as it passes in CTS indicated a highly statistically significant delay in the values of the DML and distal sensory latencies ($P < 0.001$) after the hand elevation test compared with the values recorded before the hand elevation test, whereas the F-wave latencies responses showed a nonsignificant difference ($P > 0.05$) when assessed before and after the hand elevation test. This excludes the element of proximal root compression affection by the hand elevation test.

Our results did not show any statistically significant difference in the amplitude of both compound muscle action potential and SNAP before and after the hand elevation test, which could be attributed to insufficient compression to produce recordable axonal affection.

This supports our hypothesis of the compression induced by the hand elevation test in increasing the pressure by causing venous congestion and blockage around the nerve fibers, causing circulatory stasis and mechanical compression around the nerve.

The distal motor and sensory latencies after the hand elevation test showed a sensitivity of 100 versus 78.6%, a specificity of 75 versus 81.2%, a positive predictive value of 77.8 versus 78.6%, and a negative predictive value of 100% versus 81.2%, respectively. The cut-off values of the DSL and DML after the hand elevation test were 4.40 and 5.0 ms, respectively. Thus, the hand elevation test can be used as a positive predictive test in the diagnosis of CTS with a 95% confidence interval ($= -0.003$ to 0.262) and significance level ($P = 0.055$). These findings were in agreement with the study of nerve conduction tests using ROC curves to confirm the accuracy of the tests examined [20].

There are many tests for evaluation of the sensitivity and specificity of the carpal compression test. A major limitation is that the sensitivity and specificity of the carpal compression tests depend on the physician's skills of examination and available tools (EMG device, high resolution ultrasonograph, MRI); some of them are very expensive and not available in every clinical facility as reported by several studies by [7,26,27]. Therefore, there is a need for a reliable bedside, simple to use, reproducible, cost-effective, sensitive, and specific physical examination test for the diagnosis of CTS.

The hand elevation test appears to have several advantages in the diagnosis of CTS as it does not require a skillful examiner, and it is very simple; the hand is elevated above the shoulder in the air freely and until the patient starts experiencing symptoms after a few minutes (parasthesia, numbness, and hand pain) such that the patient can note their occurrence. In addition, it is cost effective, besides assessment of history, and can be performed within 2 min of a short examination time actively or passively (or in patients who cannot tolerate other clinical tests as in cases of recent burn, operations, fractures, traumatic lacerations, or when tapping and direct pressure are intolerable). Finally, the hand elevation test has a positive predictive value in diagnosing CTS.

Conclusion

The hand elevation test can be performed by just elevating both hands of a patient above the shoulder in the air freely. It is a simple, sensitive, and specific provocative test for the diagnosis of CTS. It could be a physical examination test of choice and can be used as a first-order provocative, bedside, and easy-to-use test instead of Tinel's test, Phalen's test, and carpal compression test, and other tests; especially, in this study, we documented their provocative value electrophysiologically (Figs 3–7).

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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