

# Electrophysiological Phalen's provocation test in carpal tunnel syndrome

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## Objective

Routine nerve conduction studies (NCS) are considered the golden standard for the objective diagnosis of clinically detectable carpal tunnel syndrome (CTS); however, fallacies can still befall. Clinically, Phalen's provocation test has proven reliability for screening CTS, yet, its use during NCS is still to be assessed. Thus, we aim to evaluate the role of our newly proposed electrophysiological Phalen's provocation test (EPPT) in the diagnostic work-up of CTS.

## Patients and Methods

One-hundred clinically suspected CTS hands and forty healthy hands were included in this study. Routine median motor and sensory NCSs were performed twice; once before and secondly, after provocation with wrist in 90 degrees flexion for 60 seconds (EPPT).

## Results

All patients showed significantly delayed median distal motor and sensory latencies than controls ( $P < 0.001$ ). After EPPT, the percentage of change in median nerve distal sensory latency (MDSL) only was significantly higher in patients compared to controls ( $P < 0.05$ ). Moreover, the increased MDSL after provocation was more significant among clinically Phalen's positive hands ( $P = 0.001$ ). In addition, a cut off value of 3.2 msec could detect median sensory neuropathy at the thumb after provocation and it showed better performance than distal sensory recording before provocation.

## Conclusion

EPPT might be promising for early detection of sensory neuropathic changes in CTS.

## Keywords:

carpal tunnel, electrodiagnosis, Phalen's test, provocative tests

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## Introduction

Carpal tunnel syndrome (CTS) accounts for 90% of all entrapment neuropathies [1]. The syndrome may present with numbness or tingling in the hand, pain that awakens the patient from sleep, and, finally, atrophy and weakness of the hand muscles [2].

Phalen's provocation test [3] has proved to be sensitive and specific for confirming the clinical diagnosis of CTS [4,5]. Ntani *et al.* [6] supported the use of Tinel's and Phalen's tests as filters when referring patients with possible CTS for nerve conduction studies (NCS).

Electrodiagnosis is considered the golden standard for the objective diagnosis of clinically detectable CTS [7,8]. However, false negative and false positive results can still occur, resulting in 16–34% of clinically defined CTS being missed with NCS [1]. Accordingly, for the decision of surgical decompression, surgeons usually depend on combination of signs, symptoms, and findings from NCS altogether [9,10]. Hence, we

planned to evaluate the usefulness of using Phalen's provocative test during the electrodiagnosis of CTS.

## Objective

This work was designed to assess the diagnostic value of applying Phalen's provocation technique during electrophysiological studies for clinically suspicious CTS cases (electrophysiological Phalen's provocation test, EPPT).

## Patients and methods

The study was a prospective case–control study conducted at Physical Medicine & Rehabilitation Department, Electrophysiological Laboratory. The nature of the study was explained for patients and controls and a written consent for participation was

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obtained. Approval of the Institute Medical Ethical Committee was granted for the study.

### Study groups

The study included 100 hands of 56 patients with symptoms and clinical signs suggestive of idiopathic CTS. They were primarily diagnosed on a clinical basis according to practice guidelines by Rempel *et al.* [11].

Exclusion criteria included patients with previous hand or wrist injury, traumatic nerve lesion, peripheral neuropathy, history of previous neurological disorder (multiple sclerosis, stroke, and cervical radiculopathy), history of systemic disease (diabetes, thyroid, alcohol abuse, renal disease), pregnancy or intake of contraceptive pills, rheumatic arthritis, and recurrent or postoperative CTS. Exclusion was based on clinical assessment, radiological findings, and NCS with F-wave and electromyography if necessary.

The control group included 40 hands of 20 healthy matched volunteers, not complaining of any sensory or motor symptoms, with free neurological examination and negative clinical and electrodiagnostic tests for CTS.

### Methodology

Patients and controls were subjected to the following:

- (1) Full medical history assessment with particular attention to disease duration, nocturnal pain, and paresthesia in affected digits. Clinical suspicion was based on symptoms of nocturnal or activity-related pain and/or paresthesia in the median nerve distribution or whole hand, as well as pain relief with hand shaking [12].
- (2) Thorough clinical examination including sensory and motor hand examination; search for hypoesthesia in the median nerve distribution with or without weakness of thumb abduction; and/or opposition with or without atrophy of the thenar muscles.
- (3) Special tests:

These included Tinel's and Phalen's provocation tests [13]. Clinical Phalen's provocation test (CPPT) was done for all patients and controls as follows: the patient placed the elbow on the examination table and the forearm remained flexed and perpendicular to the table while the wrist fell down to complete flexion with gravity by the weight of the hand. This position was maintained for 1 min and test considered positive if symptoms of occurrence or aggravation of

paresthesia within the region supplied by the median nerve was reported [3,5].

### (4) Electrophysiological assessment:

NCS were used for definite diagnosis of CTS according to the practice recommendations of American Association of Electrodiagnostic Medicine for electrodiagnosis of CTS by Jablecki *et al.* [14].

We used Toennies Neuro-screen device (Schwarzer \Topaz; made in Germany) electrodiagnosis device. In motor studies, responses were recorded at a sweep speed of 5 ms/division and gain of 4 mV. In sensory studies, sweep was adjusted at 2 ms and gain at 20  $\mu$ V. Temperature was kept constant through all the tests at 33–34°C.

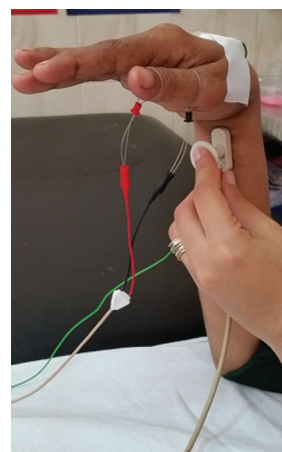
The electrophysiological studies were done for both patients and controls. Median motor and sensory distal latencies were recorded once in neutral position and recorded another time during wrist provocation in 90° flexion for 1 continuous minute (EPPT), provided there was no change in the site of stimulating and recording electrodes (Fig. 1).

### Sensory studies

Routine median nerve sensory recording was done from the first digit with wrist stimulation in the neutral position 10 cm proximal to G1 with recording ring electrodes (G1 over proximal phalanx and G2 over the distal phalanx).

Median-versus-radial sensory latency difference (MRS�) was calculated, where radial nerve was stimulated at the wrist over lateral radius in the

**Figure 1**



The position of the hand during Electrophysiological Phalen's provocation test (sensory stimulation of the median nerve).

neutral position using identical distances (10 cm) proximal to G1 with recording ring electrodes over digit 1 (G1 over proximal phalanx and G2 over the distal phalanx). Peak latencies of sensory nerve action potentials of both nerves were compared.

#### Motor studies

**Routine median motor NCS:** it was recorded from abductor pollicis brevis muscle and stimulated at wrist 8 cm proximal to recording electrodes and at the elbow. Distal motor latency, amplitude, and conduction velocity were determined. F-wave latencies of the median nerves 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. Routine ulnar motor NCS was done while stimulating at wrist, below elbow, and above elbow and recording from abductor digiti-minimi muscle.

#### Statistical analysis

The collected data were coded, tabulated, and statistically analyzed using IBM SPSS statistics

software, 2013, version 22.0 (IBM Corp., Chicago, Illinois, USA). Descriptive statistics were done for quantitative data as minimum and maximum of the range, as well as mean $\pm$ SD for quantitative parametric data. Statistical analysis were done using 95% confidence interval and independent *t*-test in cases of two independent groups with parametric data; for the nonparametrically distributed data, Mann–Whitney test (*Z*) was used. Receiver operating characteristic curve analysis was used to evaluate the performance of different tests and to differentiate between certain groups. *P* value less than or equal to 0.050 was considered significant, *P* value less than or equal to 0.001 was considered highly significant, and otherwise considered nonsignificant.

#### Results

The patients' group included 46 females and 10 males whose ages ranged from 22 to 57 years with a mean of 39.5 $\pm$ 17 years. The control group included 17 females and three males whose ages ranged from 24 to 52 years with a mean of 38 $\pm$ 14 years. Both groups were matched with no significant difference regarding age or sex (*P*>0.05). Duration of symptoms among the patients ranged from 1.5 to 12 months with a mean of 5.5 $\pm$ 4 months.

Clinical data and special tests done for our patients are shown in Table 1. Electrophysiological findings of patients and controls before and after EPPT are shown in Table 2.

There was a statistically high significant difference between patients and controls regarding both median motor and sensory latencies (*P*<0.001) before provocation and after provocation. No difference was detected regarding median motor amplitude or

**Table 1 Distribution of clinical data among the patients**

Clinical findings	Patients' hands ( <i>n</i> =100)
Activity-related hand pain and paresthesia	70
Tingling and numbness (lateral 3 and half fingers)	89
Nocturnal pain and paresthesia (relieved by hand shaking)	80
Hypoesthesia	69
Weakness of abductor pollicis/thenar atrophy	8
Phalen's test positive	72
Tinel's test positive	45

The most predominant presentation/clinical finding among the patients was tingling and numbness followed by nocturnal pain/paresthesia and then positive Phalen's test.

**Table 2 Electrophysiological findings of the patients in comparison with normal controls**

Latencies (ms)	Participants	<i>N</i>	Mean $\pm$ SD	Range	95% CI	<i>P</i> <sub>a</sub>	Significance
MDML before provocation	Patient	100	3.7 $\pm$ 0.7	2.4–5.3	3.5–3.9	<0.001*	HS
	Control	40	3.0 $\pm$ 0.3	2.4–3.8	2.9–3.1		
MDML after Phalen's provocation	Patient	100	3.9 $\pm$ 0.7	2.5–5.2	3.7–4.0	<0.001*	HS
	Control	40	3.2 $\pm$ 0.3	2.5–4.0	3.1–3.3		
%ΔMDML	Patient	100	4.7 $\pm$ 5.7	0.0–31.4	3.4–6.0	0.455	NS
	Control	40	5.1 $\pm$ 4.5	0.0–15.2	3.8–6.4		
MDSL before provocation	Patient	90	3.4 $\pm$ 0.4	2.1–4.5	3.3–3.5	<0.001*	HS
	Control	40	2.6 $\pm$ 0.3	2.4–2.9	2.8–2.9		
MDSL after Phalen's provocation	Patient	90	3.5 $\pm$ 0.5	2.1–5.0	3.4–3.7	<0.001*	HS
	Control	40	2.9 $\pm$ 0.3	2.4–3.3	2.8–3.0		
%ΔMDSL	Patient	90	4.7 $\pm$ 4.1	0.0–15.2	3.7–5.6	0.017*	S
	Control	40	2.8 $\pm$ 4.0	0.0–20.0	1.7–3.9		

CI, confidence interval; HS, highly significant; MDML, median distal motor latency; MDSL, median distal sensory latency; %Δ, percentage of change in latency; S, significant. <sup>a</sup>Independent *t*-test. \*Significant.

conduction velocity. No significant difference was noticed regarding ulnar motor parameters, radial sensory parameters, or F-wave latencies ( $P>0.05$ ).

The percentage of change (% $\Delta$ ) in median distal latencies (motor and sensory) after wrist flexion for 1 min (EPPT) was calculated using the following equation:

$$\left( \frac{\text{Distal nerve latency after provocation} - \text{value before provocation}}{\text{Value before provocation}} \right) \times 100.$$

A significant difference between patients and controls was detected regarding mean percentage of change in median nerve sensory latency (% $\Delta$ MDSL) after provocation ( $P<0.05$ ). On the other hand, no significant difference was detected regarding percentage of change in median motor latency (% $\Delta$ MDML) after provocation among patients and controls ( $P>0.05$ ), as seen in Table 2.

CPPT hands showed a significantly higher % $\Delta$ MDSL compared with the CPPT negative hands ( $P=0.001$ ), as seen in Fig. 2.

In our study, 90% of the symptomatic hands were true positive for CTS by one or more gold-standard basic electrodiagnostic tests of CTS [14], and all the controls were true negative.

Diagnostic performance testing using receiver operating characteristic curve analysis for median nerve distal sensory latency testing before and after EPPT used to detect median neuropathy at wrist is seen in Table 3. It is worth mentioning that a cutoff value of 3.2 ms can be used to detect median sensory neuropathy at the thumb after provocation, and it showed better performance

than distal sensory recording before provocation. In our work, MRS� difference at a cutoff value of 0.4 ms could be detected in eight out of the 10 patients who could not be previously diagnosed by one or more of the golden conventional tests for detecting CTS.

## Discussion

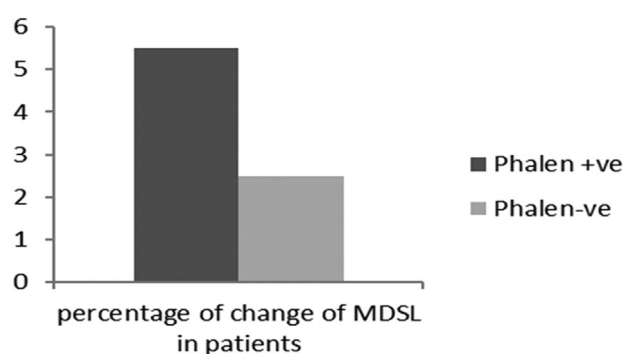
Electrodiagnostic studies are considered the gold standard for confirming the diagnosis of CTS because of their objectivity, but still some patients with clinical symptoms can remain undiagnosed by routine electrodiagnostic testing [15,16]. This necessitates the search for new tests to confirm the early electrodiagnosis of CTS.

In this work, we evaluated the effect of the Phalen's provocation with wrist flexion during electrodiagnostic testing of CTS (EPPT). Electrophysiological testing revealed significant difference between clinically suspicious CTS hands and healthy controls regarding both median motor and sensory latency both before and after EPPT, but no difference regarding median motor amplitude or conduction velocity mostly because most of our patients presented with early CTS with symptom duration less than 6 months.

In the current study, there was no difference between patients and healthy controls regarding % $\Delta$ DML after EPPT. However, a significant difference was detected between patients and healthy controls regarding % $\Delta$  MDSL after EPPT ( $P<0.05$ ). Sensory nerve fibers seem to be more sensitive to compression neuropathy than motor fibers. Also, sensory fibers typically demonstrate changes on NCS earlier than motor fibers [7].

Previous studies that assessed the value of wrist flexion in electrodiagnosis of CTS were controversial, as some suggested that it added no value to conventional studies [17], whereas others suggested it could be useful in borderline cases [18,19]. In this work, we

Figure 2



Bar chart showing the highly significant percentage of change of median distal sensory latency (MDSL) after Electrophysiological Phalen's provocation (EPPT) among the clinical Phalen's provocation test (CPPT) positive patients compared to the (CPPT) negative hands ( $P=0.001$ ).

Table 3 Diagnostic performance test for median distal sensory latency recorded both before and after provocation for predicting carpal tunnel syndrome

Test	AUC	SE	P	95% CI
MDSL before provocation	0.851	0.033	<0.001*	0.786–0.916
MDSL after Phalen's provocation	0.873	0.031	<0.001*	0.813–0.934

AUC, area under the curve; CI, confidence interval; MDSL, median distal sensory latency. \*Median distal sensory latency recorded after EPPT shows higher diagnostic performance for CTS compared to before provocation (i.e. highly significant because whenever area under curve gets bigger towards 1 the more its significant).



assessed the diagnostic performance of EPPT versus conventional testing of sensory distal latency in neutral position. MDSL after EPPT showed higher diagnostic performance compared with MDSL before provocation, denoting its value in confirming CTS in borderline cases.

Phalen's provocation test is commonly used for clinical diagnosis, and screening of CTS. Its estimated sensitivity is 68% and specificity is 73% [5]. In our study, clinical Phalen's test was positive in 72% of the symptomatic hands. Clinical Phalen's test positive patients revealed a highly significant  $\Delta$ MDSL after EPPT compared with clinically negative Phalen's test patients ( $P=0.001$ ). This might be attributed to further compression of the sensitive sensory fibers with wrist flexion in predisposed patients. This finding is consistent with the previous old work of Boland and Kiernan [20], who found that a positive clinical Phalen's test was more likely to be associated with NCS changes that are consistent with CTS.

Furthermore, we found that MRS� difference increased after provocation to a value of 0.4 ms in eight of the patients who were otherwise missed by other conventional tests of CTS. However, we could not confirm CTS in those patients as the radial nerve distal latency was not recorded in the flexed position after provocation, considered a contemporary limitation of our study.

## Conclusion

We conclude that EPPT is complementary to clinical Phalen's provocative test. Moreover, it may add supplementary benefit to the electrodiagnostic study by confirming early median sensory neuropathy in clinically suspected CTS hands. Although the test was unsatisfactory for some of the patients because of symptoms exacerbation with wrist flexion, yet, it is recommended to be studied on a larger group of patients with mild symptoms who could not be diagnosed by other electrophysiological sensitive tests for CTS.

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Nil.

## Conflicts of interest

There are no conflicts of interest.

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