

İDİOPATİK HAFİF KARPAL TÜNEL SENDROMLU HASTALARDA FARKLI ELEKTRODİAGNOSTİK ÇALIŞMALARIN DUYARLILIĞI

SENSITIVITIES OF THE ELECTRODIAGNOSTIC TESTS IN IDIOPATHIC MILD CARPAL TUNNEL SYNDROME

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ÖZ

AMAÇ: Karpal Tünel Sendromu (KTS) en sık görülen tuzak nöropatisidir. Tanısı klinik bulgularla ile konulabilir, ancak tanıyı doğrulamak ve tedaviyi planlamak için elektrodagnostik çalışmalara ihtiyaç vardır. Bu çalışmada, idiyopatik hafif KTS'li hastalarda klinik semptomlar ve provokatif testler ile elektrodagnostik testlerin duyarlılığını değerlendirmek amaçlandı.

GEREÇ VE YÖNTEM: Çalışmaya 75 idiyopatik hafif KTS tanılı hasta (90 el) ve 15 sağlıklı gönüllü (30 el) alındı. Hastalarda median sinir innervasyon alanında ağrı, parestezi, elde güçsüzlük, uyku sırasında artan ağrı ve uyuşma ile elleri silkeleme ile şikayetlerde rahatlatma semptomları sorgulandı; Tinel ve Phalen testleri yapıldı. Elektrodagnostik incelemede; median sinir motor, miks, 1-2-3-4. parmak ve avuç içi duyuşal iletim çalışmaları, ulnar sinir motor, miks ve 5. parmak duyuşal iletim çalışmaları, median ve ulnar F dalgası, radial sinir 1. parmak duyuşal iletim çalışması yapıldı. Çalışılan tüm sinirler için distal latans ve sinir iletim hızı değerleri hesaplandı. Parmak (1, 2, 3, 4) ve avuç içi median duyuşal distal latansları ve iletim hızlarının; karşılaştırmalı elektrodagnostik testlerden 1. parmaktan median-radial duyuşal distal latans farkının (DDLDF), 4. parmaktan median-ulnar DDLDF, 2-5, 3-5, 4-5. parmaklar arasında median-ulnar DDLDF; median ve ulnar F dalgası latans farklarının duyarlılığı hesaplandı.

BULGULAR: İdiyopatik hafif KTS'li hastalarda en sık rastlanan iki semptom parestezi (%95.6) ve gece uyuşması (%88.8) idi. Phalen testi ve Tinel testlerinin duyarlılığı sırasıyla %67.8 ve %56.7 olarak bulundu. Elektrodagnostik testlerin sonuçları değerlendirildiğinde, 1. parmak-bilek ve avuç içi-bilek segmenti duyuşal iletim hızı çalışmaları %98.9 ile duyarlılığı en yüksek testler olarak bulundu. Uygulanan karşılaştırmalı testlerden 4-5. parmak median-ulnar DDLDF %93.3 ile en duyarlı karşılaştırmalı test olarak tespit edildi. Median-ulnar F latans farkı duyarlılığı en düşük test (%38.9) olarak saptandı.

SONUÇ: En duyarlı elektrodagnostik testler 1. parmak-bilek ve avuç içi-bilek segmenti duyuşal iletim hızıydı. 4-5 parmak median-ulnar DDLDF diğer karşılaştırmalı sinir iletim çalışmalarından daha duyarlı olarak bulundu. KTS elektrodagnostik tanısında bu testlerin kullanılması ile duyarlılık artırılabilir.

ANAHTAR KELİMELE: Karpal tünel sendromu, elektrodagnostik test, duyarlılık

ABSTRACT

OBJECTIVE: Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy. The diagnosis is based on the history, clinical signs and symptoms of the patient, but electrodiagnostic studies are done to confirm the diagnosis and to manage the treatment. This study aimed to assess sensitivities of clinical symptoms, provocative tests and electrodiagnostic studies (EDS) in patients with idiopathic mild CTS.

MATERIAL AND METHODS: The study included 90 hands of 75 patients with idiopathic mild CTS and 30 hands of 15 healthy volunteers. The patients were questioned for symptoms in the innervation area of the median nerve such as pain, paresthesia, weakness in the hand and numbness and pain worsening at night, relief from the symptoms by shaking hands. Tinel and Phalen tests were done. The EDS included; motor, mixed and sensorial (digits 1-2-3-4 and palm) nerve conduction studies (NCS) for median nerve; motor, mixed and sensorial (fifth digit) NCS for ulnar nerve, sensorial NCS (first digit) for radial nerve, median and ulnar F waves. The values for distal latency and nerve conduction velocity (NCV) were calculated for all studied nerves. Sensitivities of median sensory distal latency and NCV to digits 1,2,3,4 and palm-wrist segments and sensitivities of the following comparative tests were detected; median-radial sensory distal latency difference (SDLD) to the first digit, median-ulnar SDLD to the fourth digit, median-ulnar SDLD to the digits 2-5, 3-5, 4-5 and median-ulnar F latency difference.

RESULTS: The most common symptoms in patients with idiopathic mild CTS were paresthesia (95.6%) and nocturnal numbness (88.8%). The sensitivity of Phalen's and Tinel's tests were 67.8% and 56.7%, respectively. Among the EDS, first digit and palm-wrist sensorial NCV were the most sensitive tests (98.9%). Of the comparative tests, median-ulnar SDLD to digits 4-5 was the most sensitive one (93.3%). Median-ulnar F latency difference had the lowest sensitivity (38.9%).

CONCLUSIONS: The most sensitive EDS were first digit and palm-wrist sensorial NCV. Median-ulnar SDLD to digits 4-5 was more sensitive than the other tests. With use of these tests, the diagnostic sensitivity of EDS may be increased in patients with mild CTS.

KEYWORDS: Carpal tunnel syndrome, electrodiagnostic test, sensitivity.

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INTRODUCTION

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy that occurs as a result of mechanical compression and local ischemia of the median nerve in the carpal tunnel (1-3). The diagnosis is based on the history, clinical signs, symptoms of the patient and the electrodiagnostic studies (EDS) (2). EDS are used to confirm the diagnosis and plan the treatment program. In the literature, there are studies both stating EDS as the "gold standard" for the diagnosis of CTS and not agreeing. Different EDS are reported to have sensitivities varying between 49% and 84% (1,2-4,6). Although conventional sensorial nerve conduction studies (NCS) for digit to wrist segment are most commonly used, some studies advocate the superiority of palm to wrist NCS. This study aimed to investigate which of the studied clinical symptoms, provocative tests, EDS (motor, sensorial, mixed NCS and comparative tests) were more sensitive in patients with mild CTS.

MATERIALS AND METHODS

The study was approved by the institutional review board and the procedures followed were in accord with the Helsinki Declaration of 1975.

The patients who applied to our outpatient clinic with an initial diagnosis of CTS were questioned and examined for CTS after obtaining informed consent, they underwent standard electrodiagnostic tests.

Patients with endocrine or inflammatory diseases (such as diabetes mellitus, hypothyroidism, rheumatoid arthritis, amyloidosis, acromegaly), the ones with a history of previous surgery for CTS, fracture of the hand and wrist and polyneuropathy were excluded from the study.

The study included 90 hands of 75 patients diagnosed with mild CTS who admitted to electroneuromyography laboratory with an initial diagnosis of CTS. With regard to the EDS results, the patients with prolonged sensory nerve action potential (SNAP) distal latency (obtained by orthodromic, antidromic, or palmar methods), decreased sensory nerve conduction velocity (NCV), decreased SNAP amplitude below the lower limit of normal but no prolonged medi-

an distal motor latency (DML) were accepted to have mild CTS and included in the study.

Fifteen volunteer subjects (30 hands) with no risk factors for neuropathy and no neurological abnormalities were used as controls.

Data of the patients including age, gender, and presence of repetitive hand movements, side of the dominant and affected hand were recorded.

The patients were questioned for pain and paresthesia in the innervation area of the median nerve, hand weakness, nocturnal exacerbation of numbness, the need for shaking hands and pain and duration of any existing symptoms. Phalen and Tinel tests were applied (7,9).

All electrodiagnostic tests were performed on both hands, while the patients lying in supine position, by using Neuropack 2-MEB 7102-K 2 channels EMG-EP device (Nihon Kohden Corp.

Tokyo, Japan) by the same examiner (SE). Median motor, sensory and mixed NCS were performed to diagnose CTS. To exclude polyneuropathy ulnar motor, sensory and mixed NCS were done. The measurements were done at a room temperature of 22-24°C and skin temperatures of the subjects were above 32°C. All the stimuli and recordings were performed by using surface electrodes. Motor, sensory and mixed NCS for median and ulnar nerves, sensory NCS for radial nerve, F waves were studied and distal latency (DL), amplitude and NCV were recorded.

Motor nerve conduction and F wave studies

A surface bar electrode was used for motor NCS.

Compound muscle action potentials (CMAP) were generated via bipolar surface stimulator with 0.1 ms supramaximal stimulation.

The onset of CMAP was measured as DML. The distance between the highest and the lowest points of the potential was defined as the amplitude. The recording electrode was placed over the muscle belly of the abductor pollicis brevis and the reference electrode was placed over the distal tendinous insertion. The ulnar motor NCS were performed by recording CMAPs from abductor digiti minimi. The CMAPs for median

and ulnar nerves were obtained by stimulating 8 cm proximal to the active electrode on the wrist and from the elbow, respectively. F waves were recorded by surface electrodes using at least 10 stimulations from the same motor point where CMAP were obtained for both nerves. The lowest F wave latency was used for the study. The latency differences for median and ulnar nerves were calculated (8,10).

Sensory nerve conduction studies

Sensory nerve action potentials (SNAP) were determined by orthodromic stimulation of the median and ulnar nerves and antidromic stimulation of the radial nerve. Median sensory NCS were performed by stimulating from thumb (D1), index (D2), middle (D3), radial half of the ring finger (D4) and palm and those of the ulnar nerve were performed by stimulating from ulnar half of the ring (D4) and little finger (D5).

All responses were recorded from the wrist. The SNAPs were determined by stimulating from an 8 cm distance in D1-wrist and the palm-wrist segments and by stimulating from 13 cm proximally in the other digits. Radial sensory NCS were performed by stimulating from the forearm and recording from the thumb (antidromic). The stimulation was characterized by a duration of 0.1 ms and intensity of 10-30 mA.

The supramaximal responses were obtained. To determine the distal sensory latency and the amplitude, the peak of the evoked action potential and the distance between the top and the bottom of the evoked potential were used, respectively. All sensory responses were averaged after repeating for at least 10 times.

The median-radial sensory distal latency difference (SDLD) was defined using latency difference between median–thumb and radial–thumb recordings. The median-ulnar SDLD was defined using latency differences of the median recordings from D2, D3, D4 and ulnar recordings from D5 median and ulnar recordings from D4.

Median and ulnar mixed NCV were measured orthodromically within the wrist-elbow segment (8,10).

ETHICS COMMITTEE

Approval was obtained from the Ankara Numune Training and Research Hospital Non-Interventional Clinical Research Ethics Committee.

STATISTICAL ANALYSIS

Statistical analyses of the data were performed using the Statistical Package for Social Science (SPSS) version 15.0 statistical program. Descriptive statistics, including mean and standard deviation (SD), were determined. Normal values for upper and lower limits of the NCS were defined as the mean \pm 2.5 SD, using the data obtained from the control group. Values out of the ranges were recognized abnormal. The sensitivity of each test was calculated as number of hands with positive test results and clinical CTS/number of hands with clinical CTS \times 100%.

RESULTS

The study was conducted on 724 subjects that applied to our electroneuromyography laboratory with a prediagnosis of CTS. Among the subjects studied 117 had severe, 321 had moderate and 170 had mild CTS. Fifteen patients had other neuropathies (polyneuropathy or mononeuropathy) and 101 subjects had normal electromyographic findings. The study was detailed in 75 patients (90 hands) who fulfilled the inclusion criteria and accepted to participate in the study and 15 healthy controls.

There was no statistically significant difference between the mean age of the patients (aged 23-74 years, the mean 46.7 \pm 11.3 years) and controls (aged 31-60 years, the mean 46.8 \pm 7.6 years). Seventy-two (96%) of the patients were female. Occupational data of the patients were as follows: 60 (80%) housewives, 7 (9.3%) farmers, 2 (2.7%) computer technicians, 1 retiree, 1 almoner, 1 cook, 1 doctor, 1 electrician and 1 construction worker (1.3% for each).

History of repetitive movements of the wrist and hand was present in 80 (88.9%) of the examined hands. All patients had right-hand dominance. The numbers of affected hands were as follows; 32 (42.6%) right hand, 28 (37.3%) left hand and 15 (20%) bilateral hands. The mean

period from the onset of symptoms to the EDS was 19.85 ± 9.14 months. The data about the symptoms and examination findings are given in (Figure 1).

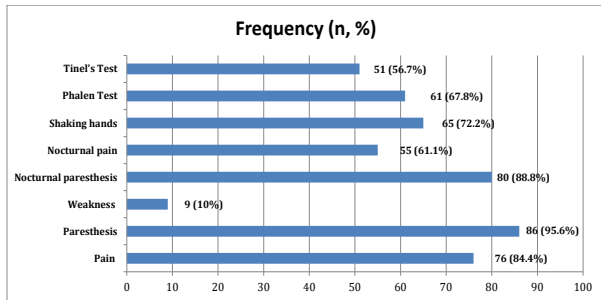


Figure 1: Symptoms and clinical findings in patients with mild carpal tunnel syndrome.

The results of the EDS conducted on the patients with mild CTS are summarized in (Tables 1, 2).

Table 1 : Results of electrodiagnostic studies in hands with mild carpal tunnel syndrome.

	Evaluated Segment	Distal latency (DL) (ms)	Amplitude (μV)	Conduction velocity (m/s)
Median				
Motor	Wrist-elbow	3.27 ± 0.23	12.33 ± 3.93	57.22 ± 3.91
Sensory	D1	2.69 ± 0.26	31.33 ± 13.23	28.80 ± 3.28
	D2	3.11 ± 0.33	20.67 ± 9.75	39.17 ± 3.80
	D3	3.41 ± 0.34	21.78 ± 10.32	38.62 ± 3.60
	D4	3.39 ± 0.38	14.31 ± 6.11	38.08 ± 4.86
	Palm	1.94 ± 0.23	89.75 ± 53.39	30.76 ± 2.18
Mixed	Wrist-elbow	3.54 ± 0.32	26.27 ± 14.96	54.92 ± 3.60
Ulnar				
Motor	Wrist-elbow	2.07 ± 0.33	10.13 ± 3.09	60.00 ± 4.27
Sensory	D4	2.65 ± 0.29	14.28 ± 10.22	46.96 ± 3.88
	D5	2.32 ± 0.27	19.53 ± 12.79	45.58 ± 3.59
Mixed	Wrist-elbow	3.67 ± 4.01	22.15 ± 9.39	55.87 ± 6.08
Radial				
Sensory	D1	2.23 ± 0.28	34.35 ± 15.87	48.79 ± 3.84

(D1-5: digit 1-5)

Table 2 : Results of comparative tests in hands with mild carpal tunnel syndrome.

	Mean \pm SD
MRSDDL (ms)	0.74 ± 0.47
MU4SDLD (ms)	0.46 ± 0.36
MU2-5 SDLD (ms)	0.79 ± 0.36
MU3-5 SDLD (ms)	1.08 ± 0.36
MU4-5 SDLD (ms)	1.06 ± 0.44
MUFLD (ms)	0.09 ± 1.63

(MR; median-radial, MU; median-ulnar, SDLD; sensory distal latency difference, MUFLD; Median-ulnar F latency difference, ms; millisecond)

Compared to the control group, in 78 of 90 hands with mild CTS, sensorial DL to D1 was prolonged and its sensitivity was 86.7%. The number and sensitivity of prolonged DL to D2, D3 and D4 were as follows; 75 hands (83.3%), 85 hands (94.4%), and 85 hands (94.4%), respectively.

Table 3 Sensory NCV in the D1-wrist segment was decreased in 89 hands (98.9% sensitivity). Other sensory NCV values are given in Table 3.

In the palm-wrist segment, the sensory DL was prolonged in 88 hands (97.8% sensitivity) and the sensory NCV was decreased in 89 hands (98.9% sensitivity).

The most sensitive comparative test was median-ulnar SDLD to D4-D5 (93.3%). Sensitivity of other comparative tests is given in (Table 3).

Table 3 : The studied tests, number of affected hands and calculated sensitivities of the tests in hands with mild carpal tunnel syndrome.

Test	Number of Affected Hands	Sensitivity
D1SDL	78	%86.7
D1DSNCV	89	%98.9
D2SDL	75	%83.3
D2DSNCV	87	%96.7
D3SDL	85	%94.4
D3 DSNCV	87	%96.7
D4SDL	85	%94.4
D4 DSNCV	86	%95.6
Palm SDL	88	%97.8
Palm DSNCV	89	%98.9
MRSDDL	76	%84.4
D4MUSDDL	57	%63.3
D2-5MUSDDL	80	%88.9
D3-5MUSDDL	83	%92.2
D4-5MUSDDL	84	%93.3
MUFLD	35	%38.9
MMixedDL	34	%37.8
MMixedSNCV	27	%30

(D1-5: digit 1-5, SDL(D); Sensory distal latency (difference), DSNCV; Distal sensory nerve conduction velocity, MR; Median-radial, MU; Median-ulnar, MUFLD; Median-ulnar F latency difference, MMixedDL; Median mixed distal latency, MMixedSNCV; Median mixed sensory nerve conduction velocity)

DISCUSSION

Symptoms related to CTS vary depending on the severity of median nerve entrapment. Symptoms are due to the involvement of sensory fibers in the earlier phase and motor fibers later.

The most frequent symptoms are pain, numbness and tingling in the median nerve territory distal to the wrist. Nora et al. reported that the most common symptoms were pain (82.9%) and paresthesia (82.4%) in 1039 patients with CTS (11). In another study of 327 patients, the most common (95.7%) symptom was paresthesia experienced in the night (38%), heavier in the night but also in the daytime (58%) and only in the daytime (5%) (2). Various studies

reported nocturnal numbness to have an incidence of 51-96% (4,10,12). In the present study, the frequency of symptoms was as follows; paresthesia (95.6%), nocturnal numbness (88.8%), pain (84.4%), shaking hands to relieve pain (72.2%), nocturnal pain (61.1%).

Phalen's and Tinel's tests are the most widely used and investigated provocative tests. Variable values for sensitivities of Phalen's (10-91%) (4,13-18) and Tinel's tests (23-67%) (4,15-17,21-23) were reported in the literature. The reason for such wide ranges may be that the tests are affected by many factors (constant regeneration of the median nerve distal to the wrist crease, the performed technique and the differences in the intensity of power while applying the Tinel's test) (23). In the present study, Phalen's and Tinel's tests had a sensitivity of 67.8% and 56.7%, respectively. It was reported that the diagnostic values of the provocative tests for CTS might be increased when used in combination (4).

Since the location of sensory fibers in the median nerve is variable, the decrease in NCV may differ in digital branches. In mild cases of CTS, the conduction abnormalities are usually restricted in the proximal segment of the nerve within the carpal tunnel and slowing in proximal segment conduction may be masked by faster conduction in the distal segment. Therefore, palm-wrist segmental sensory studies of the median nerve and comparative NCS with the other nerves of the hand are used to increase the sensitivity of EDS (24,25). In this study, slowing of sensory NCV within the wrist-palm and D1-wrist segments were the most sensitive (98.9%) findings among other tests applied to increase diagnostic sensitivity. Similarly, Aydın et al., in their study of 506 hands, detected that the most common (98.5%) electrodiagnostic finding was slowing in sensory NCV within the palm-wrist segment and among the wrist-digit segments, D1-wrist was the most commonly (95.4%) affected one (26).

In the literature, there are different reports about which sensory branch of the median nerve to be affected first. Macdonell et al. reported that slowing of NCV was most common in D1 and least common in D2 (27).

Kothari et al. stated that slowing of NCV in D1 was the most sensitive test in cases of mild CTS, however, they advocated that no differences existed between the digits of cases with prolonged DML (28). Demirci et al. detected slowing in NCV within the palm-wrist segment in 98.8% of the cases with mild CTS, and slowing within wrist-D1, D2, D3 and D4 segments were 76%, 72%, 68% and 68%, respectively (3). In a study of 72 cases with mild CTS, Terzis et al. reported that sensitivity of sensory NCV in D1, D2, D3 and D4 was 61%, 22%, 50% and 88%, respectively (29). Lauritzen et al. could detect no significant differences in median sensory NCV in D1-wrist and D3-wrist segments of patients with mild CTS (30). In the present study, we detected slowing in sensory NCV of 87 hands (96.7%) within D2-wrist and D3-wrist segments.

Although Stevens, in his review, reported that recordings from D2 were most commonly used for the diagnosis of CTS, Kothari, Macdonell, Demirci, Aydın and we detected that sensory NCV in D1-wrist segment was more sensitive (3,26-28,31).

Since the fourth digit is innervated by median and ulnar nerves, it is advantageous to compare the sensory latency differences of these nerves within D4. Therefore, the latencies can directly be compared when stimulated from the same distance. Likewise, the thumb (median-radial nerve innervated) is also favourable for comparison of sensory distal latencies. Electrodiagnostic assessment of CTS may be affected by NCV, normal variations in the amplitude and duration of the stimulated responses and temperature of the hand. These variables can be controlled by simultaneous testing of the other nerves in the same hand. Thus, the sensitivity of EDS in the detection of mild focal entrapments may be increased. Chang et al. reported that median-radial SDLD has a sensitivity of 86.7%, which was greater than that of the digital distal latencies and NCV in the palm-wrist segment (25).

Demirci et al. stated the sensitivities for median-radial SDLD, median-ulnar SDLD to D2-5 and median-ulnar SDLD to D4 were 94.1%, 89.4% and 84.7%, respectively (3). In a study of 86 cases with mild CTS, Pease et al. found the sensi-

tivity of median-radial SDLD was 87% and that of median-ulnar SDLD was 88%. They reported that the sensitivities for routine median motor DL and DL to D3 were 29% and 52%, respectively. Based on these findings, they stated that median-radial SDLD obtained within D1 and median-ulnar SDLD obtained from D3-5 were quite sensitive (32). In the present study, among the comparative studies, median-ulnar SDLD to D4-5 was the most sensitive test (93.3%). The sensitivity for median-ulnar SDLD to D4 was the least (63.3%). That rate was less than those reported by the studies, in which antidromic methods were usually used. Since the antidromic method can stimulate also motor fibers of the nerve, orthodromic method was used in this study (26,33). Future studies to compare the orthodromic and antidromic methods within D4 may be conducted. Another possible reason for the differences in results may be the diversity of anatomical involvement of the median nerve in the carpal tunnel. The fibers located anteromedially and anterolaterally are more frequently entrapped than the central fibers in the carpal tunnel (34,35). Similar to our study, Demirci et al. detected that median-ulnar SDLD was less sensitive than median-radial SDLD and median-ulnar SDLD to D2-5 and they advocated that the difference might be related to funicular topography of the median nerve (3).

The comparison of median and ulnar F wave latencies are also used in the diagnosis of CTS.

But, as known, this test is nonspecific and it can not localize the site of entrapment. Thus, it can only be used as a confirmatory in the diagnosis of CTS (36). Sander et al. investigated the use of median and ulnar F latency difference and reported a sensitivity of 78% for the test (37).

In this study, we detected 38.9% sensitivity rate for median and ulnar F latency difference. Since we included only the mild cases of CTS, but Sander did not classify the patients, this difference might have emerged. As Sander stated, F latency difference alone is not enough for the diagnosis of CTS and an additional abnormality should be indicated. CTS has bilateral involvement in 20-60% of the cases (24,25-38,40). Since tests like ANOVA, t-test and Wilcoxon non-parametric test are performed with a suggestion

that the samples are independent, analysing both hands of the same patient may cause overestimation.

In studies about CTS, unless special statistical methods are used, it seems more reasonable to evaluate the data as individual patients (rather than hands). Some solutions to overcome this issue have been recommended. These include evaluating the right and left hands individually, studying one hand randomly when evaluating both hands of the patient, selecting the more symptomatic hand, separating the dominant and non-dominant hands. But although these methods have accuracy in terms of statistics, they do not give adequate clinical results.

Usual statistical methods are not appropriate and adequate to study on both hands. Some specially designed software may be instituted, but those are unfamiliar to most researchers and not widely used. Eventually, statistical methods should be determined with regard to the aim and methods of the study (41). Since we aimed to detect which test was more sensitive and to discuss which techniques to use in the diagnosis of CTS, the aforementioned statistical tests were not performed.

CONCLUSION

In the diagnosis of CTS, various electrodiagnostic results may be obtained depending on the anatomy of the median nerve in the carpal tunnel. In this study, the sensory NCV in D1-wrist and palm-wrist segments had the highest sensitivity for electrodiagnosis of CTS. Median-ulnar SDLD to D4-5 test, with a rate of 93.3%, was the most sensitive. We concluded that, with the use of these tests, the diagnostic sensitivity of EDS may be increased in patients with mild CTS, additionally, the median-ulnar F latency difference, with a sensitivity of 38.9%, is not an adequate test individually and it should be supported with other tests.

REFERENCES

1. Jordan R, Carter T, Cummins C. A systematic review of the utility of electrodiagnostic testing in carpal tunnel syndrome. *Br J Gen Pract* 2002; 52(481): 670-3.
2. Aroori S, Spence RA. Carpal tunnel syndrome. *Ulster Med J* 2008; 77(1): 6-17.

3. Demirci S, Sonel B. Comparison of sensory conduction techniques in the diagnosis of mild idiopathic carpal tunnel syndrome: which finger, which test? *Rheumatol Int* 2004; 24(4): 217-20.
4. Katz JN, Larson MG, Sabra A, et al. The carpal tunnel syndrome: diagnostic utility of the history and physical examination findings. *Ann Intern Med* 1990; 112(5): 321-7.
5. Werner RA, Andary M. Electrodiagnostic evaluation of carpal tunnel syndrome. *Muscle Nerve* 2011;44(4):597-607.
6. Sucher BM, Schreiber AL. Carpal tunnel syndrome diagnosis. *Phys Med Rehabil Clin N Am* 2014;25(2):229-47.
7. Bland JD. Carpal tunnel syndrome. *Curr Opin Neurol* 2005; 18(5): 581-5.
8. Ertekin C. Pleksus Brakiyalisten Çıkan Sinirler. In: Ertekin C (Editor) *Sentral ve Periferik EMG*. Izmir: Meta Basım, 2006: 403-27.
9. MacDermid JC, Wessel J. Clinical diagnosis of carpal tunnel syndrome: a systematic review. *J Hand Ther* 2004; 17(2): 309-19.
10. Oh SJ. Normal values for common nerve conduction tests. In: Oh SJ (Editor) *Clinical Electromyography: Nerve Conduction Studies*. Philadelphia: Lippincott Williams&Wilkins, 2003: 86-106.
11. Nora DB, Becker J, Ehlers JA, Gomes I. Clinical features of 1039 patients with neurophysiological diagnosis of carpal tunnel syndrome. *Clin Neurol Neurosurg* 2004; 107(1): 64-9.
12. Szabo RM, Slater RR, Jr., Farver TB, Stanton DB, Sharman WK. The value of diagnostic testing in carpal tunnel syndrome. *J Hand Surg Am* 1999; 24(4): 704-14.
13. Gupta SK, Benstead TJ. Symptoms experienced by patients with carpal tunnel syndrome. *Can J Neurol Sci* 1997; 24(4): 338-42.
14. Kendall WW. Results of treatment of severe carpal tunnel syndrome without internal neurolysis of the median nerve. *J Bone Joint Surg Am* 1988; 70(1): 151.
15. Buch-Jaeger N, Foucher G. Correlation of clinical signs with nerve conduction tests in the diagnosis of carpal tunnel syndrome. *J Hand Surg Br* 1994; 19(6): 720-4.
16. Gerr F, Letz R, Harris-Abbott D, Hopkins LC. Sensitivity and specificity of vibrometry for detection of carpal tunnel syndrome. *J Occup Environ Med* 1995; 37(9): 1108-15.
17. Golding DN, Rose DM, Selvarajah K. Clinical tests for carpal tunnel syndrome: an evaluation. *Br J Rheumatol* 1986; 25(4): 388-90.
18. De Smet L, Steenwerckx A, Van den Bogaert G, Cnudde P, Fabry G. Value of clinical provocative tests in carpal tunnel syndrome. *Acta Orthop Belg* 1995; 61(3): 177-82.
19. Kaufman MA. Differential diagnosis and pitfalls in electrodiagnostic studies and special tests for diagnosing compressive neuropathies. *Orthop Clin North Am* 1996; 27(2): 245-52.
20. Bruske J, Bednarski M, Grzelec H, Zyluk A. The usefulness of the Phalen test and the Hoffmann-Tinel sign in the diagnosis of carpal tunnel syndrome. *Acta Orthop Belg* 2002; 68(2): 141-5.
21. Kuhlman KA, Hennessey WJ. Sensitivity and specificity of carpal tunnel syndrome signs. *Am J Phys Med Rehabil* 1997; 76(6): 451-7.
22. Mondelli M, Passero S, Giannini F. Provocative tests in different stages of carpal tunnel syndrome. *Clin Neurol Neurosurg* 2001; 103(3): 178-83.
23. Kuschner SH, Ebramzadeh E, Johnson D, Brien WW, Sherman R. Tinel's sign and Phalen's test in carpal tunnel syndrome. *Orthopedics* 1992; 15(11): 1297-302.
24. Padua L, Lo Monaco M, Valente EM, Tonali PA. A useful electrophysiologic parameter for diagnosis of carpal tunnel syndrome. *Muscle Nerve* 1996; 19(1): 48-53.
25. Chang MH, Liu LH, Lee YC, Wei SJ, Chiang HL, Hsieh PF. Comparison of sensitivity of transcarpal median motor conduction velocity and conventional conduction techniques in electrodiagnosis of carpal tunnel syndrome. *Clin Neurophysiol* 2006; 117(5): 984-91.
26. Aydin G, Keles I, Ozbudak Demir S, Baysal AI. Sensitivity of median sensory nerve conduction tests in digital branches for the diagnosis of carpal tunnel syndrome. *Am J Phys Med Rehabil* 2004; 83(1): 17-21.
27. Macdonell RA, Schwartz MS, Swash M. Carpal tunnel syndrome: which finger should be tested? An analysis of sensory conduction in digital branches of the median nerve. *Muscle Nerve* 1990; 13(7): 601-6.
28. Kothari MJ, Rutkove SB, Caress JB, Hinchey J, Logigian EL, Preston DC. Comparison of digital sensory studies in patients with carpal tunnel syndrome. *Muscle Nerve* 1995; 18(11): 1272-6.
29. Terzis S, Paschalis C, Metallinos IC, Papapetropoulos T. Early diagnosis of carpal tunnel syndrome: comparison of sensory conduction studies of four fingers. *Muscle Nerve* 1998; 21(11): 1543-5.
30. Lauritzen M, Liguori R, Trojaborg W. Orthodromic sensory conduction along the ring finger in normal subjects and in patients with a carpal tunnel syndrome. *Electroencephalogr Clin Neurophysiol* 1991; 81(1): 18-23.
31. Stevens JC. AAEM minimonograph #26: the electrodiagnosis of carpal tunnel syndrome. *American Association of Electrodiagnostic Medicine*. *Muscle Nerve* 1997; 20(12): 1477-86.
32. Pease WS, Cannell CD, Johnson EW. Median to radial latency difference test in mild carpal tunnel syndrome. *Muscle Nerve* 1989; 12(11): 905-9.

- 33.** Oh SJ. Normal values for common nerve conduction tests. In: Oh SJ (Editor) *Clinical Electromyography: Nerve Conduction Studies*. Philadelphia: Lippincott Williams&Wilkins, 2003: 37-53.
- 34.** Uncini A, Lange DJ, Solomon M, Soliven B, Meer J, Lovelace RE. Ring finger testing in carpal tunnel syndrome: a comparative study of diagnostic utility. *Muscle Nerve* 1989; 12(9): 735-41.
- 35.** Uncini A, Di Muzio A, Awad J, Manente G, Tafuro M, Gambi D. Sensitivity of three median-to-ulnar comparative tests in diagnosis of mild carpal tunnel syndrome. *Muscle Nerve* 1993; 16(12): 1366-73.
- 36.** Preston DC, Shapiro BE. Median Neuropathy At The Wrist. In: Preston DC, Shapiro BE (Editor) *Electromyography And Neuromuscular Disorders*. Third edition Elsevier; 2013: 267-88.
- 37.** Sander HW, Quinto C, Saadeh PB, Chokroverty S. Sensitive median-ulnar motor comparative techniques in carpal tunnel syndrome. *Muscle Nerve* 1999; 22(1): 88-98.
- 38.** Bland JD. Carpal tunnel syndrome. *BMJ* 2007; 335(7615): 343-6.
- 39.** Padua L, LoMonaco M, Gregori B, Valente EM, Padua R, Tonali P. Neurophysiological classification and sensitivity in 500 carpal tunnel syndrome hands. *Acta Neurol Scand* 1997; 96(4): 211-7.
- 40.** Carroll GJ. Comparison of median and radial nerve sensory latencies in the electrophysiological diagnosis of carpal tunnel syndrome. *Electroencephalogr Clin Neurophysiol* 1987; 68(2): 101-6.
- 41.** Padua L, Pasqualetti P, Rosenbaum R. One patient, two carpal tunnels: statistical and clinical analysis--by hand or by patient? *Clin Neurophysiol* 2005; 116(2): 241-3.