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ORIGINAL ARTICLE

Median to ulnar nerve comparison on diagnosis of carpal tunnel syndrome in patients with diabetic polyneuropathy – A neurophysiological study

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Background and purpose – To analyze the utility of median nerve (MN) to ulnar nerve (UN) comparative parameters on the diagnosis of carpal tunnel syndrome (CTS) in diabetic patients with distal symmetrical sensorimotor polyneuropathy (DSMPNP).
Methods – Patients who were referred to our electroneuromyography laboratory within the last two years were included. We compared the diagnostic accuracy values of traditional MN conduction parameters, and the MN-to-UN comparative tests on electrodiagnosis of CTS between the patients with DSMPNP involving the nerves of upper and lower extremities (UEI-positive group), and the ones without the involvement of upper extremities (UEI-negative group).
Results – There were 64 upper extremities in the UEI-positive group and 70 patients in the UEI-negative group. The most accurate traditional parameter was MN distal motor latency (DML) with a diagnostic accuracy of 70.2% whereas the most accurate comparative technique was the second lumbrical-interosseous DML difference (2L-INT DMLD) with an accuracy of 81.3%. (p=0.03). In addition, when compared diagnostic accuracy values of MN parameters with their corresponding comparative parameters in the UEI-positive group which carries the major diagnostic challenges for detecting co-morbid CTS, MN to UN minimum F wave latency (mFWL) difference, SNAP amplitude ratio on the ring finger (RF), and 2L-INT DMLD had higher accuracy values than MN mFWL, MN SNAP amplitude on RF, and MN DML on lumbrical muscle, respectively (p<0.05 for all comparisons).

A nervus medianus és a nervus ulnaris összehasonlítása a carpalis alagút szindróma diagnosztikájában diabeteses polineuropathiás betegeknél – neurofiziológiai vizsgálat
Alemdar M, MD

Háttér és cél – Annak elemzése, hogy mennyire hasznos a nervus medianus (MN) és a nervus ulnaris (UN) paramétereinek összehasonlítása distalis szimmetrikus szenzomotoros polyneuropathiában (DSMPNP) szenvedő diabeteses betegek carpalis alagút szindrómájának (CTS) diagnosztizálásában.
Módszerek – Azokat a betegeket vontuk be, akiket az elmúlt két évben beutaltak elektroneuromiográfiás laboratóriumunkba. Összehasonlítottuk a hagyományos MN-vezetési paraméterek és az MN-UN összehasonlító tesztek diagnosztikus pontosságát a CTS elektrodiagnosztikájában a felső és alsó végtagok idegeit érintő DSMPNP-s betegek (UEI-pozitív csoport) és a felső végtagok érintettsége nélküli betegek (UEI-negatív csoport) között.
Eredmények – Az UEI-pozitív csoportban 64 felső végtag, az UEI-negatív csoportban pedig 70 beteg volt. A legpontosabb hagyományos paraméter az MN distalis motoros latenciája (DML) volt 70,2%-os diagnosztikus pontossággal, míg a legpontosabb összehasonlító technika a második lumbricalis-interossealis DML-különbség (2L-INT DMLD) volt 81,3%-os pontossággal (p = 0,03).
Ezenkívül, amikor az MN-paraméterek diagnosztikus pontossági értékeit összehasonlítottuk a nekik megfelelő összehasonlító paraméterekkel az UEI-pozitív csoportban, ami a legnagyobb diagnosztikai kihívást hordozza a társbetegség CTS kimutatásában, az MN-UN minimális F-hullám-latencia (mFWL) közötti különbség, a SNAP amplitúdó aránya a gyűrűsujjon (RF) és a 2L-INT DMLD nagyobb pontossággal bírt, mint az MN mFWL, az MN SNAP amplitúdó az RF-en,

Conclusion – MN to UN comparative studies have high accuracy values in electrodiagnosis of CTS in DSMPNP. In particular, 2L-INT DMLD could be helpful to overcome the diagnostic difficulty in the presence of UEI as an additional conduction technique.

Következtetés – Az MN és az UN összehasonlító vizsgálatai magas pontossági értékekkel rendelkeznek a CTS elektrodiagnosztikájában DSMPNP-ben. Kiegészítő kondukciós technikaként különösen a 2L-INT DMLD segíthet az UEI esetén jelentkező diagnosztikai nehézség leküzdésében.

Keywords: diabetes mellitus, polyneuropathy, carpal tunnel syndrome

Kulcsszavak: diabetes mellitus, polyneuropathia, carpalis alagút szindróma

Carpal tunnel syndrome (CTS) is the most common mononeuropathy and second most common type of neuropathy after distal symmetrical sensorimotor polyneuropathy (DSMPNP) in patients with diabetes mellitus (DM)[1–4]. The prevalence of CTS is 2%–3% among the general population[5, 6] whereas it is as high as 7% to 16% in diabetics[7–10]. Although a few controversial reports were also present[11, 12], many researchers reported the DM as a major risk factor for CTS[13–18]. It is not easy to document the presence of CTS in patients with DSMPNP based on clinical features as both disorders may cause similar symptoms. In addition, electrodiagnosis of CTS has particular difficulties in patients with DSMPNP as both disorders could cause analogous conduction impairments of the median nerve (MN).

Transcarpal motor and sensory nerve conduction studies (NCSs) are used to establish the impaired conduction of MN through the wrist to document the presence of CTS. Traditional MN conduction parameters recorded in a standard NCS include wrist-to-finger sensory conduction velocity (SCV), wrist-to-finger distal sensory onset latency (DSOL), sensory nerve action potential (SNAP) amplitude, wrist-to-abductor pollicis brevis (APB), muscle distal motor latency (DML), forearm motor conduction velocity (MCV), and minimum F wave latency (mFWL). However, previous studies showed a wide range of sensitivity and specificity for these parameters in electrodiagnosis of CTS[19–24]. Therefore, a variety of methods has been offered to increase the diagnostic accuracy of NCSs. Among them, comparative MN-to-ulnar nerve (UN) conduction techniques have been revealed to have satisfactory diagnostic powers in many previous studies[24–32]. DSOL difference (DSOLD) of MN on second -to-UN on the fifth finger, SCV difference between UN (wrist-to-fifth finger) and MN (wrist-to-second finger) and MN to UN SNAP amplitude ratio on those segments, MN-thenar to UN-hypothenar DML difference (DMLD), MN-thenar to UN-hypothenar mFWL difference (mFWLD), MN to UN DSOLD on the ring finger (RF), SNAP amplitude ratio on RF, and second lumbrical-interosseous DMLD (2L-INT DMLD) are main types of these techniques.

Transcarpal conduction abnormalities of MN in the presence of normal ipsilateral UN conduction are accepted as the main indicators of CTS. However, this method relying traditional conduction studies of MN and UN could not be applicable in many patients with DSMPNP that involved the upper extremities, because both disorders may cause similar conduction abnormalities on MN, and many diabetic patients have also conduction abnormalities of UN in the context of polyneuropathic involvement[33–36]. Although several previous studies reported on the usefulness of various parameters to document CTS in the presence of DSMPNP, there is no any consensus on which ones give more accurate results[35–37]. To the best of our knowledge, there is no any research analysing the diagnostic accuracy values of those parameters in patients with polyneuropathic involvement on both of upper and lower extremities, and ones with involvement on the lower extremities only. In this study, we aimed to calculate the diagnostic accuracy values of traditional and comparative conduction parameters in electrodiagnosis of CTS in patients with DSMPNP and to determine whether these values are different between those subgroups of involvement or not.

Subjects and methods

Population

The population of the present study is composed of the subjects who were referred to the electroneuromyography (ENMG) laboratory of Sakarya University Education and Research Hospital for upper limbs NCSs within the last two years. Patients having type-2 DM according to the criteria of the American Diabetes Association were enrolled[33]. The study protocol was in compliance with the Declaration of Helsinki and approved by the Local Medical Ethics Committee of Sakarya University.

ABBREVIATIONS

2L-INT DMLD: second lumbrical-interosseous distal motor latency difference
ADM: abductor digiti minimi
AH: abductor hallucis
ampl: amplitude
APB: abductor pollicis brevis
CTS: carpal tunnel syndrome
CMAP: compound muscle action potential
DM: diabetes mellitus
DML: distal motor latency
DMLD: distal motor latency difference
DSMPNP: distal symmetrical sensori-motor polyneuropathy
DSOL: distal sensory onset latency
DSOLD: distal sensory onset latency difference
EDB: extensor digitorum brevis
ENMG: electroneuromyography
LL: lover leg
m/sec: meter per second
Lumbr: lumbrical musle
MCV: motor conduction velocity
micrV: microvolt
mFWL: minimum F wave latency
mFWLD: minimum F wave latency difference
MN: median nerve
MN DSOL- II: distal sensory onset latency of median nerve on wrist-to-second finger segment
MN SCV- II: sensory conduction velocity of median nerve on wrist-to-second finger segment
MN SNAP ampl- II: sensory nerve action potential amplitude of median nerve on wrist-to-second finger segment
msec: milisecond
mV: milivolt
NCS: nerve conduction study
PN: peroneal nerve
P-to-F: poplitea to fibular head
RF: ring finger
SCV: sensory conduction velocity
SCVD: sensory conduction velocity difference
SNAP: sensory nerve action potential
TN: tibial nerve
UEI: upper extremity involvement
UN: ulnar nerve
UN DSOL- V: distal sensory onset latency of ulnar nerve on wrist-to-fifth finger segment
UN SCV - V: sensory conduction velocity of ulnar nerve on wrist-to-fifth finger segment
UN SNAP ampl- V: sensory nerve action potential amplitude of ulnar nerve on wrist-to-fifth finger segment

Medical history and clinical findings of the patients (presence of recurring night-time or activity-related numbness on two of the first three fingers, presence of positive Tinel/Phalen's test, MN sensory or motor deficits) were all noted on the first page of the ENMG result report. We included the patients with DSMPNP with or without co-existing CTS. Patients with a history of carpal tunnel release operation, a sign of UN entrapment neuropathy, plexopathy, cervical radiculopathy, neuromuscular junction, or muscle diseases were excluded.

Procedure

The patients were examined by the author with the use of a 4-channel ENMG tool (Nihon Kohden, Neuropack, Tokyo, Japan) according to the American Association of Electrodiagnostic Medicine practice guidelines[31]. Compound muscle action potentials (CMAPs) were recorded from APB muscle for MN, abductor digiti minimi (ADM) muscle for UN, abductor hallucis (AH) muscle for tibial nerve (TN), and extensor digitorum brevis (EDB) muscle for peroneal nerve (PN) by surface electrodes. Sensory nerve action potentials (SNAPs) were recorded from the second and fourth digit for MN, and the fourth and fifth digit for UN by using ring electrodes, antidromically. Surface electrodes were placed on the midpoint of the skin posterior to the lateral malleolus for the sural nerve (SN). Minimum F wave latency (mFWL) was measured for MN, UN, and TN. Elicitation of at least six F wave responses upon sixteen repetitive simulations was warranted for the mFWL recording. In addition, motor NCSs of MN to lumbrical and UN to interosseus muscles were performed with equal distances from their stimulation points on the wrist.

Reference values for NCS parameters used in our ENMG laboratory are as follows: MN SCV (wrist-to-second finger)> 44 m/sec, MN SNAP amplitude on second finger > 15 μV, MN DML on APB< 4.20 msec, MN forearm MCV > 49 m/sec, MN CMAP amplitude on APB> 5 mV, UN SCV (wrist-to-fifth finger)> 44 m/sec, UN SNAP amplitude on fifth finger> 12 μV, UN DML on ADM< 3.3 msec, UN forearm MCV> 49 m/sec, UN across elbow MCV> 44 m/sec, UN CMAP amplitude on ADM> 5 mV, MN minimum F wave latency< 29 msec,

Table 1. *Comparison of NCS results of upper extremities between UEI-negative and UEI-positive hands*

NCS Parameter	UEI-negative Grp (means ± SD)	UEI-positive Grp (means ± SD)	p*	NCS Parameter
MN DSOL- II	3.47 ± 0.59	3.58 ± 0.59	0.316	MN DML to Lumbr
MN SCV- II	40.83 ± 5.51	40.25 ± 6.33	0.593	MN CMAP ampl on Lumbr
MN SNAP ampl- II	11.69 ± 5.34	10.13 ± 6.49	0.155	UN DML to Inteross
MN DSOL to RF	3.81 ± 0.75	3.71 ± 0.49	0.431	UN CMAP ampl on Inteross
MN SNAP on RF	6.18 ± 3.90	5.70 ± 4.21	0.530	MN min FWL
MN DML to APB	4.60 ± 1.03	4.88 ± 1.17	0.150	UN min FWL
MN forearm MCV	48.87 ± 3.92	45.95 ± 5.57	< 0.001	TN DML on AH
MN CMAP ampl on APB	10.48 ± 4.26	9.68 ± 3.64	0.246	TN MCV
UN DSOL- V	2.67 ± 0.33	2.97 ± 0.41	< 0.001	TN min FWL
UN SCV - V	45.92 ± 4.83	41.44 ± 4.59	< 0.001	TN CMAP ampl
UN SNAP ampl- V	11.50 ± 6.67	8.51 ± 5.96	0.009	PN DML on EDB
UN DSOL on RF	2.86 ± 0.33	3.21 ± 0.46	< 0.001	PN LL MCV
UN SNAP ampl on RF	8.58 ± 5.49	6.90 ± 5.73	0.111	PN P-to-F MCV
UN DML on ADM	2.80 ± 0.24	3.38 ± 0.43	< 0.001	PN CMAP ampl
UN forearm MCV	54.29 ± 4.35	46.80 ± 5.53	< 0.001	SN DSOL
UN across-elbow MCV	55.23 ± 7.10	47.70 ± 8.50	< 0.001	SN SCV
UN CMAP ampl on ADM	11.50 ± 6.67	8.51 ± 5.96	0.009	SN SNAP ampl

*Student t test

Table 2. *The distribution of nerve conduction study results between study subgroups*

	Negative UEI + negative CTS (Gp1; n=24)	Positive UEI + negative CTS (Gp2; n=39)	p* (Gp1 vs. Gp2)	Negative UEI + positive CTS (Gp3; n=46)	Positive UEI + positive CTS (Gp4; n=25)
MN DSOL - II (msec)	3.19 ± 0.43	3.44 ± 0.55	0.060	3.64 ± 0.61	3.87 ± 0.56
MN SCV - II (m/sec)	42.73 ± 4.88	41.98 ± 5.99	0.605	39.65 ± 5.61	36.59 ± 5.54
MN SNAP ampl - II (μV)	11.75 ± 4.19	10.80 ± 7.19	0.559	11.65 ± 5.99	8.73 ± 4.56
MN DSOL to RF (msec)	3.39 ± 0.31	3.64 ± 0.44	0.019	4.07 ± 0.83	3.87 ± 0.57
MN SNAP ampl on RF (μV)	6.60 ± 4.70	5.55 ± 4.33	0.384	5.92 ± 3.36	6.03 ± 4.05
MN DML to APB (msec)	4.01 ± 0.54	4.48 ± 0.63	0.004	4.92 ± 1.10	5.54 ± 1.53
MN MCV (m/sec)	47.59 ± 3.30	45.20 ± 5.87	0.073	49.55 ± 4.09	47.16 ± 4.92
MN mFWL (msec)	28.70 ± 2.25	32.09 ± 3.58	<0.001	29.75 ± 3.06	31.44 ± 2.83
MN CMAP ampl on APB (mV)	10.84 ± 3.62	10.56 ± 3.48	0.761	10.29 ± 4.59	8.24 ± 3.50
MN DML to Lumbr (msec)	3.80 ± 0.38	4.33 ± 0.58	<0.001	4.84 ± 1.37	5.11 ± 1.54
UN DSOL -V (msec)	2.74 ± 0.30	3.00 ± 0.49	0.022	2.63 ± 0.34	2.91 ± 0.25
UN SCV -V (m/sec)	43.95 ± 5.02	40.77 ± 5.29	0.024	45.60 ± 4.68	42.45 ± 2.73
UN SNAP ampl -V (μV)	10.95 ± 5.33	7.75 ± 6.31	0.046	11.80 ± 7.33	9.67 ± 5.30

UEI-negative Grp (means ± SD)	UEI-positive Grp (means ± SD)	p*
4.48 ± 1.23	4.63 ± 1.11	0.482
3.14 ± 1.43	3.01 ± 1.49	0.605
3.46 ± 0.35	3.92 ± 0.57	< 0.001
6.44 ± 2.79	5.85 ± 2.70	0.216
29.39 ± 2.83	31.84 ± 3.30	< 0.001
28.13 ± 2.44	32.23 ± 3.19	< 0.001
4.31 ± 1.07	5.09 ± 1.28	< 0.001
37.50 ± 3.80	35.23 ± 4.14	0.002
58.87 ± 5.67	62.47 ± 6.76	0.002
5.85 ± 3.52	4.21 ± 3.23	0.013
3.94 ± 0.75	4.55 ± 1.34	0.018
39.26 ± 7.95	36.19 ± 4.50	0.013
44.46 ± 7.48	37.93 ± 5.48	< 0.001
2.27 ± 1.89	2.21 ± 1.73	0.865
3.16 ± 0.46	3.27 ± 0.54	0.257
39.36 ± 5.53	37.43 ± 4.78	0.060
6.96 ± 3.45	5.29 ± 3.04	0.010

p* (Gp3 vs. Gp4)	p# (Gp1 to Gp4)
0.190	<0.001 (Gp3≈Gp4>Gp1≈Gp2)
0.060	0.002 (Gp3≈Gp4>Gp1≈Gp2)
0.073	0.315 (Gp1≈Gp2≈Gp3≈Gp4)
0.401	<0.001 (Gp3>Gp2>Gp1,Gp4>Gp1, Gp3≈Gp4, Gp2≈Gp4)
0.918	0.814 (Gp1≈Gp2≈Gp3≈Gp4)
0.057	<0.001 (Gp3≈Gp4>Gp1≈Gp2)
0.035	<0.001 (Gp3≈Gp4>Gp1≈Gp2)
0.026	<0.001 (Gp2≈Gp4>Gp1≈Gp3)
0.061	0.082 (Gp1≈Gp2≈Gp3≈Gp4)
0.458	<0.001 (Gp3≈Gp4>Gp2>Gp1)
<0.001	<0.001 (Gp2≈Gp4>Gp1≈Gp3)
0.004	<0.001 (Gp1≈Gp3>Gp2≈Gp4)
0.221	0.041 (Gp1≈Gp3>Gp2≈Gp4)

UN minimum F wave latency< 29 msec, TN DML on AH< 6.0 msec, TN MCV> 39 m/sec, TN minimum F wave latency< 55 msec, TN CMAP amplitude on AH> 3 mV, PN DML on EDB < 5.0 msec, PN MCV> 39 m/sec, PN CMAP amplitude on EDB> 2 mV, SN SCV> 39 m/sec, SN SNAP amplitude > 8 μV. Electrodiagnosis of DSMPNP is based on obtained abnormalities in NCS parameters using these reference values of our laboratory. Abnormal conduction results other than the findings of compressive neuropathy in one or more nerves in upper limbs in addition to one or more nerves in lower limbs are accepted as indicators of DSMPNP. The neurophysiological study is extended if a suspicious finding is observed (such as signs of ulnar compressive neuropathy, radiculopathy, etc).

Conduction abnormalities indicating diffuse involvement of both sensory and motor fibres of UN without any sign of focal compression were accepted as upper extremity involvement (UEI) of DSMPNP. The study population was divided into UEI-positive and UEI-negative groups, and then further classified according to clinical diagnoses of CTS as UEI-positive + CTS-positive group, UEI-positive + CTS-negative group, UEI-negative + CTS-positive group, and UEI-negative + CTS-negative group for the statistical analysis.

Statistics

All data were analysed using VassarStats (©Richard Lowry 1998-2021, USA). A p-value less than 0.05 was considered statistically significant. After tests for normality, differences between the means of the groups and subgroups were tested by independent sample t-test for normally distributed data and Mann-Whitney U test for the data not normally distributed. ANOVA was used to test the possible differences between the averages of multiple groups in normally distributed data, and Kruskal-Wallis H test for the data not normally distributed. The Chi-square test/χ^2 or Fisher Exact Probability Test was used to consider the distribution of categorized variables.

The sensitivity, specificity, and diagnostic accuracy values in the diagnosis of CTS were reported for each parameter with its best cut-off point determined for the whole group, and each study group separately. Accuracy values obtained with these two methods were compared with the test for significance of the difference between two independent proportions using the z-ratio.

Results

NCS recordings of 134 hands belonging to 70 patients (35 females and 35 males) with DSMPNP were included. The mean age was 63.2±9.5 (range: 39–85 years, median age: 63 years). The mean disease age of DM was 12.0±8.8 (range: 1–38 years; median disease age: 10 years). Clini-

Continuation of Table 2

	Negative UEI + negative CTS (Gp1; n=24)	Positive UEI + negative CTS (Gp2; n=39)	p* (Gp1 vs. Gp2)	Negative UEI + positive CTS (Gp3; n=46)	Positive UEI + positive CTS (Gp4; n=25)
UN DML (msec)	2.82 ± 0.29	3.45 ± 0.46	<0.001	2.79 ± 0.22	3.27 ± 0.36
UN MCV (m/sec)	52.44 ± 4.13	44.71 ± 5.39	<0.001	55.25 ± 4.19	50.07 ± 4.00
UN across-elbow MCV (m/sec)	53.52 ± 6.48	46.31 ± 9.59	0.047	56.12 ± 7.32	49.86 ± 6.00
UN mFWL (msec)	28.78 ± 2.58	33.64 ± 3.06	<0.001	27.80 ± 2.33	30.03 ± 1.90
UN CMAP ampl (mV)	11.84 ± 3.32	10.35 ± 4.33	0.155	12.59 ± 2.62	11.75 ± 3.15
DSOLD of MN on 2nd -to-UN on 5th finger	0.45 ± 0.32	0.44 ± 0.49	0.948	1.05 ± 0.50	1.01 ± 0.54
SCVD of MN on 2nd -to-UN on 5th finger	1.22 ± 5.97	-0.84 ± 6.32	0.214	6.14 ± 5.32	6.46 ± 6.65
SNAP ampl ratio of MN on 2nd-to-UN on 5th finger	1.26 ± 0.69	2.52 ± 3.73	0.109	1.27 ± 1.04	0.91 ± 0.38
MN on APB-to-UN on ADM DMLD	1.20 ± 0.45	1.03 ± 0.74	0.307	2.13 ± 1.08	2.27 ± 1.58
MN -to-UN mFWLD	-0.08 ± 1.77	-1.55 ± 2.10	0.006	1.87 ± 2.46	1.39 ± 2.74
DSOLD of MN-to-UN on RF	0.45 ± 0.35	0.36 ± 0.48	0.474	1.25 ± 0.80	0.89 ± 0.65
SNAP ampl ratio of MN-to-UN on RF	1.38 ± 1.22	1.37 ± 1.05	0.974	0.77 ± 0.81	0.83 ± 0.49
2L-INT DMLD	0.28 ± 0.28	0.22 ± 0.57	0.640	2.79 ± 0.22	3.27 ± 0.36
TN DML (msec)	4.20 ± 1.18	5.42 ± 1.40	0.001	4.37 ± 1.02	4.63 ± 0.95
TN MCV (m/sec)	37.09 ± 3.51	34.90 ± 3.40	0.025	37.71 ± 3.96	35.68 ± 5.02
TN mFWL (msec)	58.42 ± 4.85	63.83 ± 7.24	0.003	59.08 ± 6.06	60.78 ± 5.80
TN CMAP ampl (mV)	7.22 ± 3.07	3.92 ± 4.39	0.004	5.17 ± 3.56	4.60 ± 2.61
PN DML (msec)	3.80 ± 0.72	4.77 ± 1.63	0.010	4.01 ± 0.76	4.06 ± 0.72
PN LL MCV (m/sec)	41.03 ± 3.53	35.03 ± 4.76	<0.001	38.31 ± 9.41	37.74 ± 3.67
PN P-to-F MCV (m/sec)	43.78 ± 6.43	35.83 ± 5.26	<0.001	44.83 ± 8.04	40.69 ± 4.52
PN CMAP ampl (mV)	2.79 ± 2.49	2.32 ± 1.99	0.443	1.99 ± 1.42	2.07 ± 1.32
SN DSOL (msec)	3.26 ± 0.69	3.43 ± 0.61	0.433	3.13 ± 0.36	3.08 ± 0.36
SN SCV (m/sec)	39.07 ± 6.44	36.59 ± 4.84	0.170	39.46 ± 5.27	38.49 ± 4.58
SN SNAP ampl (μV)	6.46 ± 2.97	4.99 ± 3.25	0.165	7.13 ± 3.16	5.67 ± 2.79

*Student t test, #ANOVA

Table 3. *Best cut off points for tested conduction parameters and their diagnostic accuracy values in whole study population*

Parameter	Best cut off point	UEI-negative group (n=70)			UEI-positive group (n=64)		
		Sensitivity	Specificity	Diagnostic Accuracy	Sensitivity	Specificity	Diagnostic Accuracy
MN DSOL to 2nd finger	3.48 ms	66.7% (30/45)	75.0% (18/24)	69.6% (48/69)	73.9% (17/23)	65.8% (25/38)	68.9% (42/61)
MN SCV to 2nd finger	37.3 m/s	46.7% (21/45)	91.7% (22/24)	62.3% (43/69)	65.2% (15/23)	81.5% (31/38)	75.4% (46/61)

p* (Gp3 vs. Gp4)	p# (Gp1 to Gp4)
<0.001	<0.001 (Gp3≈Gp4>Gp1≈Gp2)
<0.001	<0.001 (Gp3>Gp1>Gp4>Gp2)
<0.001	<0.001 (Gp3>Gp1>Gp4>Gp2)
<0.001	<0.001 (Gp2>Gp4>Gp1>Gp3)
0.234	0.030 (Gp3>Gp2, Gp3≈Gp1≈Gp4, Gp2≈Gp1≈Gp4)
0.776	<0.001 (Gp3≈Gp4>Gp1≈Gp2)
0.841	<0.001 (Gp3≈Gp4>Gp1≈Gp2)
0.166	0.027 (Gp2>Gp1≈Gp3≈Gp4)
0.665	<0.001 (Gp3≈Gp4>Gp1≈Gp2)
0.463	<0.001 (Gp3≈Gp4>Gp1>Gp2)
0.131	<0.001 (Gp3≈Gp4>Gp1≈Gp2)
0.774	0.021 (Gp1≈Gp2>Gp3≈Gp4)
0.820	<0.001 (Gp3≈Gp4>Gp1≈Gp2)
0.305	<0.001 (Gp2>Gp1≈Gp3≈Gp4)
0.069	0.014 (Gp1≈Gp3>Gp2, Gp2≈Gp4)
0.256	0.004 (Gp2>Gp1≈Gp3≈Gp4)
0.487	0.009 (Gp1>Gp2≈Gp3≈Gp4)
0.197	0.004 (Gp2>Gp1≈Gp3≈Gp4)
0.782	0.001 (Gp1>Gp2≈Gp4, Gp3>Gp2≈Gp4, Gp1≈Gp3)
0.029	<0.001 (Gp1≈Gp3≈Gp4>Gp2)
0.825	0.369 (Gp1≈Gp2≈Gp3≈Gp4)
0.593	0.041 (Gp1≈Gp2≈Gp3≈Gp4)
0.472	0.157 (Gp3>Gp2, Gp1≈Gp3≈Gp4, Gp1≈Gp2≈Gp4)
0.104	0.057 (Gp3>Gp2, Gp1≈Gp3≈Gp4, Gp1≈Gp2≈Gp4)

Whole group (n=134)			p*
Sensitivity	Specificity	Diagnostic Accuracy	
69.1% (47/68)	69.4% (43/62)	69.2% (90/130)	0.929
52.9% (36/68)	83.9% (52/62)	68.5% (89/130)	0.109

cal signs of CTS were present in 71 hands (CTS-positive), and absent in 63 hands (CTS-negative). All patients had sensory and motor conduction abnormalities on the lower extremities. Among 134 hands, 64 hands had both sensory and motor conduction abnormalities of UN and were grouped as UEI-positive. The remaining 70 hands were UEI-negative. Among those 64 hands with polyneuropathic involvement, 25 hands (39.0%) had got CTS findings (UEI-positive+CTS-positive), whereas 46 hands (65.7%) among 70 hands without polyneuropathic involvement had got them (UEI-negative+CTS-positive) (χ^2: 8.49, p=0.004)

The mean age of hands with CTS was older than hands without CTS (65.3±8.0 vs. 60.4±10.2, respectively; p=0.002). The mean known disease age of DM was not different between the hands with CTS and without CTS (12.28±8.58 vs. 11.8±9.4, respectively; p=0.780). The mean age of the UEI-negative group was older than the UEI-positive group (64.8±7.5 vs. 61.0±10.8, respectively; p=0.018). The mean known disease age of DM was not different between the UEI-negative group and the UEI-positive group (12.3±7.8 vs. 11.8±10.0, respectively; p=0.777). In subgroup analyses, mean age was 62.9 ±8.8 in negative UEI + negative CTS subgroup and 58.9 ±10.8 in positive UEI + negative CTS subgroup (p=0.130), while it was 65.8 ± 6.5 in negative UEI + positive CTS subgroup and 64.3 ± 10.3 in positive UEI + positive CTS (p=0.453). The mean known disease age of DM was 12.2 ±8.0 in negative UEI + negative CTS subgroup and 11.6 ±10.3 in positive UEI + negative CTS subgroup (p=0.800), while it was 12.3 ± 6.5 in negative UEI + positive CTS subgroup, and 12.2 ± 9.8 in positive UEI + positive CTS (p=0.959). Therefore, there were not any statistical differences in terms of age and disease age between study subgroups.

Comparisons of obtained values on NCSs between the UEI-positive group and the UEI-negative group are summarized in **Table 1**. Motor responses of TN could not be elicited on 7 of 64 patients in the UEI-positive group, and 3 of 70 patients in the UEI-negative group (OR: 0.37; p=0.129). Mean TN DML was longer, MCV was slower, mFWL was longer and CMAP was smaller in the UEI-positive group comparing with the UEI-negative group (p<0.05 for all comparisons). Motor responses of PN could not be elicited on 10 patients in the UEI-positive group, and 2 patients in the UEI-negative group (OR: 0.87; p=0.014). Mean PN DML was longer, lower leg MCV and popliteal-to-fibular head segment MCV were slower in UEI-positive group comparing with UEI-negative group (p<0.05 for all comparisons). SNAPs of SN were unelicitable on 14 patients in the UEI-positive group and 15 patients in the UEI-negative group (χ^2: 0.02; p=0.888). Mean SN SCV was slower and SNAP amplitude was smaller in the UEI-positive group comparing with the UEI-negative group (p<0.05 for both comparisons).

Continuation of Table 3

Parameter	Best cut off point	UEI-negative group (n=70)			UEI-positive group (n=64)		
		Sensitivity	Specificity	Diagnostic Accuracy	Sensitivity	Specificity	Diagnostic Accuracy
MN SNAP amplitude on 2nd finger	3.2 micrV	17.8% (8/45)	100.0% (24/24)	46.4% (32/69)	26.1% (6/23)	97.4% (37/38)	70.5% (43/61)
MN DSOL to RF	3.95 ms	60.0% (27/45)	95.8% (23/24)	72.5% (50/69)	63.6% (14/22)	73.5% (25/34)	69.6% (39/56)
MN SNAP amplitude on RF	6.5 micrV	75.6% (34/45)	50.0% (12/24)	66.7% (46/69)	77.3% (17/22)	26.5% (9/34)	46.4% (26/56)
MN DML to APB muscle	4.38 ms	69.6% (32/46)	75.0% (18/24)	71.4% (50/70)	92.0% (23/25)	53.9% (21/39)	68.8% (44/64)
MN MCV	48.6 m/s	63.0% (29/46)	66.7% (16/24)	64.3% (45/70)	32.0% (9/25)	74.4% (29/39)	53.1% (34/64)
MN CMAP amplitude on APB muscle	11.1 mV	63.0% (29/46)	50.0% (12/24)	58.6% (41/70)	92.0% (23/25)	43.6% (17/39)	62.5% (40/64)
MN DML to Lumbr (msec)	4.09 msec	82.6% (38/46)	79.2% (19/24)	81.4% (57/70)	88.0% (22/25)	38.5% (15/39)	57.8% (37/64)
MN mFWL to APB muscle	28.55 ms	65.2% (30/46)	37.5% (9/24)	55.7% (39/70)	84.0% (21/25)	7.7% (3/39)	37.5% (24/64)
DSOLD of MN on 2nd -to-UN on 5th finger	0.78 ms	71.1% (32/45)	91.7% (22/24)	78.3% (54/69)	73.9% (17/23)	81.6% (31/38)	78.7% (48/61)
SCVD of UN on 5th to MN on 2nd finger	2.9 m/s	73.3% (33/45)	70.8% (17/24)	72.5% (50/69)	69.6% (16/23)	76.3% (29/38)	73.8% (45/61)
SNAP amplitude ratio of MN on 2nd -to-UN on 5th finger	0.96	60.0% (27/45)	62.5% (15/24)	60.9% (42/69)	73.9% (17/23)	65.8% (25/38)	68.9% (42/61)
DMLD of MN on APB-to-UN on ADM muscle	1.54 ms	69.6% (32/46)	83.3% (20/24)	74.3% (52/70)	76.0% (19/25)	82.1% (32/39)	79.7% (51/64)
mFWLD of MN and UN	0.20 ms	78.3% (36/46)	54.2% (13/24)	70.0% (49/70)	76.0% (19/25)	92.3% (36/39)	85.9% (55/64)
RF DSOLD	0.74 ms	80.0% (36/45)	87.5% (21/24)	79.7% (55/69)	68.1% (15/22)	88.2% (30/34)	80.4% (45/56)
SNAP amplitude ratio on RF	1.35	95.5% (43/45)	41.7% (10/24)	76.8% (53/69)	90.9% (20/22)	61.8% (21/34)	73.2% (41/56)
2L-INT DMLD	0.43 ms	91.3% (42/46)	70.8% (17/24)	84.3% (59/70)	92.0% (23/25)	69.2% (27/39)	78.1% (50/64)

*Test for the significance of the difference between the diagnostic accuracy values of UEI-negative group and UEI-positive group

Table 4. *Best cut off points of tested conduction parameters for each study subgroups divided based on UEI and their diagnostic accuracy values*

Parameter	UEI-negative group (n=70)			
	Best cut off point	Sensitivity	Specificity	Diagnostic Accuracy
DSOL of MN on 2nd finger	3.48 msec	67.4% (31/46)	75.0% (18/24)	70.0% (49/70)
SCV of MN to 2nd finger	38.9 m/sec	60.9% (28/46)	79.2% (19/24)	67.1% (47/70)
SNAP amplitude of MN on 2nd finger	6 microV	32.6% (15/46)	95.8% (23/24)	54.3% (38/70)
DML of MN on APB muscle	4.16 msec	78.3% (36/46)	66.7% (16/24)	74.3% (52/70)

Whole group (n=134)			p*
Sensitivity	Specificity	Diagnostic Accuracy	
20.6% (14/68)	98.4% (61/62)	57.7% (75/130)	0.006
61.2% (41/67)	82.8% (48/58)	71.2% (89/125)	0.729
76.1% (51/67)	36.2% (21/58)	57.6% (72/125)	0.023
77.5% (55/71)	61.9% (39/63)	70.2% (94/134)	0.735
53.5% (38/71)	71.4% (45/63)	61.9% (83/134)	0.189
73.2% (52/71)	46.0% (29/63)	60.5% (81/134)	0.642
84.5% (60/71)	54.0% (34/63)	70.2% (94/134)	0.003
71.8% (51/71)	19.0% (12/63)	47.0% (63/134)	0.034
72.1% (49/68)	85.5% (53/62)	78.5% (102/130)	0.953
72.1% (49/68)	74.2% (46/62)	73.1% (95/130)	0.866
64.7% (44/68)	64.5% (40/62)	64.6% (84/130)	0.342
71.8% (51/71)	82.5% (52/63)	76.7% (103/134)	0.458
77.5% (55/71)	77.8% (49/63)	77.6% (104/134)	0.027
76.1% (51/67)	87.9% (51/58)	80.0% (100/125)	0.928
94.0% (63/67)	46.5% (27/58)	75.2% (94/125)	0.643
91.5% (65/71)	69.8% (44/63)	81.3% (109/134)	0.360

Sensory responses of MN on the second finger were unelicitable on 8 patients in the UEI-positive group, and 7 patients in the UEI-negative group (OR: 0.37; p=0.129). The sensory response of MN on the ring finger was unelicitable on 15 patients in the UEI-positive group, and 8 patients in the UEI-negative group (χ^2: 2.60; p=0.159). Motor responses of MN were unelicitable on one hand in each group (OR: 0.91; p=0.729). Sensory responses of UN on the fifth finger were unelicitable on 6 patients in the UEI-positive group, and 1 patient in the UEI-negative group (OR: 0.14; p=0.045). Motor responses of UN were elicitable on all hands in each group. Mean MN MCV was slower and mFWL was longer in the UEI-positive group than the UEI-negative group (p<0.05 for both comparisons). Mean UN DSOL was longer, SCV was slower, SNAP amplitude was smaller, DML was longer, forearm MCV and after-to-below elbow segment MCV were slower, CMAP amplitude was smaller, and mFWL was longer in the UEI-positive group comparing with UEI-negative group (p<0.05 for all comparisons).

Comparisons of mean values of conduction parameters between our four study subgroups are summarized in **Table 2**. Best cut-off points regarding NCS parameters for the whole study group, and their diagnostic accuracy values for the whole study group, for UEI negative group and UEI positive group, are demonstrated separately in **Table 3**. There were four patients with unelicitable responses on both of the MN (on the second finger) and UN (on the fifth finger) traditional sensory studies. The same condition is also true for nine patients on RF sensorial studies. These patients were not included in calculations of diagnostic accuracy values for corresponding NCS parameters. When accuracy values were calculated with the best cut-off points determined for the whole study group, the most accurate traditional parameter was MN DML with the rate of 70.2%, whereas the most accurate comparative technique was 2L-INT DMLD having the rate of 81.3% (p=0.03). The electrodiagnostic parameters yielding the correct diagnosis on approximately every third of four extremities or more were DSOLD of MN on 2nd -to-

UEI-positive group (n=64)				Whole group (n=134)
Best cut off point	Sensitivity	Specificity	Diagnostic Accuracy	Diagnostic Accuracy
3.46 msec	80.0% (20/25)	64.1% (25/39)	70.3% (45/64)	70.2% (94/134)
34.7 m/sec	64.0% (16/25)	79.5% (31/39)	73.4% (47/64)	70.2% (94/134)
5 microV	48.0% (12/25)	82.1% (32/39)	68.8% (44/64)	61.2% (82/134)
4.38 msec	92.0% (23/25)	53.9% (21/39)	68.8% (44/64)	71.7% (96/134)

Continuation of Table 4

Parameter	UEI-negative group (n=70)			
	Best cut off point	Sensitivity	Specificity	Diagnostic Accuracy
Forearm MCV of MN	49.8 m/sec	50.0% (23/46)	83.3% (20/24)	61.4% (43/70)
CMAP of MN on APB muscle	10.0 mV	52.2% (24/46)	70.8% (17/24)	58.6% (41/70)
mFWL of MN on APB muscle	30.8 msec	30.4% (14/46)	91.7% (22/24)	51.4% (36/70)
DSOLD of MN on 2nd -to-UN on 5th finger	0.65 msec	76.1% (35/46)	87.5% (21/24)	80.0% (56/70)
SCVD of UN on 5th to MN on 2nd finger	6 m/sec	60,9% (28/46)	87.5% (21/24)	70.0% (49/70)
SNAP amplitude ratio of MN on 2nd finger-to-UN on 5th finger	1.14	78.3% (36/46)	54.2% (13/24)	68.6% (48/70)
DMLD of MN on APB-to-UN on ADM muscle	1.58 msec	67.4% (31/46)	87.5% (21/24)	74.3% (52/70)
mFWLD of MN and UN	1.30 msec	56.5% (26/46)	83.3% (20/24)	65.7% (46/70)
RF DSOLD	0.57 msec	80.4% (37/46)	79.2% (19/24)	80.0% (56/70)
RF SNAP amplitude ratio	0.49	47.8% (22/46)	91.7% (22/24)	62.9% (44/70)
2L-INT DMLD	0.86 msec	63.0% (29/46)	100% (24/24)	75.7% (53/70)

Table 5. *The comparison of diagnostic accuracy values calculated with the best cut off points determined for whole study group and ones with the best cut off points determined in separate for each study subgroups divided based on the status of UEI*

Parameter	Diagnostic Accuracy 1 (calculated with normative values determined for whole study group)	Diagnostic Accuracy 2 (calculated with normative values determined in separate for both subgroups of UEI)	p*
DSOL of MN on 2nd finger	69.4% (93/134)	70.2% (94/134)	0.894
SCV of MN to 2nd finger	68.7% (92/134)	70.2% (94/134)	0.791
SNAP amplitude of MN on 2nd finger	58.1% (78/134)	61.2% (82/134)	0.619
DML of MN on APB muscle	70.2% (94/134)	71.7% (96/134)	0.788
Forearm MCV of MN	61.9% (83/134)	60.0% (79/134)	0.617
CMAP of MN on APB muscle	60.5% (81/134)	60.5% (81/134)	1.000
mFWL of MN on APB muscle	47.0% (63/134)	53.0% (71/134)	0.329
DSOLD of MN on 2nd -to-UN on 5th finger	77.6% (104/134)	78.4% (105/134)	0.883
SCVD of UN on 5th to MN on 2nd finger	73.1% (98/134)	72.4% (97/134)	0.891
SNAP amplitude ratio of MN on 2nd finger-to-UN on 5th finger	64.9% (87/134)	69.4% (93/134)	0.435
DMLD of MN on APB-to-UN on ADM muscle	76.7% (103/134)	76.7% (103/134)	1.000
mFWLD of MN and UN	77.6% (104/134)	75.4% (101/134)	0.666
DSOLD of MN-to-UN on RF	74.6% (100/134)	76.1% (102/134)	0.776
SNAP amplitude ratio of MN-to-UN on RF	70.9% (83/117)	61.9% (83/134)	1.000
2L-INT DMLD	78.2% (104/133)	78.4% (105/134)	0.883

*Chi-Square test

UEI-positive group (n=64)				Whole group (n=134)
Best cut off point	Sensitivity	Specificity	Diagnostic Accuracy	Diagnostic Accuracy
44.4 m/sec	68.0% (17/25)	48.7% (19/39)	56.3% (36/64)	60.0% (79/134)
11.1 mV	92.0% (23/25)	43.6% (17/39)	62.5% (40/64)	60.5% (81/134)
32.05 msec	68.0% (17/25)	46.2% (18/39)	54.7% (35/64)	53.0% (71/134)
0.78 msec	72.0% (18/25)	79.5% (31/39)	76.6% (49/64)	78.4% (105/134)
1.5 m/sec	88.0% (22/25)	66.7% (26/39)	75.0% (48/64)	72.4% (97/134)
0.93	76.0% (19/25)	66.7% (26/39)	70.3% (45/64)	69.4% (93/134)
1.54 msec	76.0% (19/25)	82.1% (32/39)	79.7% (51/64)	76.7% (103/134)
0.68 msec	76.0% (19/25)	92.3% (36/39)	85.9% (55/64)	75.4% (101/134)
0.87 msec	72.0% (18/25)	71.8% (28/39)	71.9% (46/64)	76.1% (102/134)
1.35	92.0% (23/25)	41.0% (16/39)	60.9% (39/64)	61.9% (83/134)
0.54 msec	88.0% (22/25)	76.9% (30/39)	81.3% (52/64)	78.4% (105/134)

UN on 5th finger (78.5%), DMLD of MN on APB-to-UN on ADM muscle (76.7%), mFWLD (77.6%), DSOLD on RF (80.0%), and 2L-INT DMLD (81.3%). The same parameters also yielded accuracy values of 75% or higher, when the best cut-off points were determined separately for each study subgroups divided based on UEI **(Table 4)**. Comparisons of accuracy values obtained with the two different above-mentioned methods of best cut-off point detection were revealed in **Table 5**. The accuracy values obtained with these two different methods were different in none of the searched NCS parameters ($p > 0.05$ for all comparisons). **Table 6** shows the results of comparisons between the accuracy values of traditional MN conduction parameters and their corresponding comparative conduction parameters.

Discussion

The co-existence of CTS and DSMPNP is a common clinical condition. According to the study of Perkins and colleagues on 418 diabetic patients and 52 controls in 2002, the incidence of CTS in combination with DSMPNP is 30%, and that of CTS in combination with DM is 14% with traditional NCSs[10]. In similar, *Oge* and colleagues reported that 27.8% of the patients with DSMPNP had also CTS in their study on 100 patients with type 2 DM and 50 controls in 2004[15]. With the application of new neurophysiological techniques, CTS accompanying DSMPNP has been gradually recognized. In our study population, clinical findings of CTS were present in more than half of the hands of the patients with DSMPNP. Advanced age and duration of DM could have played a role in the development of CTS in diabetic patients. The mean age of our UEI-negative group was older than of the UEI-positive group, whereas the mean known disease ages of DM were similar. CTS was more frequent in our UEI-negative group than in the UEI-positive group which could be either caused by the thickening of flexor retinaculum with longer terms of hand and wrist usages in the UEI-negative group consisting of older patients and/or from the obscuring effects of polyneuropathic damage over the symptoms of CTS in UEI-positive group.

The means of MN MCV and mFWL, the parameters used in the assessment of longer motor nerve segments, besides the means of UN conduction parameters were worse in our UEI-positive group. The conduction values on lower extremities in the UEI-positive group were also disturbed more than the UEI-negative group. Remembering the length depended on the involvement pattern of DSMPNP, all of these aforementioned findings revealed a more prominent axonal degeneration and myelin loss due to polyneuropathic damage in the UEI-positive group. When we analyzed conduction values in patients without CTS, UEI- positive group has more disturbing values in both MN and UN conduction studies than the UEI-negative group. However, conduction values of MN were not different between these groups in patients with CTS probably because the entrapment of MN has more prominent negative effects on MN conduction values than the polyneuropathic involvement.

Table 6. *The comparisons of diagnostic accuracy values of MN conduction parameters with their corresponding comparative parameters*

Parameters	Diagnostic Accuracy Values for UEI-negative group	p*	Diagnostic Accuracy Values for UEI-positive group	p*	Diagnostic Accuracy Values for whole group	p*
MN DSOL to 2nd finger vs. DSOLD of MN on 2nd -to-UN on 5th finger	69.6% (48/69) vs. 78.3% (54/69)	0.244	68.9% (42/61) vs. 78.7% (48/61)	0.216	69.2% (90/130) vs. 78.5% (102/130)	0.090
MN SCV to 2nd finger vs. SCVD of UN on 5th to MN on 2nd finger	62.3% (43/69) vs. 72.5% (50/69)	0.203	75.4% (46/61) vs. 73.8% (45/61)	0.835	68.5% (89/130) vs. 73.1% (95/130)	0.413
MN SNAP amplitude on 2nd finger vs. SNAP amplitude ratio of MN on 2nd-to-UN on 5th finger	46.4% (32/69) vs. 60.9% (42/69)	0.087	70.5% (43/61) vs. 68.9% (42/61)	0.843	57.7% (75/130) vs. 64.6% (84/130)	0.252
MN DML to APB muscle vs. DMLD of MN on APB-to-UN on ADM muscle	71.4% (50/70) vs. 74.3% (52/70)	0.703	68.8% (44/64) vs. 79.7% (51/64)	0.157	70.2% (94/134) vs. 76.7% (103/134)	0.212
MN mFWL to APB muscle vs. mFWLD of MN and UN	55.7% (39/70) vs. 70.0% (49/70)	0.080	37.5% (24/64) vs. 85.9% (55/64)	<0.001	47.0% (63/134) vs. 77.6% (104/134)	<0.001
MN DSOL to RF vs. DSOLD of MN-to-UN on RF	72.5% (50/69) vs. 79.7% (55/69)	0.318	69.6% (39/56) vs. 80.4% (45/56)	0.190	71.2% (89/125) vs. 80.0% (100/125)	0.105
MN SNAP amplitude on RF vs. SNAP amplitude ratio on RF	66.7% (46/69) vs. 76.8% (53/69)	0.185	46.4% (26/56) vs. 73.2% (41/56)	0.003	57.6% (72/125) vs. 75.2% (94/125)	0.117
MN DML on lumbrical muscle vs. 2L-INT DMLD	81.4% (57/70) vs. 84.3% (59/70)	0.654	57.8% (37/64) vs. 78.1% (50/64)	0.013	70.2% (94/134) vs. 81.3% (109/134)	0.032

*Test for the significance of the difference between two independent proportions

NCSs are among the most reliable tools in detecting and monitoring polyneuropathies[38]. Polyneuropathies and CTS cause similar complaints on the upper extremities of diabetic patients. In addition, the traditional NCSs show comparable results in both disorders. However, the establishment of correct diagnosis is important for choosing appropriate treatment as CTS can be successfully treated by surgery, even in diabetics. Differentiation of MN conduction impairments due to entrapment on the carpal tunnel from the polyneuropathic impairment in diabetic patients could be difficult if the DSMPNP affects both the upper and lower extremities. Islam and colleagues reported that 153 (43.2%) patients had symptoms of CTS among 354 diabetic patients[39]. However, only 54 (58.7%) of those symptomatic patients had neurophysiologically proven CTS with traditional NCSs. They observed that 26.0% of patients with established DSMPNP had also got CTS. In the study of Akulwar and colleagues, the frequency of CTS in diabetics was 16.98%, 15.09%, and 24.53% with clinical assessment, routine NCSs, and comparative NCSs, respectively[13]. Therefore, there is a clear need to apply additional NCS techniques to clinical and routine NCS assessments for better recognizing CTS in patients with DSMPNP.

In a previous study, *Gazioglu* and colleagues reported that MN to UN DSOLD on RF has a sensitivity of 90% and specificity of 85% in electrodiagnosis of CTS in diabetic polyneuropathy patients[35]. In similar, *Yagci* and colleagues also reported high diagnostic yields with MN to UN comparative techniques in patients with DM. They concluded that 2L-INT DMLD can identify CTS in diabetic patients better than DSOLD on RF[37]. In accordance with the aforementioned studies, we also confirmed that comparative techniques had more satisfying diagnostic accuracy values in electrodiagnosis of CTS in patients with DSMPNP. The diagnostic accuracy of our most accurate comparative technique, 2L-INT DMLD, was significantly higher than the most accurate traditional parameter, MN DML to APB muscle, in our study. In addition, when we compared diagnostic accuracy values of MN parameters with their corresponding comparative parameters in the UEI-positive group, which carries the major diagnostic challenges for detecting co-morbid CTS, MN to UN mFWLD, SNAP amplitude ratio on RF, and 2L-INT DMLD had higher accuracy values than MN mFWL, SNAP amplitude on RF, and DML on lumbrical muscle, respectively. These analyses clearly reveal that

these comparative parameters are helpful to overcome the electrodiagnostic difficulty of CTS in patients of DSMPNP with UEI.

The UEI of DSMPNP could affect the normative values of MN to UN comparative parameters by disturbing the UN conduction. As our research was conducted in a third-level hospital, the study population includes diabetic patients who were more prone to have upper extremity involvement of DSMPNP and co-morbid CTS. Therefore, to evaluate the probability of obtaining more precise accuracy values, we also determined the best cut-off points for UEI-positive and UEI-negative groups, separately. We revealed that diagnostic accuracy values calculated with this method were not higher than ones calculated with the conventional method of the cut-off point determination for the whole study population in any searched parameters.

In conclusion, conventional NCS techniques have severe limitations when searching for a comorbid CTS in the presence of DSMPNP. Our study confirms that MN to UN comparative studies have high accuracy values in electrodiagnosis of CTS in DSMPNP. In particular, 2L-INT DMLD could be helpful to overcome the diagnostic difficulty in the presence of UEI as an additional conduction technique.

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