Median to Ulnar Nerve Comparative Conduction Studies on Diagnosis of Carpal Tunnel Syndrome in Early Grades

Erken Evrelerdeki Karpal Tünel Sendromunun Tanısında Mukayeseli Median ve Ulnar Sinir İleti Çalışmaları

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The data used in this study belong to the patients that were examined by the author in his previous institute; Yenikent State Hospital (Adapazarı, Sakarya, Turkey).

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ABSTRACT Objective: To analyze the utility of various comparative median (MN) to ulnar nerve (UN) conduction study (NCS) techniques in detecting carpal tunnel syndrome (CTS). **Material and Methods:** We retrospectively analyzed our NCS recordings that belong to the patients who were consecutively referred to our laboratory within a year. The best cut off points and diagnostic efficiencies of the parameters based on comparison of MN and UN distal sensory onset latencies (DSOLs) and peak latencies (DSPLs) over fourth finger and second-to-fifth finger, SNAP amplitudes, MN-thenar and UN-hypothenar distal motor latencies (DMLs), minimum F wave latencies (mFWLs), CMAP amplitudes, motor conduction velocities, and MN sensory and UN motor latency (MS-UM) on electrodiagnosis of CTS were detected beside ones of conventional conduction parameters. **Results:** Totally 109 recordings among the 210 upper extremity recordings were included. CTS was clinically diagnosed in 59 hands (54.1%). MN DSOL and DSPL over fourth finger had the highest diagnostic efficiency values (88.1% and 87.2%, respectively) among conventional parameters, whereas MN to UN DSOL and DSPL differences over fourth finger had the highest ones (93.6% and 90.8%, respectively) among comparative parameters. MN DSOL and DSPL values, over both second and fourth fingers, had good overall agreement in confirming the CTS diagnosis. That was also true for MN to UN DSOL and DSPL differences on fourth finger, but not for ones on second to fifth finger DSOL and DSPL comparisons. The diagnostic efficiency values were 80.7% for DML difference and 78% for mFWL difference. **Conclusion:** DSOL and DSPL differences over fourth finger have a favorable diagnostic efficiency values on CTS diagnosis. Although the MN to UN DML and mFWL differences are more efficient in CTS diagnosis, their diagnostic efficiency rates are lower than ones of sensory parameters. Future studies are warranted to consider their possible usefulness of them for diagnosing CTS in patients with concomitant polyneuropathy or unelicitable sensory responses because of technical pitfalls during the sensory NCSs.

Key Words: Carpal tunnel syndrome; median nerve; ulnar nerve

ÖZET Amaç: Karpal Tünel Sendromunun (KTS) tespitinde, median sinir (MN) ve ulnar sinir (UN) kıyaslanmasına dayalı değişik sinir iletim çalışmaları tekniklerinin kullanılabilirliğini analiz etmek. **Gereç ve Yöntemler:** Bir yıl süresince laboratuvarımıza refere edilen hastalara ait sinir iletim çalışmalarının kayıtlarını retrospektif olarak analiz ettik. Geleneksel parametrelerinkinin yanısıra, 4. parmak ve 2-5. parmak üzerinden kaydedilen MN-UN duyusal başlangıç latansları (DSOL) ve tepe latansları (DSPL), duyusal yanıt amplitüdleri, median-tenar ve ulnar-hipotenar distal motor latansları (DML), minimum F dalga latansları (mFWL), bileşik kas aksiyon potansiyeli amplitüdleri, motor ileti hızları, ve MN duyusal-UN motor latanslarının (MS-UM) kıyaslanmasına dayalı parametrelerin KTS tanısındaki en iyi eşik değerleri ve tanısal etkinlikleri tespit edildi. **Bulgular:** İkiyüz on üst ekstremite kaydı içinden 109 kayıt çalışmaya dahil edildi. KTS tanısı klinik olarak 59 elde (%54,1) konulmuştu. Geleneksel parametreler arasında dördüncü parmak üzerinden kaydedilen MN DSOL ve DSPL değerleri en yüksek tanısal etkinliğe sahipken (sırasıyla; %88,1 ve %87,2), kıyaslamaya dayalı parametreler arasında ise dördüncü parmak MN-UN DSOL ve DSPL farkı değerleri en yüksek etkinleğe sahipti (sırasıyla; %93,6 ve %90,8). Hem 4. parmak hem de 2. parmak üzerinden kayıtlanan MN DSOL ve DSPL değerleri KTS tanısı konusunda iyi bir genel uyuma sahiptiler. Bu durum, 4.parmak MN-UN DSOL ve DSPL farkı için de geçerliydi, ancak 2-5. parmak MN-UN DSOL ve DSPL kıyaslamaları için geçerli değildi. Tanısal etkinlik değerleri DML farkı için %80,7 ve mFWL farkı için %78'dir. **Sonuç:** Dördüncü parmak MN-UN DSOL ve DSPL farkı KTS'de tatminkar tanısal etkinlik değerlerine sahiptir. MN-UN DML ve mFWL farkları KTS tanısında diğer motor parametrelere kıyasla daha etkin olmalarına rağmen tanısal etkinlik oranları duyusal parametrelerinkinden daha düşüktür. Bu parametrelerin eşlik eden polinöropatisi olan veya teknik hatalar nedeniyle duyusal yanıtları kaydedilemeyen hastalarda KTS'nin tanısındaki olası kullanışının değerlendirilmesi için ileri çalışmalar gerekmektedir.

Anahtar Kelimeler: Karpal tünel sendromu; median sinir; ulnar sinir

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Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy caused by focal compression of the median nerve (MN) in the carpal tunnel. The incidence of symptomatic CTS is about 2.8-3.5 cases per 1,000 person-years, and prevalence is about 3% among women and 2% among men.[1-3] The diagnosis of CTS is mainly based on typical symptoms in history and signs in physical examination.[4] However, electrophysiologic studies are important to confirm the median neuropathy at wrist. The severity of the CTS could also be graded according to abnormalities on nerve conduction studies (NCSs). Grading the nerve compression is useful in deciding the treatment strategy and following up the disease progress.[5-9] Electrophysiologic studies are also important to detect the CTS when the classic defining features are absent.[10]

In electrophysiologic practice, numerous NCS techniques are used. The main indicator of CTS in a NCS is transcarpal MN sensory conduction impairment with or without a motor conduction abnormality in the presence of normal ipsilateral ulnar nerve (UN) conduction. Wrist-abductor pollicis brevis (APB) muscle MN distal motor latency (DML), wrist-to-finger or wrist-to-palm MN distal sensory onset latency (DSOL), distal sensory peak latency (DSPL) and sensory conduction velocity (SCV) are some of the commonly used conventional parameters for electrodiagnosis of CTS. However, the previous studies showed a wide range of sensitivity and specificity values for them.[5,6,11-16] Because the sensory fibers compose the outer layers of the MN in its topographical anatomy, the abnormalities in transcarpal sensory studies of MN are expected to occur in earlier stages of the nerve compression in carpal tunnel than ones in motor responses. Therefore, the sensitivities of MN transcarpal sensory conduction studies (SCSs) could be assumed to be higher than of motor conduction studies.

The comparative conduction tests of MN to UN are being used to increase the diagnostic sensitivities of NCS in detecting the CTS. MN to UN DSOL difference (DSOLD) and DSPL difference (DSPLD), the ratio of sensory nerve action potential (SNAP) amplitudes, comparison of sensory conduction velocities, DML differences (DMLD), and minimum F wave latency difference (mFWLD) are the main kinds of the previously studied comparative techniques.[5,8,12,17-21] In particular, comparing the MN and UN sensory responses on fourth finger was revealed as a useful tool on the electrodiagnosis of CTS even in early grades of the disease.[13,18,19,21-26]

In this study, we searched the sensitivity and specificity values of various MN to UN comparative tests in diagnosis of CTS in early stages of the compression. MN and UN DSOLD, DSPLD, SNAP amplitude ratio, MN-thenar to UN-hypothenar DMLD, motor conduction velocity (MCV) difference, compound muscle action potential (CMAP) amplitude ratio and MN-thenar to UN-hypothenar mFWLD, which were easily applicable procedures by consuming a little time in a routine NCS, included to the study. As in many laboratory, we preferred the second finger as major recording side for MN sensory response, because it has a well preserved sensory branch even in the later stages of nerve compression.[27,28] Because the MN to fourth finger SCSs were shown as more sensitive for detecting the CTS in many previous researches, this finger is used as a second recording side for MN sensory responses, and also used for comparison of MN and UN sensory conduction. We aimed to compare diagnostic efficiency values of those comparative techniques with the conventional MN conduction parameters including the DSOL, DSPL, SNAP amplitude, DML, CMAP amplitude, MCV and minimum F wave latency (mFWL).

MATERIAL AND METHODS

The population of this study is composed of the patients who were referred to Yenikent State Hospital, Electroneuromyography (ENMG) Laboratory (Sakarya, Turkey) for the upper extremity NCSs with the suspicion of CTS within a year. The study is retrospective and includes the data of NCSs which were applied consecutively by same practitioner. The neurological examination of the subjects were also done by him after reporting the result of NCSs to avoid any bias. CTS was diagnosed clinically if the typical sensory symptoms were present in the hand area of MN innervation, and the typical signs were detected in neurological examination. The hand diagram of Katz was used to assess the symptom distribution on suspected cases. These records were analyzed to detect best cut off points and diagnostic efficiencies of parameters based on comparison of DSOLs and DSPLs of MN and UN over fourth finger and second-to-fifth finger, SNAP amplitudes, MN-thenar and UN-hypothenar DMLs, mFWLs, CMAP amplitudes, motor conduction velocities, and MN sensory and UN motor latencies (MS-UM) on electrodiagnosis of CTS beside ones of conventional conduction parameters.

The exclusion criteria were: 1- History of carpal tunnel release operation in studied extremity, 2- Signs of plexopathy, cervical radiculopathy or polyneuropathy, 3- Any abnormality in UN conduction studies, 4- Absence of MN sensory responses over second and/or fourth finger, 5- Any surgical intervention over studied extremity. Beside, the NCS recordings of the normal hands of the patients with unilateral CTS were not included to avoid the possible biases arising from the probability of subclinical CTS on these hands. Normative values used for UN conduction studies used in our laboratory were as follows: orthodromic UN wrist to abductor digiti minimi muscle (ADM) motor latency <3.30 msec, antidromic UN wrist to fifth finger DSPL <3.00 msec, orthodromic UN forearm MCV >50 m/s, and UN mFWL over ADM muscle <30.0 msec. Our study population composed of healthy hands and hands with mild or moderate CTS, as the hands with absent MN to second and/or fourth finger sensory responses were excluded.

All subjects were tested by using a Medelec Synergy ENMG tool. The electrophysiologic study was conducted according to the American Association of Electrodiagnostic Medicine (AAEM) practice guidelines. Electrophysiological examination consisted of motor and sensory NCSs and F wave studies of the MN and UN. Needle electromyography was used to exclude polyneuropathy or cervical radiculopathy in suspected cases in affected arms. The nature of the procedure was explained to the subjects, a signed informed consent was obtained. They sit on a padded table with the upper limb supported. NCSs were performed while wrist was in its neutral position and the forearm was flexed 35-45°. All the studies were performed in a warm room with the temperature maintained at 26–28°C. If necessary, the limb was warmed to maintain the temperature of 30°C or over.

NCSs were performed using standard techniques of supramaximal percutaneous stimulation with a constant current stimulator and surface electrode recording on upper extremities of each subject. The distances were measured with an anthropometer. Supramaximal stimulus intensity level was calculated as the level that is 25% more than the intensity creating maximal response amplitude. The parameters of the ENMG tool were adjusted as follows: sensitivity= 5 mV/div for the motor waveforms, 5 mV/div for M wave and 500 mV/div for F wave, sweep speed= 2 ms/div, low filter was 10 Hz and high filter was 10000 Hz. MN and UN motor and sensory conduction studies and F wave studies were done in both extremity of all patients. Latency of a compound muscle action potential (CMAP) was defined as the time period (msec) from the start of the electrical artifact to the start of CMAP potential for motor responses. MCV was calculated dividing the distance by the difference of proximal and distal onset latencies (m/sec). Peak latency was defined as the time period (msec) from the start of the electrical artifact to the peak of the SNAP.

The motor conduction of MN was examined by stimulating it on wrist and antecubital fossa. The nerve was stimulated with bipolar surface electrodes and the recording was carried out over the belly of APB muscle with surface electrodes. MN SCSs were performed by stimulating it on wrist and recording the responses from second and fourth finger, antidromically. Motor conduction studies of the UN were performed by stimulating it on wrist and ulnar groove in elbow by bipolar surface electrodes. The motor responses were recorded over ADM muscle with surface electrodes. UN SCSs were performed by stimulating it on wrist and recording the responses from fourth and fifth finger, antidromically. In order to study MN and UN F wave responses, the nerves were stimulated on their stimulation points over wrist with bipolar surface electrodes and the recordings were carried out over the belly of APB and ADM muscles with surface electrodes, respectively. The shortest F wave latency was measured after 20 repetitive simulations and elicitation of 7 F wave responses at least. In another term, the F wave firing ratio over 1/3 was warranted for the mFWL recording.

The demographic features, signs and symptoms of the patients and their clinical diagnoses were all noted on the first page of the ENMG result reports that were prepared after the procedure. Numerical values of NCS parameters measured during the procedure, and graphs of motor and sensory responses were all documented on ENMG reports.

We calculated the best cut off points for detecting the CTS from the results of nerve conduction tests by using the 0.05 msec intervals for each variable. The point which indicates the least number of misdiagnosed cases (minimum value of sum of the false negative and false positive hands) was determined as the best cut off point. The sensory response of MN is expected to be affected earlier than motor response except for unusual cases. Therefore, we calculated the cut off point for MN DML by determining the point just over the longest motor latency value among the hands with the normal following sensory conduction values: wrist to second finger DSOL (DSOL-II), DSPL (DSPL-II), wrist to fourth finger DSOL (DSOL-IV) and DSPL (DSPL-IV).

The sensitivity and specificity values were calculated for the following conventional conduction parameters: 1- Antidromic MN DSOL-II and DSOL-IV, 2- Antidromic MN DSPL-II and DSPL-IV, 3- MN DML to APB, 4- MN forearm MCV, 5- MN mFWL. Then we calculated the sensitivities and specificities of following comparative tests: 1- Antidromic DSOLD and DSPLD between MN to second finger and UN to fifth finger (DSOLD II-V and DSPLD II-V, respectively), 2- Antidromic MN to UN DSOLD and DSPLD over fourth finger (DSOLD IV and DSPLD IV, respectively), 3- Ratio of the MN (second finger) to UN (fifth finger) SNAP amplitude, 4- Ratio of the MN to UN SNAP amplitude over fourth finger, 5- MN-thenar to UN-hypothenar DMLD, 6- MN-thenar to UN-hypothenar mFWLD, 7- MN-thenar to UN-hypothenar CMAP ratio, 8-UN to MN MCV difference, 9- MN sensory to UN motor latency differences.

All data was analyzed using SOFA - Statistics Open For All package (released with open source AGPL3 license © 2009-14; Paton-Simpson & Associates Ltd, USA). A p value < 0.05 was considered as statistically significant. After tests for normality, statistical significance between the means was calculated using an independent sample t test for normally distributed data and the Mann-Whitney U test for data not normally distributed. We calculated optimal cut-off points based on the method of maximization of the sensitivity and specificity product. Z test was used to compare the efficiency rates of tested conventional transcarpal MN conduction measures and corresponding MN to UN comparison parameters.

RESULTS

STUDY POPULATION

Totally, 210 upper extremity recordings of 114 individuals were evaluated for the inclusion. Twenty-five extremities with ulnar neuropathy at elbow, four extremities with the concomitant sign of polyneuropathy, two extremities with Guyon's canal entrapment neuropathy, one extremity with unelicitable MN F wave response, one extremity with the history of UN injury causing total dissection, twenty-three recordings belonging to the normal hands of the patients with unilateral CTS, eight extremities with absent second finger (and also fourth finger) SNAP and thirty-seven ones with absent fourth finger SNAP were excluded. Therefore, 109 extremities belong to 65 subjects were included. Among them, 98 extremities belong to females and 11 to males. The mean age was 44.4±11.1 years (range was 16-71 years). Fifty-nine extremities belong to 40 subjects had a clinical diagnosis of CTS (54.1%). Among disease group, 21 subjects had unilateral CTS, and 19 subjects had bilateral CTS. Fifty (45.9%) extremities belong to 25 subjects were normal. The mean age of the extremities with CTS tended to be older than one of the healthy ones, however the difference was not statistically significant (46.1±11.5 and 42.4±10.3, respectively). (p=0.07)

NERVE CONDUCTION STUDIES

The mean MN DML, DSOL, DSPL and mFWL of the hands with CTS were longer than ones of healthy hands (p<0.05 for all). In addition, the mean MN SNAP amplitudes on second and fourth fingers in hands with CTS were smaller than in healthy hands (p<0.05). The mean MN forearm MCV was slower in hands with CTS than in healthy hands (p<0.05). The mean UN DSOLs, DSPLs, SNAP amplitudes, DML, forearm MCV and mFWL were not different between these two groups (p>0.05 for all). MN and UN DSOLD and DSPLD, both on second-to-fifth finger and on fourth finger comparisons, were significantly greater in hands with CTS than in healthy hands (p<0.05 for all). MN and UN SNAP ratio on second-to-fifth finger comparison was lower in hands with CTS than in healthy hands (p<0.05). However, MN and UN SNAP ratio on fourth finger comparison was not statistically different between two groups (p>0.05) (Tables 1, 2).

The calculated best cut off points which yielded maximization of the sensitivity and specificity product in discrimination of hands with CTS from the healthy hands were shown in Table 3 and 4 for the researched sensory and motor nerve conduction tests, respectively. As expected, the conventional NCS parameters regarding the timing measures of MN sensory responses (DSOL and DSPL on second finger and on fourth finger) have higher diagnostic efficiency values than the parameters belong to MN motor responses (DML to APB muscle, MCV and mFWL) on electrodiagnosis of CTS (p<0.05 for all). The same conclusion was also true for MN and UN comparative techniques; DSOLD II-V, DSPLD II-V, DSOLD IV and DSPLD IV had higher efficiency values than MN-thenar to UN-hypothenar DMLD and mFWLD (p<0.05 for all). The best cut off points derived from MN DSOL and DSPL have similar

TABLE 1: Comparison of sensory nerve conduction study parameters between healthy hands and hands with CTS.

Parameter	Healthy Hands (mean±SD)	Hands with CTS (mean±SD)	p value
MN DSOL-II	2.39± 0.19	2.95 ±0.45	<0.001*
UN DSOL-V	2.04±0.17	2.03±0.18	0.738*
MN-UN DSOLD II-V	0.35±0.16	0.92±0.43	<0.001*
MN DSPL-II	3.06±0.19	3.70±0.51	<0.001*
UN DSPL-V	2.62±0.20	2.63±0.20	0.765*
MN-UN DSPLD II-V	0.44±0.17	1.08±0.46	<0.001*
MN SNAP amplitude (on 2nd finger)	38.93±11.79	30.55±15.68	0.002*
UN SNAP (on 5th finger)	40.72±11.90	38.88±16.21	0.508*
MN/UN SNAP ratio (2nd-to-5th finger)	0.97±0.19	0.81±0.31	0.002*
MN DSOL-IV	2.47±0.26	3.24±0.65	<0.001*
UN DSOL-IV	2.28±0.21	2.24±0.20	0.273*
MN-UN DSOLD-IV	0.19±0.18	1.00±0.63	<0.001 #
MN DSPL-IV	3.09±0.25	3.97±0.71	<0.001*
UN DSPL-IV	2.89±0.25	2.85±0.22	0.330*
MN-UN DSPLD-IV	0.20±0.18	0.95±0.66	<0.001 #
MN SNAP amplitude (on 4th finger)	24.03±10.30	15.93±9.54	<0.001 #
UN SNAP amplitude (on 4th finger)	25.57±13.26	21.57±11.74	0.097 #
MN/UN SNAP ratio (on 4th finger)	1.13±0.69	0.89±0.64	0.016 #

* Independent sample t test; # Mann Withney U test.

TABLE 2: Comparison of motor nerve conduction study parameters between healthy hands and hands with CTS.

Parameter	Healthy Hands (mean±S.D.)	Hands with CTS (mean±S.D.)	p value
MN DML (over APB)	3.28±0.30	3.94±0.68	<0.001*
UN DML (over ADM)	2.46±0.27	2.40±0.22	0.185*
MN-UN DML difference (APB-ADM)	0.82±0.35	1.55±0.65	<0.001*
MN MCV	59.8±4.2	56.6±4.4	<0.001*
UN MCV	63.0±5.7	60.6±5.1	0.021*
UN-MN MCV difference	3.2±5.6	4.1±5.9	0.440*
MN CMAP (over APB)	8.85±3.00	8.94±3.20	0.877*
UN CMAP (over ADM)	6.446±2.27	6.95±2.42	0.276*
M/U CMAP ratio	1.35±0.805	1.21±0.822	0.688 #
MM mFWL	23.7±1.5	25.2±2.1	<0.001*
UN mFWL	24.0±1.7	23.8±1.2	0.565*
MN-UN mFWLD	-0.3±0.84	1.3±1.47	<0.001*

* Independent sample t test; # Mann Withney U test.

diagnostic efficiency values, both for second and fourth fingers (p>0.05). MN DSOL and DSPL values, both over second and fourth fingers, had good overall agreement in confirming the CTS diagnosis. The same conclusion was also true for DSOLD and DSPLD values on fourth finger comparison, but not for ones over second to fifth finger comparison (Table 3).

Conventional parameters (MN DSOL, DSPL and DML) could define the CTS electrophysiologically in 51 of 59 hands with clinically diagnosed as CTS (86.4%). In general, MN DSOL-IV and DSPL-IV had the highest diagnostic efficiency values (88.1% and 87.2%, respectively) among the conventional NCS parameters whereas MN and UN DSOLD-IV and DSPLD-IV had the highest ones (93.6% and 90.8%, respectively). The comparative techniques for MN and UN sensory conduction measures yielded a bit higher efficiency rates than corresponding conventional MN conduction parameters except for SNAP ratio on fourth finger (Table 3). However, none of the differences in efficiency rates between conventional MN conduction parameters and MN to UN comparative ones (DSOL -II *vs.* DSOLD II-V, DSPL-II *vs.* DSPLD II-V, DSOL-IV *vs.*DSOLD-IV, DSPL-IV *vs.* DSPLD-IV) was statistically significant (Z Test for proportions, p>0.05 for all comparisons). The same statistical

TABLE 3: The sensitivity, specificity and diagnostic efficiency values of researched sensory conduction parameters on electrodiagnosis of CTS.

Parameter	Normative Value (Best Cut Off)	Sensitivity	Specificity	Diagnostic Efficiency
MN DSOL-II	<2.6 msec	86.4% (51/59)	88.0 % (44/50)	87.2% (95/109)
MN-UN DSOLD II-V	<0.6 msec	78.0% (46/59)	94.0% (47/50)	85.3% (93/109)
MN DSPL-II	<3.4 msec	81.4% (48/59)	92.0% (46/50)	86.2% (94/109)
MN-UN DSPLD II-V	<0.65 msec	89.8% (53/59)	86.0% (43/50)	88.1% (96/109)
MN SNAP amplitude (on 2nd finger)	>32.5 microV	64.4% (38/59)	70.0% (35/50)	70.0% (73/109)
MN/UN SNAP ratio (2nd-to-5th finger)	>0.8	61.0 % (36/59)	86.0% (43/50)	72.5% (79/109)
MN DSOL-IV	<2.75 msec	84.8 % (50/59)	92.0% (46/50)	88.1% (96/109)
MN-UN DSOLD-IV	<0.45 msec	91.5 % (54/59)	96.0% (48/50)	93.6% (102/109)
MN DSPL-IV	<3.4 msec	84.8 % (50/59)	90,.0% (45/50)	87.2% (95/109)
MN-UN DSPLD-IV	<0.5 msec	89.8% (53/59)	92.0% (46/50)	90.8% (99/109)
MN SNAP amplitude (on 4th finger)	>19.4 microV	59.3% (35/59)	66.0% (33/50)	62.4% (68/109)
MN/UN SNAP ratio (on 4th finger)	>0.95	69.5% (41/59)	50.0% (25/50)	60.6% (66/109)

* Independent sample t test; # Mann Withney U test.

conclusion is also true for motor response studies (Table 4). The best cut off points for MN sensory to UN motor latency comparisons, and their sensitivity, specificity and diagnostic efficiency values on electrodiagnosis of CTS were shown on Table 5. The diagnostic efficiency values of both conventional and comparative sensory conduction parameters are significantly higher than corresponding motor conduction parameters on electrodiagnosis of CTS (Z Test for proportions, p<0.05 for all comparisons).

DISCUSSION

In electrodiagnostic practice, the results of transcarpal MN motor and sensory conduction studies are compared with the commonly used limits determined from published charts or the limits of the laboratory itself for CTS diagnosis. Because the sensory fibers compose the outer layers of the MN in its topographical anatomy, the abnormalities in transcarpal sensory studies are expected to occur in earlier stages of the nerve compression in carpal tunnel than ones in motor responses. Therefore, the sensitivities of MN transcarpal SCSs could be assumed to be higher than of transcarpal motor conduction studies. Results of the present study also confirmed this assumption. In our study group, the conventional NCSs that were testing the timing measures of MN sensory responses (MN DSOLs and DSPLs) had higher sensitivities than studies testing the motor responses (DML, MCV and mFWL) on electrodiagnosis of CTS. Common questions about the usage of transcarpal SCSs are that if we use the latency values of MN and UN from the same distances for SCSs, does DSOL or DSPL get a higher accuracy values, and which finger's SCS values yield the best diagnostic efficiency ? We showed that the best cut off points derived from MN DSOLs and DSPLs have similar diagnostic efficiency values for CTS, both for second and fourth fingers. The MN DSOLs and DSPLs showed a nearly complete overall agreement on electrodiagnostic outputs of the studied extremities in our study group. In a recent study, Kasius et al. also compare the diagnostic accuracy of onset versus

TABLE 4: The sensitivity, specificity and diagnostic efficiency values of researched motor conduction parameters on electrodiagnosis of CTS.

Parameter	Normative Value (Best Cut Off)	Sensitivity	Specificity	Diagnostic Efficiency
MN DML	<4 msec	37.3% (22/59)	100 % (50/50)	66.1% (72/109)
MN-UN DMLD (APB-ADM)	<1.0 msec	86.4% (51/59)	74.0% (37/50)	80.7% (88/109)
MN forearm MCV	>58.5 m/sec	69.5% (41/59)	62.0% (31/50)	66.1% (72/109)
U-M MCV difference	<3.5 m/sec	59.3% (35/59)	56.0% (28/50)	57.8% (63/109)
Median nerve CMAP	>10.4 mV	71.2% (42/59)	36.0 % (18/50)	55.1% (60/109)
M/U CMAP ratio	>1.3	57.6% (34/59)	52.0% (26/50)	68.8% (75/109)
Median mFWL	<25.3 msec	35.6% (21/59)	90.0% (45/50)	60.6% (66/109)
M-U mFWLD	<0.85 msec	61.0% (36/59)	98.0% (49/50)	78.0% (85/109)

TABLE 5: The sensitivity, specificity and diagnostic efficiency values of median nerve sensory to ulnar nerve motor latency differences and ratios on electrodiagnosis of CTS.

Parameter	Normative Value (Best Cut Off)	Sensitivity	Specificity	Diagnostic Efficiency
Median DSOL II-Ulnar DML	<0.25 msec	81.4% (48/59)	88.0 % (44/50)	84.4% (92/109)
Median DSOL II/Ulnar DML	<1.07	86.4% (51/59)	82.0 % (41/50)	84.4% (92/109)
Median DSPL II-Ulnar DML	<0.95 msec	81.4% (48/59)	92.0 % (46/50)	86.2% (94/109)
Median DSPL II/Ulnar DML	<1.33	86.4% (51/59)	80.0 % (40/50)	83.5% (91/109)
Median DSOL IV-Ulnar DML	<0.40 msec	83.1% (49/59)	88.0 % (44/50)	85.3% (93/109)
Median DSOL IV/Ulnar DML	<1.1	88.1% (52/59)	80.0 % (40/50)	84.4% (92/109)
Median DSPL IV-Ulnar DML	<0.90 msec	88.1% (52/59)	82.0% (42/50)	86.2% (94/109)
Median DSPL IV/Ulnar DML	<1.37	83.1% (49/59)	86.0 % (43/50)	84.4% (92/109)

peak latency measurements of MN SNAPs in electrodiagnosis of CTS.[29] They also found a good overall agreement in confirming the clinical diagnosis of CTS for MN sensory responses from first finger, fourth finger and palm. In our study, we revealed that both of the onset and peak latency values of the second and fourth finger could be used with high diagnostic efficiency values. However, during the study inclusion period we also observed that sensory responses of MN over fourth finger disappeared earlier than second finger. Therefore, studying sensory responses of another finger than fourth one and testing the motor responses are essential rules during the electrodiagnostic studies for CTS as recommended in many guidelines.[5,12]

Recording the sensory responses of fourth finger as a MN and UN comparative technique is an easy and quick procedure. Our results re-affirmed that MN and UN DSOLD-IV and DSPLD-IV were highly efficient parameters on electrodiagnosis of CTS. Because the fourth finger has dual innervations, comparing the sensory latency values of MN and UN recorded over identical distances from the wrist is useful in determining the MN conduction slowing. Many previous researches revealed the value of fourth finger MN to UN latency differences in the diagnosis of CTS.[16,22-25,30] However, these clinical trials yielded different sensitivity values particularly for detecting the CTS cases in early phases. We revealed that MN to UN DSOLD-IV and DSPLD-IV had the highest sensitivity, specificity and efficiency values (over 90%) among the parameters that we researched on electrodiagnosis of CTS. In addition, we found that the differences between the searched MN to UN sensory conduction parameters and corresponding conventional MN sensory conduction parameters were not statistically different. However, to verify this conclusion, prospective studies on larger study populations are warranted.

We also derived the best cut off points for the other rarely searched MN to UN conduction comparison tests (DSOLD II-V and DSPLD II-V, SNAP amplitude ratio, MN-thenar to UN-hypothenar DMLD, CMAP amplitude ratio and mFWLD), and determined their diagnostic efficiency values on electrodiagnosis of CTS. In an early study, Loong and Seah observed that the amplitude of MN SNAP recorded at the wrist upon stimulation of the second finger was consistently greater than that of the nerve SNAP evoked by stimulation of the fifth finger of the same hand (orthodromic technique).[17] They found that this ratio was less than one for twenty of the 22 clinically affected hands with CTS, including three of the four hands with a normal motor latency to threshold stimulation and four of the five hands with a normal sensory conduction. They concluded that the estimation of the ratio of the MN to UN sensory potential amplitude is a sensitive test in the diagnosis of CTS and is particularly useful in those patients who show a normal motor latency and sensory conduction. However, our study results did not reach same conclusion with the use of antidromic recording technique. We could not get a satisfying diagnostic efficiency values for SNAP amplitudes and amplitude ratios both on second-to-fifth finger and fourth finger comparisons on electrodiagnosis of CTS.

DML has relatively small values that represent the early response to the activation of a peripheral nerve near to the recording side. Its usage in electrodiagnosis of entrapment neuropathies aids to detect the conduction disturbances of motor nerve fibers on compression point. As we mentioned, since the sensory fibers compose the outer layers of the MN in its topographical anatomy passing through the carpal tunnel, the elongation of DML values are expected to occur in later stages of the nerve compression than of sensory latency values. Therefore, the sensitivity of MN DML studies could be assumed to be low in a disease group composing only mild or moderate CTS cases as in our study group. However, comparing DML value of MN with one of UN which does not pass through the carpal tunnel could improve its diagnostic efficiency values on CTS. F waves are late responses to antidromic activation of motor neurons. Their classical application is related to the evaluation of conduction along the peripheral nerves, and not expected to be sensitive in detecting the local nerve compression. MN is an extension of the medial cord of the brachial plexus. The larger of the two terminal branches of medial cord of brachial plexus continues as UN, while the smaller terminal branch forms medial root of MN. MN innervates APB muscle by its motor fibers originated from C8 and T1 roots. UN innervates ADM muscle by its motor fibers again originated from same spinal roots. Therefore, generation of F waves of these two nerves over the mentioned muscles shares a common pathway at the level of brachial plexus and medulla spinalis. Any pathological condition involving C8 and/or T1 roots or medial cord of brachial plexus is expected to prolong F wave latencies of both nerves, whereas CTS is expected to prolong ones of MN only. Therefore, the utilities of DMLD and mFWLD on electrodiagnosis of CTS could be higher than DML and FWL. Our results revealed that, although they did not show statistically significant differences, these comparative techniques tended to improve the efficiency values. We found a relatively high specificity values for electrodiagnosis of mild and moderate degree CTS, although their sensitivity values, mFWLD in particular, were not satisfying.

Sander et al.first reported that MN-thenar to UN-hypothenar DMLD and mFWLD could be valuable in diagnosis of CTS, and detected diagnostic sensitivities as 85-88% and 75-78%, respectively.[20] In a study of Chang et al., MN-thenar to UN-hypothenar DMLD was found to have a sensitivity of 70% in diagnosis of CTS.[16] However, the grades of the CTS were not reported in both papers. Beside, Ozge et al. revealed the value of F wave parameters in increasing the diagnostic yield and differentiation of CTS subtypes (which were prominent demyelinating, prominent axonal, slight demyelinating types).[31] Our study researched the value of DMLD or mFWLD in detecting the extremities with mild or moderate degree CTS that compose the main groups having major diagnostic challenge in clinical practice. We reached similar efficiency values for DMLD and for mFWLD with the previous researches. However, as we had not got high sensitive values, we do not offer usage of these techniques in a routine NCS for CTS searching. Rather, we think that, similar with the suggestion of other researchers, these techniques could be useful on electrodiagnosis of CTS when a concomitant polyneuropathy was present, and presence of technical pitfalls on SCSs.

Value of comparing MN distal sensory latency to UN distal motor latency on electrodiagnosis of CTS was described by Bodofsky et al. on their study over 179 hands.[32] They reported to found 82% sensitivity on hands with symptoms and signs of CTS but negative conduction study results by standard criteria. Although they have considerable diagnostic efficiency values, we did not detect any significant differences between the sensitivity or specificity values of conventional NCS parameters and various MN distal sensory latency-to-UN DML comparison parameters. We revealed that usage of this comparison did not result in any significant improvement in the usage of NCS on electrodiagnosis of CTS. Beside, in different from DMLD and mFWLD, these comparative techniques needs both sensory and motor recordings, therefore they are not expected to be useful on electrodiagnosis of CTS with concomitant polyneuropathy, or the technical pitfalls during the NCS recordings.

In neurophysiologic practice, to detect a conduction abnormality, obtained results from the NCS are compared with the normative values derived from published charts or the reference values of studied laboratory itself. Ideally, these normative values must be detailed according to the gender, ages and heights of the patients. The main limitation of our study is the lack of this detailed normative value charts for MN and UN conduction parameters. The comparison of patients' results with the detailed normative values would probably result in better sensitivity and specificity values for conventional NCS parameters than ones we obtained. Another limitation might be the number of the studied extremities in our study was not large enough to reveal the differences of studied parameters among the disease and healthy groups in statistical analyses. Our study has also limitations regarding the absence of a gold standard laboratory test usage for the precise determination of the CTS existence, therefore the distribution of the includers into the study groups was mainly based on clinical features. Future prospective studies are warranted to reveal the diagnostic efficacies of NSC parameters searched in our study.

In conclusion, many MN to UN comparison techniques are highly efficient on electrodiagnosis of CTS. MN to UN DSOLD-IV and DSPLD-IV has the highest diagnostic efficiency values among the researched parameters in our study. Therefore, these parameters could be recommended to use when confirming the CTS diagnosis. However, if an ENMG laboratory determines its own normative values as ours, the usage of conventional MN and UN conduction parameters could be as effective as usage of the comparative techniques on electrodiagnosis of CTS. Beside, when analyzing our NCS recordings for inclusion to the study, we clearly showed that the CTS and UN entrapment were not infrequently occur together. This constitutes a major limitation for comparison techniques on CTS diagnosis in ENMG practice. In addition, the unelicitability of the MN sensory responses over fourth finger in earlier times of the disease comparing with the second finger limited the usage of the MN to UN sensory conduction comparative techniques over fourth finger. In these cases, MN to UN DSOLD II-V, DSPLD II-V, DMLD and mFWLD could be useful on electrodiagnosis of CTS with a considerable efficiency and easy application.

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