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Ultrasound Examination of the Median Nerve at Different Levels: Inter-rater Reliability Study

Medyan Sinirin Farklı Seviyelerden Ultrason ile İncelenmesi: Değerlendiriciler Arası Güvenilirlik Çalışması

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Abstract

Objective: In this study, we aimed to investigate the inter-rater reliability of the median nerve, evaluated at different levels by ultrasound (US) in asymptomatic subjects.
Materials and Methods: A cross-sectional study. This study included 61 healthy controls. The mediolateral and anteroposterior diameters and cross-sectional area (CSA) of the median nerve at the carpal tunnel inlet were measured. The CSA of the median nerves at the carpal tunnel outlet and forearm level was measured. Flattening ratio, wrist-forearm ratio and wrist-forearm difference were calculated.
Results: In the inter-rater comparison of the measurements, there was a statistically significant difference only in the carpal tunnel outlet cross sectional area ($p<0.048$). There was no statistically significant difference between the observers in terms of other measurements ($p>0.05$). For the median nerve measurement, agreement was also moderate to good inter-rater reliability [intraclass correlation coefficient (ICC) =0.54-0.81] except for the forearm cross sectional area, swelling ratio of the medial nerve. For the median nerve forearm cross sectional area, agreement was excellent inter-rater reliability (ICC =0.91). However, for swelling ratio, agreement was poor interrater reliability (ICC =0.27).
Conclusion: In this study, US showed to be a reliable tool for measuring median nerve dimensions in asymptomatic subjects.
Keywords: Ultrasound, reliability, median nerve

Öz

Amaç: Bu çalışmada asemptomatik bireylerde ultrason (US) ile farklı seviyelerde değerlendirilen medyan sinirin değerlendiriciler arası güvenilirliğinin araştırılması amaçlandı.
Gereç ve Yöntem: Bu çalışma kesitsel bir çalışmadır. Bu çalışmaya 61 sağlıklı kontrol dahil edildi. Medyan sinirin karpal tünel girişindeki mediolateral ve ön-arka çapları ve kesit alanı ölçüldü. Karpal tünel çıkışında ve ön kol seviyesinde medyan sinirlerin kesit alanı ölçüldü. Düzleşme oranı, bilek-ön kol oranı ve bilek-ön kol farkı hesaplandı.
Bulgular: Ölçümlerin gözlemciler arası karşılaştırılmasında sadece karpal tünel çıkış kesit alanında istatistiksel olarak anlamlı farklılık vardı ($p=0,048$). Diğer ölçümler açısından gözlemciler arasında istatistiksel olarak anlamlı bir fark yoktu ($p>0,05$). Medyan sinir ölçümlerinde; ön kol kesit alanı ve medyan sinirin şişme oranı dışında, gözlemciler arası güvenilirlik orta ile iyi düzeydeydi [sınıf içi korelasyon katsayısı (ICC) =0,54-0,81]. Medyan sinir ön kol kesit alanı için güvenilirlik, değerlendiriciler arası mükemmeldi (ICC =0,91). Ancak şişme oranı açısından, gözlemciler arası güvenirlik zayıftı (ICC =0,27).
Sonuç: Bu çalışmada US'nin asemptomatik bireylerde medyan sinir boyutlarını ölçmek için güvenilir bir araç olduğu gösterilmiştir.
Anahtar kelimeler: Ultrason, güvenilirlik, medyan sinir

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Introduction

The most common type of neuropathy caused by entrapment of the median nerve is carpal tunnel syndrome (CTS). Clinical history, physical examination findings and electrodiagnostic evaluations are used in the diagnosis of CTS (1,2). Although electrodiagnostic evaluation is important in the diagnosis of CTS, it has a false negative rate of 16-34% (3). Ultrasound (US) is often preferred to evaluate the morphological and mechanical properties of the median nerve in the diagnosis of CTS. It has been stated that the US is a highly accurate, effective, and cost-effective diagnostic method for diagnosing CTS, and the evaluation period is a short diagnostic method (1). However, it is emphasized that reference values should be determined for the diagnosis of CTS. One of the most important factors determining the reliability and accuracy of US use in the diagnosis of CTS is the accurate identification of landmarks (2).

There are studies investigating the reliability of the cross-sectional area (CSA) (4-8), flattening ratio (FR) (5,6), anteroposterior (AP), and mediolateral (ML) diameters (4), and carpal tunnel inlet (CTI) to forearm ratio (9). In this study, we aimed to evaluate the reliability of the median nerve CSA at CTI, chronic total occlusion (CTO), and forearm levels, as well as the AP and ML diameters and FR of the median nerve at the CTI level. In addition, we aimed to evaluate the reliability of the CTI/CTO ratio, the CTO/forearm ratio, and the wrist-forearm CSA difference used in the ultrasonographic diagnosis of CTS, but whose reliability was not evaluated.

Materials and Methods

In our inter-rater reliability study, which was carried out as a single center, 66 healthy volunteers who were hospital staff were included. However, five healthy volunteers were not included in the study. A bifid median nerve was detected in three of them; two of them did not want to continue studying after the first measurement. The study continued with 61 healthy volunteers.

Each subject provided written informed consent. The research was carried out in conformity with the Helsinki Declaration's criteria. The study was started after ethical approval was obtained from the Clinical Research Ethics Committee of University of Health Sciences Turkey, İstanbul Training and Research Hospital number (date: 07.04.2023, decision no: 90).

Inclusion criteria in the study: Healthy volunteers between the ages of 18 and 65; exclusion criteria in the study: Individuals with clinical signs and symptoms of CTS, diabetes mellitus, thyroid abnormalities, rheumatological disease history, previous surgery, or fractures in the upper extremity. Median nerves that were found to be bifid during the US examination were not included in the study. The dominant extremity of the participants was evaluated.

The gender, height, weight, and body mass indexes (BMI) of all participants in the study were recorded.

Sample Size Calculation: Power Analysis and Sample Size Software 15 (2017) by NCSS, LLC (Kaysville, UT, USA; www.ncss.com/software/pass) was used to calculate the sample size. Using a one-way random-effects analysis of variance model, a random sample of 66 wrists who were tested twice produced a two-sided 95% confidence interval with a width of 0.200 when the estimated intraclass correlation was 0.840 (5).

US Examination: US evaluation was performed by physiatrists with 5 years (B.T.D.) and 4 years (F.K.) experience in the musculoskeletal US. Examinations were performed with a wired US device [MyLab50 (Esaote Biomedica, Genova, Italy)] using a 12 MHz linear probe. The examinations were performed on a table at rest with the elbow in flexion position, forearm in supination, wrist in neutral position and fingers in semi-flexion position. The median nerve was visualized by positioning the US probe transversely approximately 10 cm proximal to the distal wrist line. The probe was shifted distally and the median nerve was visualized at CTI at the scaphoid-pisiform bone level. The probe was shifted slightly distally and the median nerve was visualized at the CTO at the level of the hamate-trapezium bone. Three images were taken from each of the three imaging levels and recorded in the database.

Calculations and measurements were made by taking the arithmetic mean of the data obtained from the three recorded images. If the nerve had an elliptical form, the electronic ellipse function was applied for the CSA measurement (Figure 1a). The continuous tracing method was used if the nerve was not elliptical. During the evaluations, the border of the median nerve was evaluated as the line between the hyperechoic nerve sheath and hypoechoic nerve fascicles (4). CSA measurements were performed at the forearm, CTI and CTO levels. AP and ML diameter measurements were performed only at the CTI level (Figure 1b, c). After the measurements, the ratio of ML diameter to AP diameter, known as FR, was calculated. The swelling ratio is calculated by dividing the CSA of the nerve at the CTO by that of the nerve at the CTI. The ratio of the "CSA of the nerve at the CTO or CTI levels to the CSA of the nerve at the forearm level", also known as the wrist/forearm ratio. CTI CSA-forearm CSA difference and CTO CSA-forearm CSA difference were calculated (wrist-forearm difference) (10).

During this study, in order to the standardization of the measurements, two sessions were conducted with 5 participants before the start of the study and the differences between the observers were discussed and a consensus was reached. However, the data of these 5 participants were not used in the study.

Statistical Analysis

Statistical analysis was carried out using IBM SPSS version 22.0 software (IBM Corp., Armonk, IL, USA). Normal distribution was determined using the Kolmogorov-Smirnov/Shapiro-Wilk test, kurtosis and skewness values and histogram plots. When presenting descriptive analyses, mean and standard deviation values or median and minimum-maximum values are given for quantitative variables. Since the data showed a normal distribution, the correlation between numerical variables

was determined with the parametric Pearson correlation test. After the measurements and calculations, the intraclass correlation coefficient (ICC), minimum detectable change (MDC) and standard error of the mean (SEM) were calculated. SEM=(standard deviation) x√(1-ICC) and MDC=(SEM)x(√2) x(1.96). To evaluate inter- and intra-rater reliability, ICC was used. When analyzing the reliability of ICC, ICC =0.5-0.75 indicates moderate reliability, ICC =0.75-0.90 indicates good reliability and ICC≥0.90 indicates excellent reliability (11).

Results

A total of 61 wrists were evaluated. The mean age of the participants included in the study was 48.0±11.1 years; 25 (78%) were women. The mean BMI was 29.0±5.7.

In the inter-observer comparison of the measurements, there was a statistically significant difference only in the CTO CSA (p<0.048). There was no statistically significant difference between the observers in terms of other measurements (p>0.05) (Table 1).

For the median nerve measurement, agreement was also moderate to good inter-rater reliability (ICC =0.54-0.81), except for the forearm CSA and swelling ratio of the median nerve. For the median nerve forearm CSA, agreement was excellent inter-rater reliability (ICC =0.91). However, for the swelling ratio, the agreement had poor inter-rater reliability (ICC =0.27). The inter-rater ICC's, SEM's, and MDC's for US measurements are displayed in Table 2.

Discussion

This study found the interrater correlation coefficient for the US measurement of the median nerve at different levels. In our study, we obtained excellent inter-rater reliability for forearm CSA. Except for the swelling ratio, we obtained moderate to good inter-rater reliability in other measurements.

Previous studies have shown that the US has higher sensitivity (82%) and specificity (87%) when compared to electrophysiological methods in the diagnosis of CTS (12). In fact, some researchers believe that the US is more sensitive than

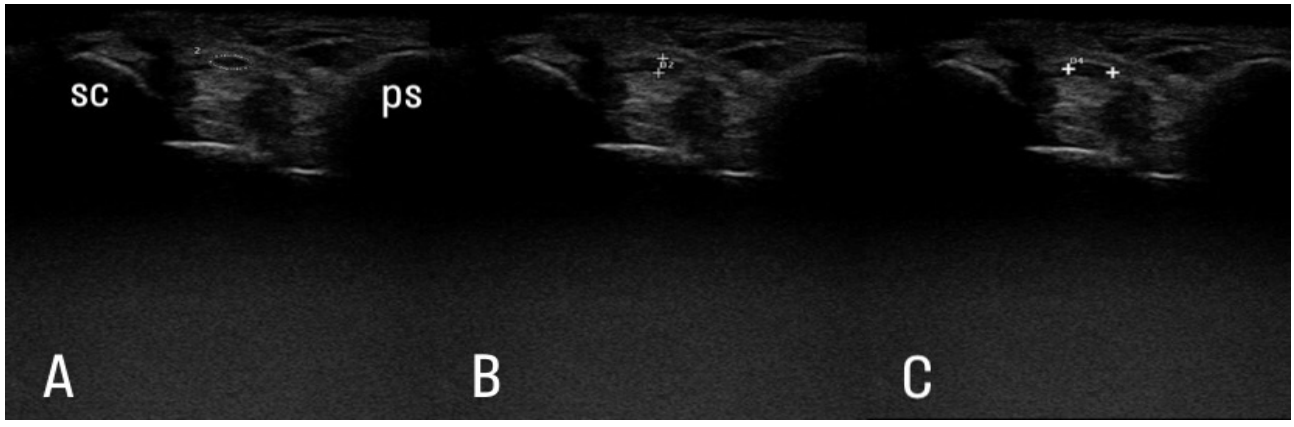

Figure 1. Median nerve measurements in the transverse plane at the scaphoid (sc) and pisiform (ps) bone level A) cross-sectional area, B) anteroposterior diameter, C) mediolateral diameter

Table 1. Comparison of measurements between observers

	Observer 1	Observer 2	p-value
Forearm CSA	1.64±0.26	1.73±0.50	0.756
CTI CSA	6.93±1.51	7.27±1.22	0.170
CTI FR	3.51±0.80	3.32±0.92	0.241
CTI AP diameter	1.64±0.26	1.73±0.50	0.209
CTI ML diameter	5.63±0.92	5.47±0.92	0.325
CTO CSA	6.90±1.44	7.39±1.26	**0.048***
Swelling ratio	1.00±0.12	0.99±0.11	0.456
CTI/forearm ratio	1.83±0.41	1.91±0.36	0.279
CTO/forearm ratio	1.82±0.37	1.93±0.35	0.110
CTI-forearm difference	3.11±1.37	3.42±1.21	0.189
CTO-forearm difference	3.08±1.30	3.52±1.19	0.053

*p<0.05
CSA: Cross-sectional area, CTI: Carpal tunnel inlet, FR: Flattening ratio, AP: Anteroposterior, ML: Mediolateral, CTO: Chronic total occlusion

Table 2. Reliability results of the median nerve measurements at the different levels

	ICC (95% CI)	SEM	MDC
Forearm CSA	0.91 (0.82-0.93)	0.173	0.480
CTI CSA	0.81 (0.68-0.88)	0.578	1.603
CTI FR	0.72 (0.54-0.83)	0.454	1.259
CTI AP diameter	0.54 (0.23-0.72)	0.259	0.718
CTI ML diameter	0.75 (0.58-0.85)	0.460	1.276
CTO CSA	0.78 (0.63-0.87)	0.635	1.760
CTI/CTO ratio	0.27 (-0.20-0.56)	0.100	0.277
CTI/forearm ratio	0.76 (0.61-0.85)	0.189	0.524
CTO/forearm ratio	0.71 (0.51-0.82)	0.195	0.541
CTI-forearm difference	0.78 (0.63-0.86)	0.606	1.679
CTO-forearm difference	0.70 (0.51-0.82)	0.682	1.890

ICC: Intraclass correlation coefficient, CI: Confidence interval, SEM: Standard error of the mean, MDC: Minimum detectable change, CSA: Cross-sectional area, CTI: Carpal tunnel inlet, FR: Flattening ratio, AP: Anteroposterior, ML: Mediolateral, CTO: Chronic total occlusion

electrophysiological methods (13). Wong et al. (1) proposed an algorithm in which sonography for patients suspected of having CTS is the first study and electrodiagnostic tests are performed only in cases where the sonographic results are not confirmatory. Although US is widely used in the diagnosis of CTS, for sonographic evaluation of the median nerve for CTS, there is no universally accepted standard. When the literature is examined, different sonographic techniques and different levels are used in the evaluation of the median nerve. These differences in measurements necessitated the need to assess the reliability of the measurement parameters (9).

According to Junck et al. (9) the median nerve CSA at the CTI level was highly reliable both between and within raters. However, it was less reliable at the pronator quadratus and middle forearm levels. In addition, like our study, they examined the reliability of the wrist/forearm ratio in their studies and found the reliability value to be 0.73 in patients with CTS and 0.69 in the control group. Impink et al. (14) investigated the reliability of the CSA, FR, and swelling ratio of the median nerve at the different levels. In their study, they found that the reliability of the median nerve CSA at the psiform bone level was higher than the CSA at the hamat bone level and the FR measured at the psiform bone level. In their study, they also stated that intra-rater reliability is superior to inter-rater reliability. However, they used generalizability theory, unlike the ICC, to assess the reliability of measurements in their studies. Therefore, it is difficult to compare the data in their study with our study.

Gonzalez-Suarez et al. (4) investigated the reliability of sonographic measures of the median nerve at various levels. In this study, they obtained excellent inter-rater reliability (ICC =0.89) for the median nerve CSA at the forearm level. They found that the inter-rater reliability value of the median nerve CSA at the forearm level was greater than that evaluated at the psiform and hamat bone level (ICC =0.57, ICC =0.75, respectively). In this study, they obtained fair to good inter-rater reliability for the AP diameter and ML diameter of the median nerve, which were evaluated at the psiform bone level (ICC =0.67, ICC =0.58, respectively). Furthermore, it was reported in this study that using external landmarks in sonographic measurements of the median nerve increased inter-rater reliability (4).

In a study, Bueno-Gracia E et al. (5) investigated the reliability of median nerve measurements at the CTI level. In their studies, they obtained good to excellent inter-rater reliability for the median nerve CSA and ML diameter (ICC =0.89, SEM =0.56, MDC =2.07; ICC =0.81, SEM =0.38, MDC =1.70, respectively). However, they obtained moderate to good inter-rater reliability for AP diameter and FR (ICC =0.74, SEM =0.12, MDC =0.98; ICC =0.62, SEM =0.43, MDC =1.81 respectively).

SEM and MDC values were indicated in only two of the studies investigating the reliability of sonographic measurements of the median nerve (5,14). SEM and MDC values are specified because the large SEM value and the small SEM value, respectively, indicate an imprecise and precise estimate. The MDC value is also an important measurement. It indicates the smallest difference that is clinically significant for the measurements made to be considered reliable.

When the literature is examined, the CTI/CTO ratio and the wrist-forearm CSA difference are shown to be significantly different between CTS patients and the control group. However, to the best of our knowledge, the study examining the reliability of these parameters from sonographic measurements of the median nerve was non-existent (10,15,16). In our study, we aimed to contribute to the literature by examining the reliability of these parameters. This aspect makes our study special. However, we state that future studies are needed to support our findings.

Study Limitations

If we list the limitations of our study, the first is that we did not investigate the reliability of measurements of FR, AP diameter, and ML diameter at the forearm level and CTO level; second, our reliability study was only on the control group; and more importantly, we did not investigate intra-rater reliability.

Conclusion

In this study, agreement was also moderate to good, except for the forearm CSA, and swelling ratio of the median nerve. For the median nerve forearm CSA, agreement was excellent inter-rater reliability achieved. As a result, in this study, US was shown to be a reliable tool for measuring median nerve dimensions in asymptomatic subjects.

Ethics

Ethics Committee Approval: Ethical approval to report this case was obtained from Clinical Research Ethics Committee of University of Health Sciences Turkey, İstanbul Training and Research Hospital number (date: 07.04.2023, decision no: 90).
Informed Consent: Written informed consent was obtained from the patients for their anonymized information to be published in this article.

Authorship Contributions

Surgical and Medical Practices: B.T.D., F.K., Concept: B.T.D., M.O., F.B., E.A., Design: B.T.D., F.K., E.A., Data Collection or Processing: B.T.D. F.K., Analysis or Interpretation: B.T.D. F.K. M.O., E.A., Literature Search: B.T.D., F.B., E.A., Writing: B.T.D., F.K., F.B.
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