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Occurrence of bifid median nerve in healthy and carpal tunnel syndrome patients

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ABSTRACT

We investigated the possible association between median nerve morphology and carpal tunnel size, hand side and nerve conduction measurements. The study included a patient group (n = 58; 44 women) with idiopathic carpal tunnel syndrome (CTS) in 100 hands and a control group of healthy volunteers (n = 56, 112 hands; 44 women). The following data were recorded: (1) median and ulnar motor and sensory nerve conduction parameters (2) ultrasonographic dimensions of the carpal tunnel inlet area (CTA_{in}) and inlet area of the median nerve. The prevalence of bifid median nerve was 19% in the CTS hands and 13.3% in the control group. Bilateral bifid nerve was detected in 7 subjects and unilateral in 23, with no side or sex preponderance. The median nerve area was larger in the participants with single than those with bifid median nerve. No correlation was found between CTA_{in} and median nerve area for single or bifid nerves in controls or patients. It was concluded that bifid median nerve was not a rare variation. We could not, however, support its etiological relation to CTS. Ultrasonographic examination of the carpal tunnel region supplementing neurophysiology provided a reliable means to detect median nerve size and morphology.

Clinical trial registration number: 84; 5/3/15.

1. Introduction

Technical advances in ultrasound imaging of peripheral nerves have strongly improved the detection of anatomical variations, previously observed only in surgical and cadaveric studies (Lanz, 1977). A number of variations of the median nerve at the wrist level have been described, including the division of the nerve, just before its entry into the carpal tunnel, known as bifid median nerve (Iannicelli et al., 2000). It is widely accepted that the knowledge of the precise median nerve morphology is very helpful for hand surgeons to avoid inadvertent damage to the nerve during decompression surgery. However, the potential implication of bifid morphology in the pathogenesis of Carpal Tunnel Syndrome (CTS) is still a matter of debate. Early studies have suggested that the presence of a bifid nerve was associated with an increased risk of developing CTS (Lindley and Kleinert, 2003; Tountas et al., 1983; Bayrak et al., 2008). On the other hand, more recent studies have not been able to confirm an increased prevalence of bifid median nerve in patients with CTS compared to healthy controls (Borire et al., 2016; Kasius et al., 2014; Walker et al., 2013; Granata et al., 2011).

In a previous study we have shown that carpal tunnel ultrasonographic dimensions have been related to CTS tendency (Chiotis et al., 2013). We set this prospective study to examine whether median nerve morphology is related to carpal tunnel size, hand side or to nerve conduction measurements and therefore indirectly connected to CTS predisposition.

2. Material and methods

2.1. Material

Fifty-eight consecutive Caucasian patients (44 women mean age ± SD, 52.21 ± 11.48 years; range 23–78 years) participated in this study. Inclusion criteria were: clinically overt CTS with typical symptoms (i.e., paresthesias and nocturnal pain in the distribution of the median nerve) and electrophysiological confirmation of the diagnosis with definite abnormalities in median Nerve Conduction Studies (NCS), as described in the nerve conduction methodology. Participants with a medical condition associated with CTS such as hypothyroidism, rheumatoid arthritis, diabetes, pregnancy or a history of wrist fracture were excluded. None of the patients had received any type of treatment

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such as local injection or wrist splinting.

The control group consisted of 56 age- and sex-matched healthy volunteers (44women; mean age ± SD, 49.01 ± 11.62 years; range 22–69 years) who had no symptoms of CTS. Informed consent was obtained from all individual participants included in the study and the hospital's ethics committee approved the study protocol (ref. no. 84, 5/3/2015). All procedures performed in the study were in accordance with the 1964 Helsinki declaration and its later amendments.

2.2. NCS methodology

For NCS, a two-channel Keypoint ver. 3.25 electromyographic apparatus (Medtronic-Dantec Electronics, Skovlunde, Denmark) was used. Two examiners who were blind as to the clinical condition of each subject performed all the tests. All individuals were instructed to remain relaxed in the recumbent position with the upper limb placed on an arm board, while the skin temperature of the hand was maintained at 33 °C ± 0.5 °C throughout the recording procedure. Nerves in both hands were studied according to the CTS protocol used in our laboratory, which included the following: 1. Median and ulnar nerve sensory conduction (2nd and 5th digit to wrist, respectively, orthodromic technique) with measurements of peak-to- peak amplitude of sensory action potentials (SAPs) and sensory conduction velocities (SCVs). 2. Median nerve motor conduction with measurements of peak-to-baseline amplitude of compound muscle action potential (CMAP) recorded from the Abductor Pollicis Brevis muscle and distal motor latency (DML) from wrist midline to thenar eminence. Ulnar NCS was performed to exclude polyneuropathy according to AAEM guidelines (Jablecki et al., 1993). The signal was recorded with band-pass filtering between 20 Hz and 10 kHz using a display sensitivity of 5 mV/division for CMAP and 10 uV/division for SAP, 16 bits A/D conversion, sampling at 5 kHz, input impedance > 1000 M Ohm/25 pF, common mode rejection ratio > 100 dB, noise level (RMS) < 1 μV and acquisition sweep speed 3 ms/division.

The neurophysiological criteria for the diagnosis of CTS were set at: a DML of 4.2 ms or longer and SCV of < 49 m/s for the median nerve. In cases with compatible symptoms that did not meet the above limits we used two additional criteria: 1. SCV of median nerve < 10 m/s compared to ulnar SCV. 2. Double–peak of SAP stimulating the 4th finger. CTS severity was classified according to neurophysiological results as: i. Minimal: normal standard tests and abnormal additional tests; ii. Mild: slowing of median digit-wrist segment and normal DML; iii. Moderate: slowing of median digit-wrist segment and abnormal DML; iv. Severe: absence of median SAP and abnormal DML; v. Extreme: absence of thenar motor and sensory responses (Padua et al., 1997).

2.3. Ultrasonographic measurements

Employing a Philips iU22 apparatus, ultrasonographic measurements were performed by a single researcher and supervised by a senior examiner. Both radiologists were blind as to the group to which each individual belonged. The subjects maintained their elbow flexed at 90°, while their forearm was supported in supination with the wrist at a neutral position. Median nerve was imaged in longitudinal and transverse planes by keeping the probe perpendicular over the nerve and moving it from approximately 5–6 cm proximal to the carpal tunnel down to the tunnel's end. Ultrasonographic estimates of the Carpal Tunnel Inlet Area (CTA_{in}) were performed at the level of the pisiform bone. The perimeter of the median nerve was traced and the software program calculated the area. Two main types of median nerve morphology were identified: a. single nerves and b. bifid nerves. The latter type was subdivided into tangent bifid if the branches remained in contact and distant if the branches were separated by intermediate tissue (a median artery or a small septum) (Lanz, 1977; Walker et al., 2013; Demirkay et al., 2011). The areas of the bifid nerves were measured as the summation of the areas of both branches.

2.4. Statistical analysis

The Shapiro–Wilk test was used on continuous variables to test possible deviations from the assumption of normality. Variables with a significant Shapiro-Wilk test are presented as median (25% quartile-75% quartile). For comparisons between patients' and controls' hands and between the nerve morphology groups the non-parametric Mann-Whitney test for independent-samples was applied. Discrete variables were treated with a chi-square (χ^2) test. Statistical significance was set at $p < 0.05$. All analyses were performed using SPSS for Windows, version 23 (SPSS, Inc, Chicago, IL).

3. Results

3.1. Neurophysiological measurements

In the patient group (n = 58), CTS was detected bilaterally in 42 patients (72.4%), on the right side in 14 patients (24.1%) (12 right-handed) and on the left side in 2 patients (3.4%) (1right handed). In a total of 116 median nerves, 100 median nerves met the neurophysiological criteria of CTS. CTS was classified as minimal in 11% of the examined hands, mild in 23%, moderate in the majority of the hands (43%), severe in 20% and extreme severe in 3%. The results of the neurophysiological study and statistical comparison between patients and controls are demonstrated in Table 1.

3.2. Ultrasound measurements

The CTA_{in} and the median nerve area were found significantly larger in patients than in the healthy subjects, as shown in Table 1. Regarding morphology of median nerve in the ultrasound study the findings are presented in Table 2. Median nerve trifurcation was visualized at the right hand of a healthy control (Fig. 1).

To explore any potential neurophysiological or ultrasonographic differences between subjects with single and those with bifid median nerve, all subjects, patients and healthy controls, were divided in two groups: 191 subjects who had single median nerves and 37 with uni- or bi- lateral bifid, tangent or distant, median nerves. All above defined neurophysiological and ultrasound measurements were compared between these two groups. The only statistical significant finding was that the median nerve area was larger in the "single median nerve" group [0.11 (0.09–0.14) cm^2] in comparison to the "bifid median nerve" group [0.10 (0.07–0.14) cm^2] ($p = 0.015$). The possible influence of median nerve morphology on the association between median nerve area and CTA_{in} was examined (Fig. 2A and B). No correlation was proved between the two variables for single or bifid nerves, in both groups (inpatients r^2 linear in single vs. bifid nerve was 0.034 and

Table 1
Neurophysiological and U/S measurements of the median nerve in patients' pathological hands compared to controls'.

NCS	Patients (n = 100) Median (25% -–75% quartile)	Controls (n = 112) Median (25%-–75% quartile)	*P*
SCV (m/sec)	40.5 (31.3–47.8)	61.0 (56.0–67.0)	**< 0.05**
SAP (mV)	7.5 (3.0–15.0)	13.0 (10.0–20.0)	**< 0.05**
DML (ms)	4.4 (3.9–5.3)	3.2 (3.0–3.5)	**< 0.05**
CMAP (mV)	5.1 (4.1–6.7)	6.3 (5.6–8.2)	**< 0.05**
U/S study			
CTRin (mm^2)	1.88 (1.72–2.13)	1.72 (1.54–1.91)	**< 0.05**
Median nerve area (mm^2)	0.12 (0.09–0.17)	0.10 (0.09-0.12)	**< 0.05**

NCS: Nerve Conduction Study; SCV: Sensory Conduction Velocity; SAP: Sensory Action Potential; DML: Distal Motor Latency; CMAP: Compound Motor Action Potential; U/S: Ultrasound; CTAin: Carpal Tunnel inlet Area.
p: referred to comparison of the measurements between patients and healthy controls.