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The significance of ultrasonographic carpal tunnel outlet measurements in the diagnosis of carpal tunnel syndrome

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HIGHLIGHTS

- Median nerve enlargement in CTS is significantly greater at the tunnel outlet than at the inlet.
- It is postulated that pressure progressively increases from proximal to distal within the tunnel.
- The addition of outlet measurements increases diagnostic sensitivity and accuracy of CTS.

ABSTRACT

Objective: A retrospective study to investigate the utility of ultrasonographic carpal tunnel outlet measurements in the diagnosis of carpal tunnel syndrome (CTS).
Methods: 118 hands of 87 patients with electrophysiologically confirmed CTS and 44 control hands of 23 subjects were assessed. Cross-sectional areas (CSA) of the median nerve were measured at the tunnel inlet, outlet, and forearm. Longitudinal diameters (LAPD) were measured at the inlet, proximal tunnel, distal tunnel, and outlet.
Results: CSA at the outlet (median: 18 mm^2) and its palm-to-forearm-ratio (median: 2.7) were significantly larger than CSA at the inlet (median: 15 mm^2) and its wrist-to-forearm-ratio (median: 2.2) ($p < 0.001$). 27% of the hands showed enlargement only at the outlet versus 13% only at the inlet. LAPD jump was significantly greater, suggesting relief of higher pressure, at the outlet/distal tunnel versus inlet/proximal tunnel ($p < 0.001$).
Conclusion: Median nerve enlargement in CTS is greater at the tunnel outlet than at the inlet. We postulate that this is explained by the progressive increase of pressure within the tunnel from proximal to distal.
Significance: The addition of CSA outlet measurements to inlet measurements increased CTS ultrasonographic diagnostic sensitivity and accuracy by 15% and 10%, respectively.

1. Introduction

High resolution ultrasonography (HRUS) was first implemented as a diagnostic tool in carpal tunnel syndrome (CTS) in the early 1990s (Buchberger et al., 1991, 1992). The meta-analyzes of the large body of literature that has accumulated in the past two decades (Cartwright et al., 2012; Tai et al., 2012) showed that level A evidence support the ultrasonographic measurement of median nerve cross-sectional area at the tunnel inlet (CSA-I) as an accurate diagnostic test for CTS (Cartwright et al., 2012). The cut-off value of CSA-I showed a wide range of variation between 8 and 14 mm^2, possibly due to issues of resolution, machine settings and individual examination technique, but most of the articles set the cut-off value of CSA-I at 9–11 mm^2 (Tai et al., 2012). Furthermore, with the idea of patients serving as their own control, the use of the wrist-to-forearm ratio (WFR) of CSA-I was also proposed (Hobson-Webb et al., 2008).

Although, the swelling of the median nerve (or generally any nerve under compression) may occur both proximally and distally to the compression, to date very little attention has been paid to measurements at the carpal tunnel outlet on the palm. Multilevel measurements have been advocated (Nakamichi and Tachibana, 2002; Wong et al., 2004; Chen et al., 2011), but the recent study of Paliwal et al. (2014) was the first to specifically address the

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utility of carpal tunnel outlet measurements. They concluded that the inclusion of median nerve measurements at the carpal tunnel outlet, in addition to inlet measurements, increased diagnostic sensitivity by 19%. In line with these data, it was also our observation that in most CTS patients the swelling was conspicuous and often even more pronounced or isolated at the tunnel outlet on the palm than at the inlet at the wrist. Moreover, it was our impression that the degree of flattening of the median nerve within the carpal tunnel was usually the greatest in the distal part of the carpal tunnel under the distal edge of the retinaculum, and that the greater the distal flattening was, the greater was the swelling at the outlet. We have set out in the present paper to statistically analyze these observations with the aim of providing further evidence for the value of carpal tunnel outlet measurements in the diagnosis of CTS, and to test our hypothesis that the pronounced swelling at the outlet is related to increasing compression from proximal to distal in the tunnel.

2. Patients and methods

Anonymised data were used retrospectively in accordance with the Helsinki Declaration. Approval for retrospective analysis of patient data was obtained from the Institutional Ethics Committee.

Between October 2014 and December 2015, 87 patients (118 hands) assessed by HRUS at the Department of Neurology, Semmelweis University, a tertiary referral center for neuromuscular disorders, were included in this retrospective study. Inclusion criteria were the typical clinical symptoms and signs of idiopathic CTS and its electrophysiological confirmation. Clinical symptoms and signs included pain and paraesthesia exacerbated at night or provoked by a sustained wrist position, and relieved by changing position or shaking the hands; sensory deficit involving the median nerve distribution; and thenar atrophy. Patients ranged from mild (no clinical deficit) to extremely severe clinical symptoms (thenar atrophy, sensory loss). Exclusion criteria were bifid median nerve, previous CTS release on the relevant hand, and early division of the median nerve (within the canal or immediately at the outlet). Post-traumatic, pregnancy-related and other secondary CTS patients were excluded, but diabetes was not an exclusion criterion.

A control group was also examined, including 44 hands of 23 individuals. Control subjects were recruited from hospital staff and patients. None of the subjects had any clinical symptoms and signs suggestive for CTS. Subjects with diabetes or previous chemotherapy were excluded. As with patients, subjects with bifid median nerve, previous CTS release on the relevant hand, and early division of the median nerve were also excluded. Nerve conduction studies (NCS) were not performed on control subjects.

2.1. Nerve conduction studies

In 10 cases, electrophysiological testing was done at another institute. For the remaining 108 hands, NCS were performed at our institute using the Nicolet Viking Quest or EDX System (CareFusion Corporation) always by a physician trained in clinical neurophysiology, most often by two of the authors (A.C. and Z. A.). For confirmation of CTS, the following tests were done, as a standard protocol for CTS assessment: standard motor NCS with recording by surface electrodes from the abductor pollicis brevis muscle and stimulation at the wrist (7 cm proximal to the active recording electrode), at the antecubital fossa and on the upper arm; standard antidromic sensory NCS with recording by ring electrodes over digit 2 and stimulation at the wrist and at the antecubital fossa; segmental antidromic sensory NCS to digit 2 with stimulation on the palm and at the wrist. The following NCS parameters were used for the diagnosis and grading of CTS: distal motor latency (DML), amplitude of the compound muscle action potential (CMAP) and of the sensory response (SNAP), the distal (digit-to-wrist) sensory conduction velocity, and the digit-to-palm and palm-to-wrist sensory conduction velocities and their difference. For comparison and to exclude generalized neuropathy, ulnar motor NCS to the abductor digiti minimi muscle, and antidromic sensory NCS to digit 5 with stimulation at the wrist were also performed. NCS reference values of our laboratory were used, with skin temperature controlled by the temperature probe of the EMG device (normal limits: DML < 4 ms; distal sensory conduction velocity > 49 m/s; CAMP > 4 mV; SNAP > 10 μV). Electrophysiological categories for the severity of CTS were set up, as defined in Table 1. The categories mild, moderate, moderately severe, severe, and extremely severe correspond to focal sensory demyelination, focal sensorimotor demyelination, focal sensorimotor demyelination with sensory axon loss, focal motor demyelination with sensorimotor axon loss, and complete sensorimotor denervation, respectively.

2.2. Ultrasonography

Ultrasonography was performed by two of the authors (A.C. and Z.A.), each with several years of experience in nerve ultrasound, with a Philips Epiq 5G ultrasound system and an 18–5 MHz linear array transducer. Settings were optimized for nerve imaging, including the use of compound imaging mode. Subjects were examined in supine position with the forearm in supinated and the fingers in neutral, semi-extended position. An effort was made to keep the transducer perpendicular to the median nerve to avoid anisotropy, which required tilting the transducer when scanning in the distal tunnel and at the outlet. CSA measurements were made by the continuous trace function of the ultrasound device within the inner border of the hyperechogenic epineural rim. The flexor retinaculum served as a landmark for the tunnel inlet and outlet: the tunnel inlet was defined as immediately proximal to the proximal edge of the retinaculum, and the tunnel outlet as immediately distal to the distal edge of the retinaculum; i.e. before the nerve enters and after the nerve leaves the tunnel, respectively. Scanning was started at the wrist in the axial plane relative to the nerve. At the tunnel inlet, approximately at the level of the distal wrist crease, the examiner repeatedly traced the nerve to and fro in order

Table 1
Electrophysiological criteria for severity categories in CTS.

Severity category	Segmental sensory NCS	Sensory NCS	Motor NCS
Mild	Palm-to-wrist NCV↓	Normal	Normal
Moderate	Palm-to-wrist NCV↓	Digit-to-wrist NCV↓	DML norm./mildly↑
Moderately severe	Palm-to-wrist NCV↓ SNAP ampl.↓	Digit-to-wrist NCV↓ SNAP ampl.↓	DML↑ ±CMAP ampl.↓
Severe	NR/SNAP ampl.↓ on the palm	NR	DML↑ CMAP ampl.↓
Extremely severe	NR	NR	NR

NCS: nerve conduction study; NCV: nerve conduction velocity; DML: distal motor latency; SNAP: sensory nerve action potential; CMAP: compound motor action potential; norm.: normal; ampl.: amplitude; NR: no response.