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Original article

Reliability of measurement of the carpal tunnel and median nerve in asymptomatic subjects with ultrasound[☆]

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ABSTRACT

Background: Morphology of the carpal tunnel changes with varying wrist postures and compressive forces applied to the wrist. These changes may affect the morphology and pressure on the median nerve and could be used as part of the treatment of the carpal tunnel syndrome patients. Reliability of the ultrasonographic measurements of the median nerve has been widely studied. However, there is a lack of investigation regarding reliability of ultrasonographic measurements of the carpal tunnel.
Objective: The purpose of this study was to assess intra-tester and inter-tester reliability of measurement of dimensions of the carpal tunnel and median nerve with ultrasound in asymptomatic volunteers.
Design: A cross-sectional methodological study.
Methods: Aspects measured were mediolateral and anteroposterior diameters, flattening ratio, circularity, perimeter and cross-section area of the carpal tunnel and median nerve.
Results: Intra-tester reliability was excellent for the carpal tunnel (ICCs from 0.91 to 0.97) and for the median nerve (ICCs from 0.79 to 0.94) measurements. The flattening ratio of the median nerve showed good agreement (ICC = 0.68). Inter-tester reliability was excellent for the carpal tunnel measurements (ICCs from 0.76 to 0.95) and, for the cross sectional area, the perimeter and mediolateral diameter of the median nerve, the ICC values were 0.89, 0.84 and 0.81, respectively.
Conclusion: In the context of this study, ultrasound was a reliable instrument for measuring carpal tunnel and median nerve dimensions in asymptomatic subjects.
Level of evidence: 1b

1. Introduction

The carpal tunnel is a unique fibro-osseous structure formed by the transverse carpal ligament at the palmar side and by the carpal bones at the dorsal, the radial and the ulnar aspects. Inside the tunnel exist flexor tendons and the median nerve and occasionally an accessory or bifid median nerve and artery. The nerve being less resilient to mechanical forces than its neighboring structures leads to it being involved in the highly prevalent carpal tunnel syndrome (CTS) (Aroori and Spence, 2008).

Morphology of the tunnel has been shown to change with varying wrist postures (Garcia-Elias et al., 1992) and after surgery (Li et al., 2013; Richman et al., 1989). The rationale of carpal tunnel release surgery is to increase the size of the carpal canal and, therefore, reduce pressure on the median nerve (Richman et al., 1989; Viegas et al., 1992). Recent studies have shown that applying transversely directed compressive forces to the tunnel, also produces tunnel morphology changes (Li et al., 2013; Marquardt et al., 2015). Such force decreases the medio-lateral (ML) diameter with a consequent increase in the anterior-posterior (AP) diameter and cross-sectional area (CSA) of the tunnel. For instance, 1 mm of carpal arch narrowing in the ML direction

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[☆] This study was approved by the Ethics Committee of Clinical Research of Aragon.

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produces 0.4 mm of increase in AP dimension (Li et al., 2013). It is hypothesized that these changes could affect the function and space available for the nerve which may relate to CTS (Kato et al., 1994; Kim et al., 2013). This suggests that some of the mobilization techniques for the carpal bones could be used to produce variations in pressure of the median nerve in CTS patients.

Ultrasound is an accurate, efficient and cost-effective tool to aid in the diagnosis of CTS (Fowler et al., 2015, 2011; Kwon et al., 2014) and has shown similar sensitivity and specificity to MRI in the detection of the pathology (Pasternack et al., 2003). This is why ultrasound has become a widely used tool for measuring morphology and mechanical behaviour of the median nerve at the wrist for diagnosis of CTS (Buchberger et al., 1992; Bueno-Gracia et al., 2015; Cartwright et al., 2008; Coppieters and Alshami, 2007; Duncan et al., 1999; Fowler et al., 2011; Greening et al., 2001; LaBan et al., 2007; Tai et al., 2012). In normal conditions, the nerve has an elliptical shape, with a larger ML diameter than AP diameter. However, in CTS the AP diameter increases and the nerve acquires a more circular shape (Ablove et al., 1994; Richman et al., 1989). Thus, other measurements such as the nerve circularity (*4π*area/perimeter*^{2}) or the flattening ratio (*ML diameter/AP diameter* of the median nerve) have also been proposed for the diagnosis of CTS (Buchberger et al., 1992). Both ML and AP measurements provide an indication of the nerve's roundness. For both parameters, a value of 1.0 indicates a perfect circle.

Reliability of the ultrasonographic measurements of the median nerve has been widely studied and showed to be good (Fowler et al., 2015, 2011; Tai et al., 2012; Yazdchi et al., 2012). However, there is a lack of investigation regarding reliability of ultrasonographic measurements of the carpal tunnel. The circularity and CSA of the tunnel have been measured by magnetic resonance imaging (Li et al., 2011; Richman et al., 1989), and recently also with ultrasound (Kim et al., 2013; Li et al., 2013; Marquardt et al., 2015). But there is only one study which has analyzed the reliability of some ultrasonographic parameters (Kim et al., 2013).

Hence, the purpose of this study was to assess intra-tester and inter-tester reliability of measurement of dimensions of the carpal tunnel with ultrasound in asymptomatic volunteers. In order to analyze if the ultrasonographic measurements could be adapted to this situation, the reliability of the median nerve ultrasonographic measurements at the tunnel was settled as a secondary objective. Measurements were taken of the diameters of mediolateral and anteroposterior, flattening ratio, circularity, perimeter and cross-section area of the carpal tunnel and median nerve.

2. Methods

2.1. Design

An intra- and inter-tester reliability and precision study was designed. Ethical approval was gained from the institutional review board.

2.2. Subjects

In order to have a minimal significant ICC value of 0.60 ($1-\beta = 80$; $\alpha = 0.05$), a minimum of 20 cases was required (Tousignant-Laflamme et al., 2013).

Eighteen voluntary subjects (9 females/9 males) aged 20–37 (mean 26.44) were recruited for the study. Asymptomatic subjects were chosen to ensure stability of the variables to be measured, as opposed to a clinical sample. All were informed of the purpose of the study and signed an informed consent. Application of inclusion and exclusion criteria ensured a relatively homogeneous sample, limiting the between-subject variation and preventing inflation of the ICC. Participants completed a questionnaire and were tested with active and passive movement in relation to subjective and physical exclusion criteria (Tables 1 and 2). Subjects were removed from the study if they satisfied any of the exclusion criteria.

Two wrists were excluded due to the existence of bifid median nerve at the carpal tunnel level and one due to previous trauma. Therefore, 18 subjects (33 wrists) comprised the final sample. Fifteen subjects were measured bilaterally and three unilaterally.

2.3. Instrumentation and image capture

All patients underwent high-resolution real-time sonography of the carpal tunnel using a LOGIQ-e GE-Healthcare medical system and 10 MHz linear array transducer. Two examiners conducted ultrasound examinations on each subject in one session only, and all ultrasonographic settings were equal between the two examiners. Each examiner performed the ultrasound measurements independently and was blinded to the measurements of the other examiner. Subjects sat comfortably in a chair with the forearm resting on an examination table with the elbow in approximately 90° flexion. The wrist was placed in neutral alignment and the fingers in 0° extension. Left and right sides of each participant were examined.

The transducer was placed transverse to the forearm at the trapezium-hamate level (Fig. 1) (Fowler et al., 2015; Kim et al., 2013) without any force beyond the weight of the probe so as not to deform the tunnel or the median nerve.

Examiner 1 took the first images, followed by examiner 2 in order to measure the inter-examiner reliability, and then examiner 1 measured the same wrist again in order to measure the intra-examiner reliability. The time difference between test and retest for both intra- and inter-examiner reliability was approximately 1 h.

2.4. Image analysis

Three trials were performed for each measurement and the mean value was calculated. Once the ultrasound images were taken, all the measurements were performed. At each measurement session, new images were taken and new measurements were made on the new images for the reliability. This ensured that the entire procedure was included in the mechanism of reliability.

The CSA, the perimeter and the AP and ML diameter of the carpal tunnel and nerve were measured. The CSAs were measured by continuous tracing (Kim et al., 2013). For the CSA of the carpal tunnel the medial and lateral sides of the carpal bone constituted the inner boundaries of the carpal tunnel, whereas the flexor tendon sheath and flexor retinaculum formed the superior and inferior boundaries (Kim et al., 2013a,b) (Fig. 1). For the CSA of the median nerve the reference was the hyperechoic inner edge of the epineurium (Aleman et al., 2008; Fowler et al., 2015; Kim et al.,

Table 1
Subjective exclusion criteria.

Subjective Exclusion Criteria
Under 18 years of age
Pain, altered sensation, pins and needles, weakness, or any other discomfort in the hand, wrist, or either upper extremity in the previous 12 months
Any injuries to the spine, neck, back or upper extremity in the previous 12 months
Arthritis or any autoimmune disease
Previous surgery or fractures in the upper extremity
Diabetes or thyroid condition
Previous or current psychiatric or mental illness