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● *Original Contribution*

MEASUREMENT OF MEDIAN NERVE STRAIN AND APPLIED PRESSURE FOR THE DIAGNOSIS OF CARPAL TUNNEL SYNDROME

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Abstract—The objective of this study was to evaluate the diagnostic utility of strain and applied-pressure measurements of the median nerve in carpal tunnel syndrome (CTS). Thirty-five wrists of 23 idiopathic CTS patients and 30 wrists of 15 normal patients were examined. Median nerve strain, pressure to the skin and the pressure/strain ratio were measured at the proximal carpal tunnel level. Parameters were compared between CTS patients and controls. The areas under the receiver operating characteristic curves (AUCs) were compared for the parameters. Median nerve strain was significantly lower in the patients than in the controls ($p < 0.01$). Pressure and pressure/strain ratio were significantly higher in the patients than in the controls ($p < 0.05$: pressure, $p < 0.01$: ratio). The AUCs were 0.926, 0.681 and 0.937 for strain, pressure and pressure/strain ratio, respectively. Pressure/strain ratio is useful for evaluating the condition of the median nerve with respect to the hardness of the surrounding structures in CTS. (E-mail: yy12721@yahoo.co.jp) © 2017 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Median nerve, Strain, Pressure, Carpal tunnel syndrome, Elastography, Ultrasound.**

INTRODUCTION

Ultrasound elastography is an imaging method used for measuring tissue strain. This is based on the general principle that application of stress to tissue causes transformations, which rely on the elastic properties of tissue (Garra 2007, 2011; Ophir et al. 1991). Multiple modalities of ultrasound elastography are available, depending on the application of stress to the tissues, for example, quasi-static elastography, shear wave elastography and acoustic radiation elastography. (Garra 2007, 2011; Li and Snedeker 2011). The most commonly used method is quasi-static (compression) elastography (Drakonaki et al. 2012). Elastography is increasingly used to estimate the mechanical properties of musculoskeletal tissue in clinical practice (De Zordo et al. 2009; Drakonaki and Allen 2010; Drakonaki et al. 2012; Niitsu et al. 2011; Park and Kwon 2011). In previous studies, median nerve strain was measured using ultrasound elastography for the diagnosis of carpal tunnel syndrome (CTS). One group used the quasi-static method (Orman et al. 2013), and another group used the shear wave method (Kantarci et al. 2014). These studies suggested that the median nerves of CTS patients had lower strain (harder) than the median nerves of controls. Because chronic nerve compression is known to be followed by endoneurial edema, fibrosis and thickening of the epineurium (Mackinnon et al. 1985), which may cause changes in the material properties of the peripheral nerves.

For the quantitative assessment of peripheral nerves using quasi-static elastography, the compression–release cycles applied to the tissue need to be constant. In a previous study, we established a method for the quantitative assessment of median nerve strain using a cyclic compression apparatus (Yoshii et al. 2015). The cutoff value of median nerve strain for the diagnosis of CTS was determined. However, the pressure applied to the skin was not taken into consideration in previous studies. Because it has been suggested that the pressure inside the carpal tunnel is higher in CTS patients than in normal patients (Gelberman et al. 1981; Szabo and Chidgey 1989; Werner et al. 1983, 1997), higher pressure may need to be applied to the skin during strain measurement in CTS patients. If differences in the applied pressure in

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association with median nerve strain can be observed, it may be possible to estimate the effect of surrounding structures on the median nerve in CTS patients. Therefore, we developed a method to monitor pressure during strain measurement. In the study described here, we assessed median nerve strain with respect to the pressure applied to the skin, and compared these measurements between CTS patients and normal controls.

METHODS

The protocol for this study was reviewed and approved by our institutional review board. Thirty wrists of 15 asymptomatic volunteers (10 females and 5 males, age range: 25–58, mean age: 39.0 y) and 35 wrists of 23 idiopathic CTS patients (16 females and 7 males, age range: 30–84, mean age: 68.7 y) were evaluated by ultrasound. The ultrasound examinations were performed between October 2015 and October 2016. CTS patients with a history of systemic diseases associated with a higher incidence of CTS, such as chronic renal failure, thyroid disease, diabetes and rheumatoid arthritis, were excluded. In addition, patients who had any history of upper extremity trauma were excluded. Participants were given a brief description of the purpose of the research and the testing procedures at the initial meeting. Written consent was obtained from all study participants. CTS was diagnosed by both clinical findings and nerve conduction studies. The nerve conduction studies were performed by a clinical technician who was blinded to the clinical symptoms.

Cyclic compression apparatus and pressure monitor

The cyclic compression apparatus was developed to apply pressure to the tissue with a pre-determined cycle and displacement of the transducer. The details of the apparatus have been described previously (Yoshii et al. 2015). In brief, the apparatus has two parts: a forearm table with a motor for the compression–release cycle, and a programmed controller (Fig. 1). The table was designed so that the transducer could be placed at the level of the subject's wrist crease and the placement adjuster could adjust the height of the transducer. The programmed controller can adjust the displacement and cycles in the range of 0.1–3.0 mm and 0.46–4.80 Hz (Gyouden, Tsukuba, Japan). For pressure measurement, a pressure sensor and a force processor (F381 A, Unipulse, Tokyo, Japan) were attached to the system (Fig. 1a). This dynamic force processor was integrated with a strain gauge sensor that could measure waveforms of physical quantities, including pressure, load and torque (Fig. 1b), and could take measurements at a frequency of 4000 times/s, which were saved as digital data on an SD card.

Median nerve strain and applied-pressure measurement

Each participant was asked to sit and place the forearm on the table with the palmar side up. The forearm of the examinee was secured to the table. An ultrasound scanner (Hi Vision Avius, Hitachi Aloka Medical, Tokyo, Japan) equipped with a linear array transducer was set to a depth of 20 mm. The transducer was placed parallel to the wrist crease (proximal carpal tunnel), with the wrist in a neutral position. The transducer was maintained perpendicular to the skin surface of the wrist crease. The median nerve was identified by cross-sectional ultrasonographic imaging. Median nerve strain was measured in the "Real-time Tissue Elastography" mode of the ultrasound system (Hitachi Aloka Medical). A coupler was used to obtain clear ultrasound images by providing better adaptation of the transducer to the skin surface. The compression–release cycles were applied by the cyclic compression apparatus. The cycle and the displacement were set to 1.5 Hz and 1.0 mm. Examples of strain and pressure measurements are provided in Figures 2 and 3. The cycle was observed using a numeric scale indicator on the monitor. Strain was measured as the

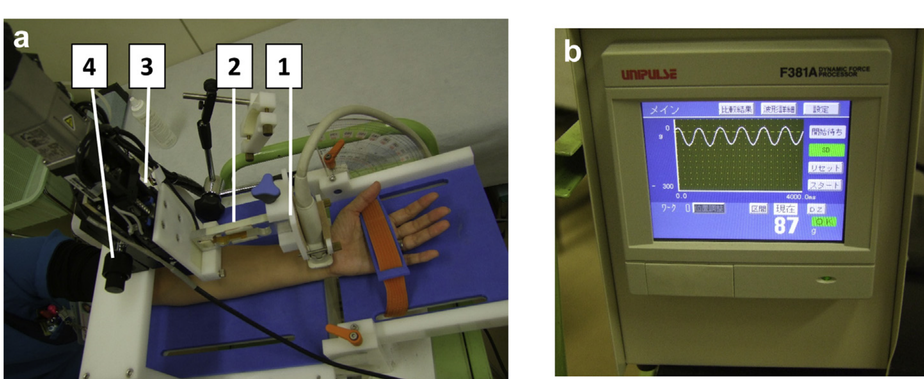

Fig. 1. Setup for strain and pressure measurement. (a) Cyclic compression apparatus: (1) transducer holder, (2) pressure sensor, (3) motor for the compression–release cycle, (4) placement adjuster. (b) Force processor.