Ultrasound elastographic evaluation of the median nerve in pregnant women with carpal tunnel syndrome

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Abstract. – OBJECTIVE: To evaluate the median nerve (MN) in pregnant women with carpal tunnel syndrome (CTS) by using ultrasound elastography.

PATIENTS AND METHODS: 30 wrists of 20 pregnant women with CTS and 25 wrists of 14 healthy control pregnant women were evaluated by ultrasound and ultrasound elastography (UE). The MN in the patients’ wrist was imaged to measure the cross-sectional area and longitudinally to calculate the elasticity value (EV) at four different locations (proximal carpal tunnel (CT) at the level of the pisiform, distal CT at the level of the hamate, middle of the CT and forearm at one centimeter above the CT). Clinical classification was performed according to a historic and objective scale of CTS. In the healthy pregnant women and pregnant women with CTS, MN area and EV were analyzed statistically by comparing with parity and clinical grade.

RESULTS: There was a statistically significant difference for MN area between the patient and control groups (p = 0.001). A positive relationship was found between parity in pregnancy and clinical grade of the CTS (p = 0.035, Pearson's correlation coefficient = 0.386). Although MN elasticity for both groups was nearly the same in the proximal region of the CT, these values were decreased in the middle of the CT. MN elasticity values were smaller in the distal region of CT, and it was statistically significant in pregnant women with CTS (p = 0.02).

CONCLUSIONS: Ultrasound elastography, which is a non-invasive, inexpensive and a favorable diagnosis technique, may be useful in the diagnosis of CTS, especially in conditions in which an invasive procedure would be problem, as in pregnancy.

Key Words: Ultrasound elastography, Median nerve, Carpal tunnel syndrome, Pregnancy

Introduction

The carpal tunnel (CT) is a bony canal formed by the carpal bones dorsally and the flexor retinaculum ventrally. The median nerve lies just below this ligament and courses ventral and parallel to the flexor tendons 1. Carpal tunnel syndrome (CTS) is the entrapment of the median nerve in carpal tunnel. Any restriction in carpal tunnel or pressure on this nerve may lead to CTS 2. The prevalence of CTS has been estimated to be 50 cases per 1000 subjects per year 3. Reports in the literature on the incidence of pregnancy related with CTS range between 0.8% and 70% 4-8.

Early diagnosis is important in pregnant women in order to keep mother and baby healthy and comfortable during pregnancy, and for the clinical diagnosis of CTS some specialized clinical examination methods (such as Tinel sign and Phalen sign) are used. Electromyography (EMG) is also used for the evaluation of nerve conduction 1,4,9,10. EMG is based on physiologic malfunction of the median nerve. The sensitivity of electrodiagnostic methods ranges between 49% and 84% with a specificity of 95% or higher 11. Nevertheless, it is important to consider that electrodiagnostic examinations are not recommended in pregnant women 12. A study showed positive ultrasonography (US) findings in patients with CTS-positive clinical results, with negative electrodiagnostic findings in 30.5% of these patients 13.

Until recently, US studies of the nerve did not have practical value for the diagnosis of CTS. In a study 14, authors have demonstrated that US
could be used to increase the sensitivity and specificity of diagnosis in combination with clinical and electrophysiological findings. B-mode US is a feasible, simple, relatively low-cost, rapid, accurate and noninvasive imaging method for evaluating the median nerve in the carpal tunnel. US is also useful to depict the anatomical variation of the nerve, space occupying lesions such as ganglia, neural tumors, and tenosynovitis. Usually, MN cross-sectional area (CSA) was evaluated by US. Cutoff values ranging from 8.5 to 12 mm² were founded for the MN CSA in these studies.

Ultrasound elastography (UE) is a new method that, by applying stress and detecting tissue displacement using ultrasound, assesses the mechanical properties of tissue. Although several techniques have been used in clinical conditions, the strain (compression) UE method is the most common technique that allows real-time visualization of the tissue. Ultrasound elastography has been found effective in detecting and assessing several different pathologies, because mechanical changes in tissue often correlate with pathological changes in tissue. Many organs and systems such as breast, thyroid, lymph nodes, prostate, kidney, and liver have already been studied with strain elastography. The importance of UE in the evaluation of the musculoskeletal system is increasing since this technique helps out early diagnosis of diseases and guides the therapy. Recently, the use of strain elastography for the evaluation of peripheral neural tissue was shown.

To our knowledge, there is no published report on the application of UE for the diagnosis of CTS in pregnant women. The fluid retention and swelling that is very common during pregnancy can increase the pressure in the carpal tunnel, which will compress the median nerve. It may also cause structural changes in the median nerve. Additionally, someone may assume that median nerve hardness may be worsened by edema in pregnancy. We aim to study the usability of UE in the depiction of elastic changes of the median nerve in pregnant women with CTS and correlate the clinical findings with UE results.

**Patients and Methods**

A total of 33 wrists of 23 pregnant women with CTS symptoms and 25 wrists of 14 asymptomatic pregnant women were examined during May and June 2012. Institutional Review Board approval was obtained for the study and then informed consent was procured from all patients. Patients were excluded from the study if they had conditions associated with an increased occurrence of CTS (diabetes mellitus, acute trauma, rheumatologic diseases, hypothyroidism, and hyperthyroidism) or if they presented with any other upper extremity problem, such as cervical radiculopathy or cubital tunnel syndrome.

The diagnoses of CTS were based on clinical findings and symptoms. A historic and objective scale of CTS was used for clinical examination by a neurology specialist. Clinical classification according to this scale: (1) Nocturnal paraesthesia only; (2) Nocturnal and diurnal paraesthesia; (3) Sensory deficit; (4) Hypotrophy or motor deficit of the median innervated thenar muscles; (5) Plegia of the median thenar eminence muscles. In the same day, US and US elastography were performed to evaluate median nerve.

Ultrasound and Real Time Elastosonography examinations were performed by a radiology specialist with ten years of sonography experience. The subjects were seated facing the examiner in a comfortable position, their wrists resting upon a flat surface, their forearms supine, and their fingers semi extended. The median nerve was imaged in the transverse plane (the short axis of the median nerve) proximal to the carpals and distal to the pisiform. The proximal carpal tunnel at the level of the pisiform, distal carpal tunnel at the level of the hamate, middle of the carpal tunnel, forearm at the site above one centimeter of the proximal carpal tunnel were scanned longitudinally. Carpal tunnel elastosonography images were obtained by performing 10-12 consecutive moderate compressions. The transducer was perpendicular to the median nerve to avoid anisotropy. When the compressions were done periodically, the sinusoid shape could be obtained for good acquisition data. Sonolasticographic images were chosen from the middle of the compression-relaxation cycle to measure the strain. Circular region of interest (ROI) was established according to the radius of the median...
nerve. Same ROI were copied and placed on the median nerve in order to investigate four different places (proximal carpal tunnel at the level of the pisiform, distal carpal tunnel at the level of the hamate, middle of the carpal tunnel, forearm area one centimeter the proximal carpal tunnel) (Figure 1). Decompression phase is more reliable to measure strain, because it is less affected by unbalanced compression\(^2\). The mode was linear and TwinView was used to view. Two-dimensional B-Mode image and the elastography image were collocated on the TwinView. The strain values on the below part of the elastogram were denoted as a percentage values to calculate local strains within the ROI.

**Statistical Analysis**

In the pregnant women with and without CTS, the median nerve area and strain values were statistically analyzed by comparing with parity, clinical examination grades, and ages of participants. Collected data were analyzed by using Statistical Package for Social Sciences version 20.0 (SPSS Inc., Chicago, IL, USA) which is a computer software designed for professional statistical analyses. The difference between groups was analyzed by using the independent sample t-test and relationship between groups was evaluated by the Pearson correlation test. The p values below 0.05 were accepted as statistically significant.

**Results**

For the participants of the study, the mean age of the pregnant women with CTS was 27 ± 5 years, while the mean age of healthy pregnant women was 30 ± 5. Two cases had bifid median nerve and one case had a ganglion cyst in the CTS group. These three cases were excluded, and total of 30 wrists of remaining 20 pregnant women with CTS were included in this study. Accessory median nerve or ganglion cyst was not found in the control group. Fluid was found in the tendon sheaths in 20 of 30 wrists with CTS and 9 of 25 wrists without CTS.

The mean weeks in pregnancy of females who had CTS was 30.3 ± 5.54 (19 weeks-39 weeks) and of those who had not CTS was 29.8 ± 8.21. Of all patients with CTS, 33.3% (10 patients) were second trimester and 66.6% (20 patients) were third trimester. No statistically significant difference was found between weeks in pregnancy and clinical grade and between weeks in pregnancy and elasticity in the median nerve (\(p > 0.05\)).

There was a statistically significant difference for the median nerve area between the patient and control groups (\(p = 0.001\)). Mean median nerve area in the patients who had CTS was 0.14 ± 0.04 cm\(^2\) and in women who had not CTS was 0.08 ± 0.02 cm\(^2\). Of the 30 symptomatic wrists, 1 wrist was grade 1; 14 wrists were grade 2; 8 wrists were grade 3 and 7 wrists had grade 4 CTS according to historic and objective scale of CTS; none of them were grade 5. There was no statistically significant difference between median nerve area and clinical grade of the CTS.

Table I summarizes the mean values and the comparisons of strain value and area of the median nerve according to clinical grade for the pregnant women with CTS. Positive relationship was found between parity in pregnancy and clinical grade of the CTS (\(p = 0.035\), Pearson’s correlation coefficient = 0.386) (Table I).

Although median nerve elasticity for both groups was nearly the same in the proximal region of the carpal tunnel, these values were decreased in the middle of the carpal tunnel in both of groups but the decrease was more pronounced in the patients who had CTS. Median nerve elasticity values were smaller in the distal region of carpal tunnel of patients who had CTS (\(p = 0.02\)) (Table II).

**Discussion**

In our study we found that median nerve elasticity was affected in the distal and middle part of carpal tunnel and the median nerve was stiffer in middle and also in distal part of carpal tunnel in pregnant women with CTS. There are only a few studies reporting sonoelastographical findings of the median nerve in CTS patients (who were not pregnant). Unlike our study, those reports used UE to examine median nerve just at the entrance into the CT, and found a decrease in elasticity at this location\(^2\). Miyamoto et al\(^2\) have shown that the combined application of strain ratio and CSA provided improved accuracy in the diagnosis of CTS with a sensitivity of 81% and a specificity of 91%. Therefore, determining the elasticity of the MN could be helpful in diagnosing CTS in combination with CSA. Orman et al\(^2\) have shown that mean tissue strain was lower in the patients with CTS than in the controls.
Figure 1. Measurement of elasticity value at four different locations [proximal carpal tunnel at the level of the pisiform (P), distal carpal tunnel at the level of the hamate (D), middle of the carpal tunnel (M), proximal (above one centimeter) forearm (F)].
Anatomically, the carpal tunnel narrows in cross section between 2.0 and 2.5 cm, from the distal end to the entrance of tunnel. When taking into account all of these findings, the following suggestions could be made in order to explain why median nerve elasticity was affected in distal and middle part of carpal tunnel: (a) during pregnancy, hormonal changes lead to fluid retention and this can narrow the carpal tunnel and cause pressure on the nerves, (b) hormones also soften the ligament that forms the roof of the tunnel, (c) increase in maternal weight, when combined with water retention, is usually a major contribution of carpal tunnel syndrome in pregnant women and is known to cause swollen tissue around the wrist, (d) often a pregnant woman having sodium rich or salty foods during pregnancy can experience water retention, and finally (e) carpal tunnel size may be also an important factor: women with smaller carpal tunnel undergo carpal tunnel syndrome more frequently than women who have larger carpal tunnel.

We found the third trimester as the trimester mostly associated with CTS, and this is similar to the other studies. The prevalence of CTS increases with advanced pregnancy, which may be due to accompanying fluid retention and hormonal fluctuations that lead to local edema. We found a relation between the severity of clinical symptoms and the parity. This may be explained by the suggestion that every pregnancy makes a different body, given the weight gain and the differentiating connective tissue response to hormonal fluctuation.

We found a statistically significant difference between pregnant women with CTS and the healthy pregnant women for the area of median nerve at the level of scaphoid-psiforme (carpal

<table>
<thead>
<tr>
<th>CTS clinical grade</th>
<th>Area</th>
<th>PMNE</th>
<th>MMNE</th>
<th>DMNE</th>
<th>Forearm</th>
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<tr>
<td>1</td>
<td>N</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>0.2</td>
<td>0.54</td>
<td>0.05</td>
<td>0.02</td>
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<td></td>
<td>SD</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>N</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
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<td>0.4493</td>
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<tr>
<td></td>
<td>SD</td>
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<td>8</td>
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<tr>
<td></td>
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<tr>
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<td></td>
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<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
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<tr>
<td></td>
<td>SD</td>
<td>0.03769</td>
<td>0.30014</td>
<td>0.22097</td>
<td>0.0293</td>
</tr>
</tbody>
</table>

PMNE: Proximal Median Nerve Elasticity; MMNE: Middle Median Nerve Elasticity; DMNE: Distal Median Nerve Elasticity.

Table I. Elasticity values, and median nerve areas according to CTS clinical grade.

<table>
<thead>
<tr>
<th>Median nerve</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std deviation</th>
<th>Std error mean</th>
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<tbody>
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<td>Inlet of the CT</td>
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<td>25</td>
<td>0.3960</td>
<td>0.36217</td>
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</tr>
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<td>1</td>
<td>30</td>
<td>0.3967</td>
<td>0.30014</td>
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<td>Middle of the CT</td>
<td>0</td>
<td>25</td>
<td>0.3064</td>
<td>0.32616</td>
<td>0.06523</td>
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<td>1</td>
<td>30</td>
<td>0.2453</td>
<td>0.22997</td>
<td>0.04034</td>
</tr>
<tr>
<td>Outlet of the CT</td>
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<td>25</td>
<td>0.2252</td>
<td>0.32548</td>
<td>0.06510</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>30</td>
<td>0.0337</td>
<td>0.02930</td>
<td>0.00535</td>
</tr>
<tr>
<td>MN in forearm</td>
<td>0</td>
<td>25</td>
<td>0.3148</td>
<td>0.23758</td>
<td>0.04752</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>30</td>
<td>0.3913</td>
<td>0.28280</td>
<td>0.05163</td>
</tr>
</tbody>
</table>

Table II. Elasticity values of the median nerve in the carpal tunnel (inlet, middle and outlet) and on the forearm for control group (0) and group with CTS (1).
tunnel inlet); it was greater in pregnant women with CTS. In this study, there was also no statistically significant difference between clinical severity of CTS and CSA of the median nerve. In previous studies, ultrasonographic measurement of median nerve enlargement at the level of the pisiform has been described as a pathologic finding in CTS, and this also supports our findings. The CSA at the entrance of the carpal tunnel seems to have the highest diagnostic sensitivity and specificity for CTS. Mohammedi et al. concluded that CSA of median nerve ultrasonography has a diagnostic value to confirm or exclude carpal tunnel syndrome, but could not be used for grading its severity.

We did not calculate the strain ratios for the median nerve; instead, we preferred to use strain values to obtain more accurate statistical calculations, like those reported by Orman et al. There are different approaches in the literature about the use of strain values and strain ratios; for example, Miyamoto et al. used strain ratios in his study while Orman used strain values, and both of them found that a decrease in the elasticity of median nerve at the entrance of CTS. In our study, there are edematous changes in the soft tissues around the median nerve of almost all of the pregnant women and because we saw that strain values are more stable than the strain index in these tissues, strain values were selected.

We did not apply gel pads or probe adaptors to obtain the elastogram. Although it was suggested that application of gel pads or probe adaptors allow better contact between the probe and the skin and ameliorate the stability of the operator’s hand, Drakonaki et al. have shown that, when performing UE for musculoskeletal applications, care should be taken not to include the gel in the box of the elastogram, as it results in marked changes, making the tendons appear considerably stiffer.

In this study, we applied sonoelastography over an area covering the carpal tunnel and 1 cm portion of the distal-forearm median nerve in the longitudinal plane. This application has removed the difference among compression levels (we applied compression at the following levels: entrance, middle and exit of CT, and distal-forearm). Drakonaki et al. have shown that longitudinal elastograms were easier to acquire and more reproducible than transverse elastograms for the tendon. The median nerve is a cylindric, symmetric, superficial and prominent structure for evaluation by US or UE, just like the tendon.

However, this study should be repeated in bigger patient groups, in order to offer US elastography as a diagnostic test for using in CTS related with pregnancy. UE is an operator-dependent test, and so it could be suggested that inter- or intraobserver variability should be studied. Although electrodiagnostic examination is the gold standard to diagnose the nerve entrapment syndrome, it could not be performed in this study because it is uncomfortable for pregnant women.

Conclusions

Elastography is a valuable method in the diagnosis of CTS, while EMG is not indicated for the diagnosis of CTS in pregnant women. US elastography can detect nerve tissue strain quantitatively, and thus, it may be useful in the diagnosis of other entrapment syndromes. Tissue strain changes in different diseases can be detected quantitatively using US elastography, but additional studies should be carried out to determine the most appropriate clinical and practical applications.

Conflict of Interest

The Authors declare that there are no conflicts of interest.

References

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