The Diagnostic and Grading Value of Diffusion Tensor Imaging in Patients with Carpal Tunnel Syndrome

Haci Taner Bulut, MD, Adem Yildirim, MD, Burcu Ekmekci, MD, Hediye Pinar Gunbey, MD

Rationale and Objectives: In this study, we investigated the diagnostic and grading value of diffusion tensor imaging (DTI) in patients with carpal tunnel syndrome (CTS).

Materials and Methods: Of the 120 subjects included in the present study, 72 were in the CTS group and 48 were in the healthy control group. In addition, the patients with CTS were further divided into three subgroups based on severity (mild, moderate, and severe) according to electrophysiological studies (EPS). DTI-derived parameters (fractional anisotropy [FA] and apparent diffusion coefficient [ADC]) were evaluated at four median nerve levels. The mean FA and ADC values of the CTS groups and healthy controls were compared separately. Correlations and possible relationships between DTI parameters and EPS results were analyzed. Receiver operating characteristics analysis was used to calculate the FA and ADC cutoff values for CTS diagnosis and grading.

Results: Statistically significant differences were observed in mean FA and ADC between the normal and mild, mild and moderate, and moderate and severe subgroups. Significant correlations were found between DTI parameters and EPS measurements based on severity. FA and ADC threshold values, as well as the sensitivity and specificity levels, for diagnosing and grading CTS were determined.

Conclusions: DTI parameters can provide helpful information for CTS. The correlations of FA and ADC measurements versus EPS measurements based on severity were significant. Moreover, FA and ADC threshold values were sufficient for the diagnosis and grading of CTS.

Key Words: Carpal tunnel syndrome; median nerve; diffusion tensor imaging; electrophysiological studies.

Carpal tunnel syndrome (CTS) is the most common peripheral neuropathy, caused by entrapment of the median nerve at the carpal tunnel level (1). Reportedly, the prevalence of CTS is 3.8% in the general population (2) and is more common in women than in men, occurring predominantly in subjects aged between 40 and 60 years (3). Combined use of clinical symptoms, physical examinations, and electrophysiological studies (EPS) are considered as the reference standard for diagnosis of CTS. However, in some cases discrepancies in the diagnosis and severity of CTS may be because of the different measured clinical and EPS parameters (4,5). Imaging methods such as ultrasound (US) and conventional magnetic resonance imaging (MRI) may resolve these discrepancies (6–10). In particular, conventional MRI may show enlargement of the median nerve, nerve flattening, increased nerve signal intensity, and bowing of the transverse carpal ligament in patients with CTS (8,9). However, the sensitivity and specificity of conventional MRI findings are inadequate for diagnosis of CTS and provide insufficient diagnostic data (1).

Diffusion tensor imaging (DTI) is an advanced MRI method used to measure the diffusion of water in tissue. The water diffusion anisotropy can be measured with DTI. Directional anisotropy of water diffusibility can be measured by microstructural parameters such as fractional anisotropy (FA; quantitative index used to characterize the degree of diffusion anisotropy) and apparent diffusion coefficient (ADC; one-third of the trace of the diffusion tensor) (11–14). The main clinical application of DTI is white matter tract visualization (15), which can be useful for imaging the median nerve (16–21). Studies showing that DTI is a feasible diagnostic method for CTS diagnosis are limited (14,22–26).

Two recent studies concluded that DTI is a useful method for CTS diagnosis using FA and ADC threshold values (23,26). In one study, DTI and EPS parameters were directly compared according to severity (14), showing only a moderate-to-weak correlation. However, neither study graded the severity using DTI parameters. Therefore, investigation of the grading value of DTI is necessary. In this study, we investigated the diagnostic and grading value of DTI in

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From the Departments of Radiology (H.T.B.); Physical Medicine and Rehabilitation (A.Y.); Neurology (B.E.), Medical Faculty of Adiyaman University, Adiyaman, 02100 Turkey; Department of Radiology, Samsun Education and Research Hospital, Samsun, Turkey (H.P.G.). Received December 15, 2013; accepted February 7, 2014. **Address correspondence to:** H.T.B. e-mail: taner.bulut02@gmail.com

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patients with CTS and examined correlations between DTI and EPS parameters using a large study cohort.

MATERIALS AND METHODS

Subjects

This prospective study was approved by the ethics committee of our university. According to clinical and EPS results obtained between February and September 2013, 72 patients (19 men and 53 women) were included in the CTS group and 48 healthy volunteers (11 men and 37 women) in the control group. The mean ages of the CTS and control subjects were 43.07 ± 7.40 (25–57) and 41.85 ± 7.81 (31–55) years, respectively. The inclusion criteria for the CTS group were as follows: patients having clinically evident CTS with typical history, symptoms and signs (eg, intermittent, particularly nightly, numbness, tingling or burning sensations in the first three fingers and the radial half part of the fourth finger, atrophy of thenar muscles, and positive Phalen and Durkan test results), and EPS findings consistent with CTS. The exclusion criteria were as follows: contraindications for MRI, the presence of rheumatoid arthritis, diabetes mellitus, space-occupying lesions in the wrist region, previous history of neurologic disease, wrist injury or surgery that could affect EPS.

Electrophysiological Studies

EPS were performed for all participants under identical conditions (24°C room temperature, with 30 minutes of rest) by the same neurologist. The EPS, including motor and sensory nerve conduction studies, needle electromyography, and F-wave latencies of the upper and lower limbs, were performed to diagnose CTS and exclude cervical radiculopathy and polyneuropathy.

The severity of CTS was graded as follows: grade 0, normal (no electrophysiological abnormality); grade 1, mild CTS (slowing of sensory nerve conduction velocity; SNCV < 50 m/s); grade 2, moderate CTS (slowing of SNCV; SNCV < 50 m/s and delayed motor nerve distal latency; MNDL > 4.5 m/s); and grade 3, severe CTS (the absence of sensory response) (24,27,28). Of the 72 CTS wrists, 27 were classified as mild, 24 as moderate, and 21 as severe. MRI studies were performed for all participants within 1 week after EPS.

MRI Studies

A 1.5-T whole-body MRI system (Achieva; Philips Medical Systems, Best, The Netherlands) was used for all MRI examinations. CTS and control subjects were scanned in the prone position with the hand extended over the head. A dedicated four-channel wrist coil was placed on the palmar aspect of the dominant wrist of the controls and the affected dominant wrist of patients with CTS. All examined wrists were immobilized using cushions and bandages.

T1-weighted three-dimensional (3D) fast-field echo magnetic resonance (MR) images (repetition time: 25 milliseconds; echo time: 4.6 milliseconds; flip angle: 35; acquired matrix size: 180 × 180 mm; field of view: RL, 90 mm, AP, 90 mm, and FH, 80 mm; voxel size: 0.5 × 0.5 × 0.5 mm [slice thickness: 0.5 mm]; reconstructed voxel size: 0.31 × 0.31 × 0.50 mm; number of slices: 160; number of signal averages: 2; acquisition time: 4 minutes 8 seconds) were acquired before DTI for anatomic reference. The latter consist of a single-shot echoplanar imaging sequence (repetition time: 10254 milliseconds; echo time: 21.2 milliseconds; b value: 1000 s/mm^2; matrix size: 108 × 83 mm; field of view: RL, 150 mm, AP, 150 mm, and FH, 80 mm; acquired voxel size: 1.39 × 1.74 × 4 mm [slice thickness: 4 mm]; reconstructed voxel size: 0.45 × 0.45 × 4 mm; no slice gap; number of gradient direction: 32; number of slices: 20; two signals acquired; fat suppression, spectral presaturation with inversion recovery; echoplanar imaging factor: 45; number of signal averages: 3; acquisition time: 4 minutes 26 seconds) were performed.

Realignment of the DTI images was performed using the diffusion registration software package (Extended MR WorkSpace, version 2.5.3.0; Philips Medical Systems). All DTI images were reoriented to match the b0 images. The coregistration procedure reduced motion artifacts and distortions before tensor calculation. The FiberTrak software package (Extended MR WorkSpace, version 2.5.3.0) was used for measurements of FA and ADC values. Regions of interest (ROIs) were chosen manually, surrounding the median nerve at four anatomic locations within the carpal tunnel: at the level of the distal radius, pisiform bone, middle of the carpal tunnel, and hook of hamate bone. The tractography image was generated from these four ROIs using FiberTrak software package program. The T1-weighted 3D fast-field echo and tract of median nerve MR images were used for anatomic reference, and ROIs were drawn on the FA map. ROIs were carefully plotted to avoid partial volume artifacts and to exclude vessels, tendons, or any surrounding fat tissue. The FA and ADC values were calculated automatically from the four ROIs (Fig. 1). All measurements were performed by two blinded and specialized radiologists with 11 and 5 years of experience with musculoskeletal MRI. The mean of the values obtained by the two readers was used for all statistical analyses.

Statistical Methods

The SPSS software was used (Statistical Package for Social Sciences, version 18; SPSS Inc., Chicago, IL) in the homogeneity test for the normal distribution of the CTS and control groups' age and gender. To assess interreader variability, Shrout and Fleiss intraclass correlation coefficients (ICCs) were used (29). ICCs were interpreted according to the criteria of Landis and Koch (30). The following ICC categories were used for interpretation: 0.01–0.20 indicated slight agreement; 0.21–0.40 fair; 0.41–0.60 moderate;