Magnetic resonance imaging evaluation of the median nerve using histogram analysis in carpal tunnel syndrome

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Abstract

Objective: Histogram analysis of digital images is a popular new tissue analysis method. It has recently attracted much attention, is used to describe prognostic biomarkers, to characterize tumors, and to assist a few applications that guide radiotherapy treatment. Here, magnetic resonance imaging (MRI) measurements of the median nerve in the carpal tunnel of patients with carpal tunnel syndrome (CTS) were analyzed.

Methods: Hospital records were scanned of the past 3 years and patients who were diagnosed as having CTS through clinical findings and electromyography (EMG) at our outpatient clinic were included retrospectively. Patients who were not diagnosed as having CTS with EMG and had MRI of the wrists were determined as the control group.

Results: A total of 96 wrist MRIs were studied, including 47 wrists with CTS (42 females, 5 males) and 49 normal wrists (39 females, 10 males). There was no significant difference between the groups in terms of sex (p=0.188), affected side (p=0.065), and age (p=0.287). The mean age of the entire patient group was 41.34±13.14 years (range, 18-65 years). Entropy values of the CTS side were significantly lower than those of the normal side. Standard deviation and variances were also low. Histogram distribution parameters, skewness, and uniformity were statistically different as compared with the controls. No significant difference was observed among the other parameters.

Conclusion: Although the intensity of the median nerve in the carpal tunnel does not change in CTS, significant changes were observed in histogram analysis. These data may be helpful in making diagnoses and treatment decisions, and determining the disease severity in CTS in the future.

Keywords: Carpal tunnel syndrome, median nerve, histogram, magnetic resonance imaging

INTRODUCTION

Carpal tunnel syndrome (CTS) is the compression of the median nerve under the retinaculum when passing through the carpal tunnel. It is mostly a peripheral neuropathy originating from idiopathic causes (1, 2). In CTS, diagnosis consists of nerve conduction studies such as electromyography (EMG), which is the standard examination method together with clinical findings. Radiologic methods have been reported to be useful in diagnosis when there is a discrepancy between clinical findings and EMG. Magnetic resonance imaging (MRI) is used as a noninvasive method to demonstrate the carpal tunnel (3).

Histogram analysis of digital images is one of a new popular group of tissue analysis methods (4). This technique, which has recently attracted much attention, is used to describe prognostic biomarkers, to diagnose interstitial lung disease, to characterize tumors, and to assist a few applications that guide radiotherapy treatment (5-15).

In clinical practice, the images used for diagnostic purposes are digital. A two-dimensional digital image consists of small rectangular blocks or pixels (picture elements). Each of these is represented by a set of coordinates on the limb and each has a value that represents the gray-level intensity of that picture or volume item on the limb (5).

We can tie the concept of texture in a digital image according to the distribution of the gray level values between the pixels of a particular region of the image. The texture of the images shows the structure and arrangement of the
parts of an object. Tissue analysis refers to various mathematical methods used to determine spatial variations in gray scale to obtain derivatives called 'texture properties,' which provide a measure of intra-lesional heterogeneity in the image. Tissue analysis is basically a technique that evaluates the signal properties, i.e., the location and density of pixels and the gray level intensity in digital images. Tissue properties are, in fact, mathematical parameters calculated from the pixel distribution that characterize the basic structure of the texture and hence the objects shown in the image (5).

Entropy is one of the parameters commonly used to measure parametric homogeneity in the region of interest (ROI) (16-19). It is a measure of gray level change in a histogram and is a parameter that shows the homogeneity in intensity (irregularity). When all data are the same, they are defined as zero and the number increases as the distribution becomes irregular (17, 19).

Uniformity refers to gray level distribution, which indicates how close the image is to having uniform distribution of gray shades, and as the number increases, the distribution becomes more uniform (17, 19). Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetrical if it looks the same to the left and right of the center point. If there are more points to the left of the middle, it is positive and vice versa. Kurtosis is a measure of whether the data are heavy-tailed or light-tailed relative to normal distribution. That is, data sets with high kurtosis tend to have heavy tails, or outliers. Data sets with low kurtosis tend to have light tails, or a lack of outliers. Uniform distribution would be the extreme case. If the histogram curve is a bell, its value is three, and if there is a sharper peak in the histogram, it is higher than three (19).

In this study, histogram analysis of MRI measurements of the median nerve in the carpal tunnel in patients with CTS were analyzed for the first time in the literature.

**METHODS**

We scanned our university hospital records of the past 3 years and patients who were diagnosed as having CTS through clinical findings and EMG at our outpatient clinic were included retrospectively. Patients who were not diagnosed as having CTS with EMG and had MRI (Philips Ingenia 1.5T; Philips, Holland) of wrists were determined as the control group. Patients with traumatic wrist injuries, a history of hand surgery, and inflammatory joint diseases that affected the wrists were excluded from the study. A scan reader radiologist was trained and totally blinded to the cases and the groups. Written informed consent form was taken from all participants. The study is complied with Helsinki declaration principles and no ethics committee approval was taken as it is designed as retrospectively.

**Statistical Analysis**

In proton density axial sections, the ROI of the portion of the median nerve corresponding to the center of the carpal...
tunnel was compared with each other (Figure 1). Histogram analysis from ROIs were performed using a (Matrix laboratory, MATLAB-based) computer program and compared using the Chi-square test and Student’s t-test. Gray level intensity, standard deviation of histogram, entropy, uniformity, skewness, and kurtosis values were calculated from the ROI values. The entire image analysis algorithm was achieved by using an in-house program (MATLAB, versionR2009b; MathWorks, Natick, Massachusetts, United States).

RESULTS
A total of 96 wrist MRIs were studied, including 47 wrists with CTS (42 females, 5 males) and 49 normal wrists (39 females, 10 males). There was no significant difference between the groups in terms of sex (p=0.188), affected side (p=0.065), and age (p=0.287) (Table 1).

The mean age of the entire study group was 41.34±13.14 years (range, 18-65 years). Entropy values of the side with CTS were significantly lower than those of the normal side. Standard deviation and variances were also lower. Histogram distribution parameters, skewness, and uniformity parameters were statistically different as compared with the controls. No significant difference was observed between the other parameters (Table 2). The histogram analysis of the number and distribution of pixels in the MRIs of wrists with CTS and normal wrists were shown at Figure 2 and 3 respectively. There was no sign of CTS in the MRIs of the wrists with CTS.

DISCUSSION
The trapping of a peripheral nerve is caused by anatomical overtightening, which has become very narrow. This results in nerve damage and loss of function. In spite of their ubiqui-
Almost half of work-related injuries involve CTS, which result in interruptions to work (25). CTS is a disabling condition, even in its early stages, negatively affecting daily life and quality of life. Diagnostic tests such as MRI, ultrasound (USG), as well as provocative tests and nerve conduction studies, help to localize CTS diagnosis and nerve damage. Conservative methods should be applied in mild-to-moderate cases, whereas surgery is recommended for severe cases (26). Magnetic resonance imaging can show signal and configuration changes in the median nerve in patients with CTS. The increased signal in the thenar muscles indicates severe denervation, which can also be confirmed by EMG (27).

Clinical symptomatic CTS does not need to be supported by nerve conduction studies. Surgical decompression can provide complete relief from these symptoms. Decision of surgical decompression will be one of the issues discussed in the future because minimally invasive techniques have been able to reduce perioperative morbidity. For this reason new diagnostic tools are needed to make this decision. Diagnostic tools that provide dynamic recognition of CTS are also required (25, 28). Magnetic resonance imaging is accurate and reliable for the diagnosis and clinical follow up of these patients. It can help to avoid surgical decompression in patients with marked clinical symptoms and without measurable median nerve conduction disturbance (29).

In recent years, the role of MRI has also been related to the functional, metabolic, and cellular characterization of tissue morphologic imaging through advanced imaging techniques and the biologic behavior of the tissue. Today, 1.5 Tesla and more powerful MRI systems provide superior anatomic and morphologic imaging of pathologic tissues with high resolution (30). Digital interpretation of histogram data of MRI images of tissues has been the subject of research in many diseases and useful information about disease severity has been obtained. Goodyear et al. reported that skewness of fractional anisotropy could detect white matter damage associated with optic neuritis and its recovery (31). Yamashita et al. demonstrated that histogram analysis of computerized tomography (CT) images might be of clinical value in diagnosing otosclerosis (32). Colombi et al. analyzed changes over time in idiopathic pulmonary fibrosis (IPF) using a fully automatic histogram-based quantitative evaluation with CT (12).

According to our study, entropy, standard deviations, and variances were found lower on the side with CTS, indicating that the nerve had become more homogeneous. The change in the skewness indicates that the histogram returns to normal distribution and that the decline in uniformity appears to be a non-uniform distribution. The MRIs of median nerves in wrists with CTS differ from normal wrists in histogram analysis. We may say that the nerve becomes more homogeneous and uniform in CTS. In CTS, structural changes can be seen in
the median nerve due to microcirculation injury, and connective tissue and synovial tissue alterations.

There are limitations such as the fact that some patients had bilateral involvement, the number of male patients was not sufficient, and the signal intensity of ROIs has not yet been standardized. Additionally, we did not question the probable etiology of CTS, which could affect the median nerve structure and study results.

CONCLUSION
Although the intensity of the median nerve in the carpal tunnel does not change in CTS, significant changes are observed in histogram analysis. These data may be helpful in making diagnosis and treatment decisions, and determining the disease severity in CTS in the future.

Ethics Committee Approval: Authors declared that the research was conducted according to the principles of the World Medical Association Declaration of Helsinki “Ethical Principles for Medical Research Involving Human Subjects”, (amended in October 2013).

Informed Consent: Written informed consent form was obtained from the patients who participated in this study.

Peer-review: Externally peer-reviewed.


Conflict of Interest: The authors have no conflicts of interest to declare.

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