Relationship between Diffusion Tensor Fractional Anisotropy and Long-term Motor Outcome in Patients with Hemiparesis after Middle Cerebral Artery Infarction

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Background: Magnetic resonance diffusion tensor fractional anisotropy (DTI-FA) is often used to characterize neural damage after stroke. Here we assessed the relationship between DTI-FA and long-term motor outcome in patients after middle cerebral artery (MCA) infarction. *Methods:* Fractional anisotropy (FA) maps were generated from diffusion tensor brain images obtained from 16 patients 14-18 days postinfarction, and tract-based spatial statistics (TBSS) analysis was applied. Regions of interest were set within the right and left corticospinal tracts, and mean FA values were extracted from individual TBSS data. Hemiparesis motor outcome was evaluated according to Brunnstrom stage (BRS: 1-6, severe-normal) for separate shoulder/elbow/forearm, hand, and lower extremity functions, as well as the motor component score of the Functional Independence Measure (FIM-motor: 13-91, null-full) 5-7 months after onset. Ratios between FA values in the affected and unaffected hemispheres (rFA) were assessed by BRS and FIM-motor scores. *Results:* rFA values were .636-.984 (median, .883) and BRS scores were 1-6 (median, 3) for shoulder/elbow/forearm, 2-6 (median, 3) for hand, and 3-6 (median, 5) for the lower extremities. FIM-motor scores were 51-90 (median, 75). Analysis revealed significant relationships between rFA and BRS data (correlation coefficient: .687 for shoulder/elbow/forearm, .579 for hand, and .623 for lower extremities) but no significance relationship between rFA and FIM-motor scores. *Conclusions:* The results suggest that DTI-FA is applicable for predicting the long-term outcome of extremity functions after MCA infarction. **Key Words:** Infarct—paresis—prognosis—recovery—stroke.

Introduction

Cerebral infarction is a leading cause of disability in the elderly population,[1] and its associated social welfare costs are a serious concern in most advanced countries.[2,3] Clinical manifestations after cerebral infarction are numerous and varied; some patients exhibit visual acuity deficits (eg, after posterior cerebral artery infarction), whereas others suffer from executive dysfunction (eg, after anterior cerebral artery infarction). The most prevalent symptom is hemiparesis, which often accompanies middle cerebral artery (MCA) infarction.[4] Because hemiparesis often results in disabilities in locomotion and hand manipulation, it is frequently associated with poor functional outcome.[5] To minimize disability, rehabilitation is typically prescribed.

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The evaluation of brain images to determine clinical severity is critically important in facilitating the most effective rehabilitative treatment. A newly developed magnetic resonance (MR) technique, diffusion tensor imaging (DTI), has recently been applied for such evaluation.[6] DTI detects the diffusion gradient path of water molecules with high sensitivity to reveal the orientation of neural fibers, which consequently enables clinically useful characterization of Wallerian degeneration after cerebral infarction.[7]

Of the parameters obtained from DTI, fractional anisotropy (FA) is a proven index of white matter axonal degeneration.[8] Recent studies on FA brain images have applied tract-based spatial statistics (TBSS) analysis for various kinds of neural diseases such as idiopathic normal pressure hydrocephalus and Parkinson disease.[9,10] Using computer-automated technology, TBSS transforms each FA brain image into the standard brain space, a procedure that enables intersubject statistical analysis, such as direct comparisons between groups or quantitative evaluation of regional FA changes in relation to clinical manifestations.[11] However, few studies have used TBSS to assess whole brain FA changes in patients after MCA infarction and in relation to its clinical symptoms.[12-14] The aim of this study was to characterize the FA changes caused by MCA infarction in relation to long-term motor outcome using TBSS methodology.

Methods

Patients

The study sampled patients admitted to Nishinomiya Kyoritsu Neurosurgical Hospital for MCA infarction between June 2010 and March 2013. Patients were typically transferred to our hospital soon after stroke onset. They were then examined by diffusion-weighted magnetic resonance imaging (MRI), and cerebral infarction was diagnosed. Brain diffusion-weighted imaging (DWI) images were inspected by our acute stroke care team consisting of board-certificated neurologists, neurosurgeons, and physiatrists. Patients who exhibited high-intensity areas within the MCA territory were diagnosed as having MCA infarction. Patients underwent conservative treatments such as medication (eg, anticoagulant or antiplatelet agents). During hospitalization, patients also received physical therapy, occupational therapy, and speech therapy for a combined daily total of up to 180 minutes. The protocols for these rehabilitative treatments followed the conventional methods stated in the Japanese Guidelines for the Management of Stroke.[15] Patients (or relatives when necessary) provided written consent for inclusion in the study, and the study protocol was approved by the hospital's institutional review board.

To minimize the variability arising from differences in prestroke status and lesion sites, the sample population was limited to first-ever stroke patients able to walk unaided who had been functionally independent in activities of daily living (ADL) in the local community before stroke. For MRI safety, patients with metal implants were excluded. Patients who subsequently required acute medical services (for recurrence of stroke, angina pectoris, or other coincidental conditions) were also excluded. To minimize the variability arising from differences in the rehabilitative therapeutic regimen, we collected data from the patients transferred to our affiliated long-term rehabilitation facility (Nishinomiya Kyoritsu Rehabilitation Hospital) to receive inpatient rehabilitative care for at least 3 months.

DWI Acquisition

On arrival at our hospital, patients with hemiparesis or related symptoms were suspected of stroke and underwent head MRI with a 3-T (Trio; Siemens AG, Erlangen, Germany) or 1.5-T (Signa; General Electric Medical Systems, Milwaukee, WI) scanner depending on availability. For the 3-T scanner, which used a single-shot echo-planar imaging sequence, the DWI scheme acquired an image with diffusion gradients (b = 1200 seconds/mm^2) and non-DWI (b = 0 seconds/mm^2). In total, 22 axial slices were obtained from each patient. The field of view was 220.0 mm × 220.0 mm, the acquisition matrix was 128 × 128, and slice thickness was 5 mm with a 1.5 mm gap. Echo time was 81 ms and repetition time was 5000 ms.[16] Settings for acquisition parameters were the same for the 1.5-T scanner, except for the diffusion gradient (b = 1000 seconds/mm^2) and echo time (100 ms).[16]

DTI Acquisition

DTI was performed 14-18 days after admission using a 3-T MR scanner (Trio; Siemens AG) with a 32-channel head coil. Previous reports have indicated a requirement of 2 weeks before signal changes can be reliably detected after ischemic stroke.[7,17,18] By means of a single-shot echo-planar imaging sequence, the DTI scheme acquired 12 images with noncollinear diffusion gradients (b = 1000 seconds/mm^2) and 1 non–diffusion-weighted image (b = 0 seconds/mm^2), and a total of 64 axial slices were obtained from each patient. The field of view was 230.4 mm × 230.4 mm, the acquisition matrix was 128 × 128, and slice thickness was 3 mm with no gaps, which resulted in voxel dimensions of 1.8 mm × 1.8 mm × 3.0 mm. Echo time was 83 ms and repetition time was 7000 ms.[16] We also obtained T1- and T2-weighted MR images for other diagnostic purposes. The total time for MRI acquisition including these scans was approximately 20 minutes per patient. Patients who were unable to remain still long enough to complete MRI acquisition were excluded from the final analytical database.