Outcome Assessment of Hemiparesis due to Intracerebral Hemorrhage Using Diffusion Tensor Fractional Anisotropy

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Background: This study aimed to evaluate the prognostic efficacy of magnetic resonance diffusion tensor fractional anisotropy (FA) for patients with hemiparesis due to intracerebral hemorrhage. *Methods:* Diffusion tensor FA brain images were acquired 14-21 days after putaminal and/or thalamic hemorrhage. The ratio of FA values within the cerebral peduncles of the affected and unaffected hemispheres (rFA) was calculated for each patient (n = 40) and assessed for correlation with Brunnstrom stage (BRS, 1-6), motor component of the functional independence measure (FIM-motor, 13-91), and the total length of stay (LOS) until discharge from rehabilitation ($P < .05$). Ordinal logistic regression analyses were conducted to determine the relationships between rFA and specific outcomes as measured by BRS range (poor, BRS 1 or 2; moderate, BRS 3 or 4; and good, BRS 5 or 6; $P < .05$). *Results:* The rFA values were .571-1.043 (median, .856) and BRS scores were 1-6 (median, 4) for shoulder/elbow/forearm, 1-6 (median, 4) for hand, and 2-6 (median, 4) for lower extremities. FIM-motor scores were 58-86 (median, 78) and LOS ranged from 42 to 225 days (median, 175.5 days). Correlation coefficients were statistically significant between rFA and shoulder/elbow/forearm BRS (.696), hand BRS (.779), lower extremity BRS (.631), FIM-motor (.442), and LOS (−.598). Logistic model fit was moderate for shoulder/elbow/forearm BRS (R^2 = .221) and lower extremity BRS (R^2 = .277), but was much higher for hand BRS (R^2 = .441). *Conclusions:* Diffusion tensor FA values are predictive of clinical outcome from hemiparesis due to putaminal and/or thalamic hemorrhage, particularly hand function recovery. **Key Words:** Hematoma—paresis—probability—prognosis—recovery—stroke.

Stroke is a leading cause of disability in most advanced countries.[1] Stroke due to intracerebral hemorrhage is often associated with severe impairment such as hemiparesis,[2] resulting in poor functional outcome.[3,4] To facilitate the most effective rehabilitation, the evaluation of brain images in relation to clinical severity is critically important.

Magnetic resonance (MR) diffusion tensor imaging (DTI) has recently been applied to assess white matter degeneration after stroke.[5] DTI detects the diffusion gradient path of water molecules to reveal preserved axonal fibers, and so, enables clinically useful characterization of Wallerian degeneration after intracerebral hemorrhage. Of the parameters obtained from DTI, fractional anisotropy (FA) has proven to be a useful index of axonal degeneration, and several studies have attempted to use

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FA values to characterize the relationships between neural degeneration and clinical manifestations of intracerebral hemorrhage.[6-11]

Patients often exhibit different outcomes for upper and lower extremity functions after intracerebral hemorrhage, with lower extremity functions generally showing better recovery than upper extremity functions.[8,11] Thus, many patients resume independent walking, leading to functional independence in activities of daily living (ADL). However, few previous studies have reported on specific clinical outcomes and their relation to DTI, analyses may be useful for tailoring rehabilitation regimens to target the most severe reversible functional deficits.

In this study, we used a variety of analytical procedures to assess the relationships between DTI-FA and multiple clinical outcomes. The results suggest that hand functions are most severely affected by putaminal and/or thalamic intracerebral hemorrhage, whereas lower extremity function and ADL are relatively spared.

Methods

Patients

The study sampled patients with intracerebral hemorrhage who were admitted to Nishinomiya Kyoritsu Neurosurgical Hospital between December 2009 and March 2014. Patients were typically transferred to our hospital soon after onset and underwent conservative treatment such as medication to reduce hypertension and, when necessary, surgical removal of hematoma. During hospitalization, they also underwent 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.[12] The work presented here extends that of our previously published study[11] that included data from 12 patients already entered in the database for the present study.

The Ethics Committee of Hyogo College of Medicine approved the study protocol, and patients (or relatives when necessary) provided written informed consent.

To minimize the variability arising from differences in prestroke health status and lesion site, the sample population was limited to first-ever stroke patients with thalamic and/or putaminal hemorrhage who were able to walk unaided and had been functionally independent in ADL before stroke. For MR imaging safety, patients with implanted metal items (eg, artificial pacemakers) were excluded. Patients who subsequently required acute medical services (for recurrence of stroke, angina pectoris, or other comorbid conditions) were also excluded. To minimize variability arising from differences in the rehabilitative therapeutic regimen, this study included data only from patients who were transferred to our affiliated long-term rehabilitation facility (Nishinomiya Kyoritsu Rehabilitation Hospital) to receive inpatient rehabilitative care for at least 1 month.

Computed Tomography Acquisition

On arrival at our hospital, patients manifesting hemiparesis or other symptoms of stroke (hemorrhagic or ischemic) underwent head computed tomography with an Aquilion 64SP scanner (Toshiba Medical Systems Corp., Tochigi, Japan). Imaging parameters were 120 kVp and 250 mA, in-plane resolution was .86 mm $\times$ .86 mm, and slice thickness was 8 mm. The volume of intracerebral hemorrhage was estimated conventionally.[13]

DTI Acquisition

DTI was performed 14-21 days after admission using a 3.0 T MR scanner (Trio; Siemens AG, Erlangen, Germany) with a 32-channel head coil. Details of the DTI acquisition protocol were reported in our previous studies.[8,11] In brief, the DTI protocol acquired 12 images with noncollinear diffusion gradients (b = 1000 seconds/mm^2) and 1 nondiffusion-weighted image (b = 0 seconds/mm^2) using a single-shot echo-planar imaging sequence. A total of 64 axial slices were obtained from each patient. The field of view was 230.4 mm $\times$ 230.4 mm, the acquisition matrix was 128 $\times$ 128, and slice thickness was 3 mm without a gap. Echo time was 83 milliseconds and repetition time was 7000 milliseconds.

Outcome Measurements

Brunnstrom stage (BRS),[14] which is commonly used by Japanese rehabilitation therapists,[12] was adopted to assess post–intracerebral hemorrhage motor impairments of the upper and lower extremities on the affected side. In this assessment, recovery of the affected extremities was evaluated by associated reactions and flexion and extension synergy patterns on a 6-point scale from severe (1) to normal (6). Conventionally, BRS is used for separate functional evaluation of the proximal (shoulder/elbow/forearm) and distal (hand) upper extremity and the entire lower extremity, and its reliability and validity are well established.[15,16] Assessments were made by occupational or physical therapists blinded to the purpose of the study.

In addition to extremity functions, we obtained scores on the motor component of the functional independence measure (FIM-motor). The FIM is a test battery commonly used for evaluating stroke rehabilitation.[17,18] It consists of individual 7-point scales (from total assistance to complete independence) for the following 13 items: eating, grooming, bathing, dressing upper body, dressing lower body, toileting, bladder and bowel management, transfer to bed/chair/wheelchair, transfer to toilet, transfer to tub/shower, walking or wheelchair propulsion, and stair