Extent of Pontine Pyramidal Tract Wallerian Degeneration and Outcome After Supratentorial Hemorrhagic Stroke

Kazuhiro Fukui, MD; Ikuzo Iguchi, MD; Akira Kito, MD; Yukio Watanabe, MD; Kenichiro Sugita, MD

Background and Purpose
Pyramidal tract Wallerian degeneration has been detected on magnetic resonance imaging (MRI) as T2-weighted high-intensity areas. We analyzed the relation between the extent of brain stem Wallerian degeneration and activities of daily living (ADL) after supratentorial hemorrhagic stroke.

Methods
Twenty-six patients with supratentorial hemorrhage were examined on the coronal T2-weighted image of the pons 3 months or later after stroke, and the percentage of Wallerian degeneration in the pons was calculated. The patients were divided into three groups. In group A (n=6), MR films were taken 3 to 6 months from the onset, and the ADL assessment was done within 2 months from the MRI. In group B (n=11), MR films were taken 3 to 6 months from the onset, and the ADL assessment was done within 10 months from the MRI (mean, 15.5 months from the onset). In group C (n=9), MR films were taken after 10 to 17 months (mean, 12.0 months) from the ictus, and the ADL assessment was done simultaneously. Barthel Index score was used for quantitative ADL assessment.

Results
All patients showed various degrees of pontine pyramidal tract Wallerian degeneration associated with capsular involvement by the hematoma. In group A, the percentage of degeneration did not correlate with the Barthel Index score (r=2.101, P=0.695). An inverse relation between percentage of degeneration and Barthel Index score was seen in groups B (r=7.354, P=0.009) and C (r=8.858, P=0.014). In groups B and C, Wallerian degeneration was higher in patients with Barthel scores less than 60 (P=0.005).

Conclusions
The extent of pontine Wallerian degeneration on MRI 3 months or later after stroke correlated with the patient's Barthel Index score 1 year after the stroke. (Stroke. 1994;25:1207-1210.)

Key Words • cerebral hemorrhage • magnetic resonance imaging • Wallerian degeneration

Pyramidal tract Wallerian degeneration has been detected on magnetic resonance imaging (MRI) as T2-weighted high-intensity areas 10 to 14 weeks after the ictus.1-4 The extent of Wallerian degeneration has been significantly correlated with motor impairment after stroke.5-7 For an objective estimation of functional recovery in stroke patients, we used the Barthel Index of activities of daily living (ADL) and compared it with the extent of pontine pyramidal tract Wallerian degeneration after hemorrhagic stroke.8

Subjects and Methods
The 26 selected case subjects (14 men and 12 women; age range, 38 to 72 years [mean, 57.4 years]) included 18 patients with putaminal hemorrhages and 8 with thalamic hemorrhages. The initial diagnosis of the hemorrhage was made by computed tomography. Hematoma volume was calculated from the computed tomographic slice. Operative hematoma evacuations were done on 15 of the putaminal hemorrhages; thalamic hemorrhages were treated conservatively.

The patients were divided into three groups according to the timing of MRI and ADL evaluation (Table 1).

MRI was performed on each patient for the detection of Wallerian degeneration at least 3 months after stroke. After 3 months, the Wallerian degeneration could be detected as high signal intensity on T2-weighted images. The MRIs were performed using a 1.5-T magnetic resonance imager (Toshiba MRT-200/FX). All T2-weighted images were obtained by spin-echo pulse sequences with repetition times of 2000 to 2500 milliseconds and echo times of 80 milliseconds. The section thickness was 5 to 7.5 mm, and the acquisition matrix was 256×192. A coronal T2-weighted image was taken along a straight line between the front edge of the medulla and the deepest point of the interpeduncular cistern for the clear identification of brain stem Wallerian degeneration (Fig 1).5 The area of high signal intensity was considered Wallerian degeneration in the pontine pyramidal tract (Fig 2, top panel). The extent of degeneration was calculated by dividing the area of pontine Wallerian degeneration by the total area of the affected half of the pons (Fig 2).

We used the Barthel Index for assessment after rehabilitation. The Barthel Index includes 15 self-care, sphincter-control, and mobility factors. Each factor is subdivided for scoring as "independent," "partial independence," and "total dependence." When summed, the total Barthel score ranges from 0 (total dependence) to 100 (complete independence).4 Statistical analysis of the data was done with simple regression analysis, unpaired t test, and Wilcoxon signed-rank test.

Results
Wallerian degeneration was detected in all patients. The percentage of Wallerian degeneration ranged from 1.6 to 66.1 (mean, 24.2±16.9). The Barthel Index score ranged from 0 to 100 after rehabilitation (mean, 76.4).
TABLE 1. Timing of Magnetic Resonance Imaging and Activities of Daily Living Evaluation in Each Patient Group

<table>
<thead>
<tr>
<th>Group</th>
<th>Timing of MRI, mo from onset</th>
<th>Timing of ADL evaluation, mo from onset</th>
<th>Group A (n=6)</th>
<th>Group B (n=11)</th>
<th>Group C (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3-6 (4.5)</td>
<td>5-8 (6.6)</td>
<td>10-17 (12.0)</td>
<td>13-16 (15.5)</td>
<td>10-17 (12.0)</td>
</tr>
</tbody>
</table>

MRI indicates magnetic resonance imaging; ADL, activities of daily living. Numbers in parentheses are mean values.

In putaminal hemorrhages, patients with posterior limb invasion by hematoma showed a higher percentage of degeneration (n=12; 39.0±13.0%) than patients without posterior limb invasion (n=6; 25.3±15.5%) with significant difference ($P=.0002$) (Table 2). In patients with thalamic hemorrhages, all showed capsular involvement, and Wallerian degeneration of the pons was detected in all cases.

The results of comparison among the three groups are shown in Table 3. In group A, percentage of degeneration did not correlate with Barthel Index score ($P=.6895$) (Table 3). However, an inverse relation between percentage of degeneration and Barthel Index score was seen in group B ($r=.7354, P=.0099$) and group C ($r=.818, P=.0014$) (Table 3, Fig 3). In groups B and C, Wallerian degeneration was significantly higher in patients with Barthel scores less than 60 ($P=.005$) (Table 4).

**Discussion**

There has been some effort to compare the degree of pyramidal tract Wallerian degeneration seen on MRI with clinical outcome. Sonoda et al$^6$ compared Wallerian degeneration on axial MR images and motor impairment. They concluded that the extent of Wallerian degeneration is helpful in predicting the degree of motor impairment in the upper extremities.$^6$ Watanabe and Tashiro$^7$ reported that Wallerian degeneration was seen in 90% of patients with low-stage disease by Brunnstrom criteria. Orita et al$^5$ reported that the mean percentage of Wallerian degeneration was 26.1±5.1 in patients with severe motor dysfunction and 10.1±5.4 in patients with mild motor dysfunction.

![Fig 1. Midsagittal T1-weighted magnetic resonance image. A line indicates the coronal section between the front edge of the medulla and the deepest point of the interpeduncular cistern.](image1)

![Fig 2. Coronal T2-weighted magnetic resonance images 3 months after the onset of left putaminal hemorrhage. Wallerian degeneration is seen as a longitudinal high signal band from the left putamen to the pontine pyramidal tract (left). The areas of Wallerian degeneration in the pons (left) and half of the pons (right) were measured.](image2)
patients with mild motor dysfunction, which was of statistical significance. Within 4 to 10 weeks after supratentorial stroke, pyramidal tract Wallerian degeneration displays a low-intensity area on both T2-weighted images and proton density images. However, 10 to 14 weeks after the ictus, it changes to a high-intensity area on T2-weighted images and a low-intensity area on T1-weighted images. Kuhn et al reported that Wallerian degeneration was detected in 20 of 23 stroke patients, with a mean time between onset and MRI of 4.8 years. Pujol et al found that all of the patients with pyramidal tract Wallerian degeneration on MRI showed clinical alteration of pyramidal tract function.

The Barthel Index score is a quantitative assessment of the ADL and is widely used as a scale of disability and handicap in stroke patients. Patients with a Barthel score of 40 or less were markedly dependent; those with scores of 60 or above were easier to manage and required less assistance. None in the group aged 41 to 60 years could dress their upper body, wash, or bathe by themselves, but those in the group aged 61 to 80 years were relatively free from dependence on others. From our analysis, the degree of Wallerian degeneration was significantly higher in patients with Barthel scores less than 60.

In our patients with putaminal hemorrhages, hematomas involving the posterior limb of the internal capsule resulted in a higher percentage of Wallerian degeneration as a result of pyramidal tract degeneration. In patients with thalamic hemorrhages, the comparison with and without capsular involvement was not done because all patients showed capsular involvement. Wallerian degeneration seen in thalamic hemorrhages is also presumably caused by pyramidal tract impairment.

In group A Wallerian degeneration did not correlate with Barthel Index score; however, in groups B and C a significant inverse correlation was seen. The Barthel Index assessment may have been performed too early to describe the patients' final outcome after rehabilitation. In groups B and C, ADL assessment was done more than 1 year after the ictus, when the patients' functional recovery had become stable. In group A, the percentage of Wallerian degeneration might correlate with Barthel Index score if the assessment was performed later. As seen in group B, measurement of pontine Wallerian degeneration by MRI 3 months after supratentorial hemorrhagic stroke correlated with the patient's ADL after 1 year and may therefore have predictive value in the patient's clinical outcome. In group C, the mean time between onset to MRI was 1 year with concurrent assessment of ADL, and Wallerian degeneration was readily detected. The late follow-up MRI in group C confirms the predictive value of the MRI performed 3 months after stroke.

### Table 3. Relation Between Extent of Wallerian Degeneration and Outcome After Stroke in Each Patient Group

<table>
<thead>
<tr>
<th>Patients with posterior limb invasion, %</th>
<th>Group A (n=6)</th>
<th>Group B (n=11)</th>
<th>Group C (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pontine Wallerian degeneration, %</td>
<td>83.3</td>
<td>63.6</td>
<td>88.9</td>
</tr>
<tr>
<td>Barthel Index scores</td>
<td>23.6±10.5</td>
<td>32.8±15.0</td>
<td>22.6±20.4</td>
</tr>
<tr>
<td>Correlation of Wallerian degeneration with ADL*</td>
<td>P=0.6895</td>
<td>P=0.0099</td>
<td>P=0.0014</td>
</tr>
</tbody>
</table>

ADL indicates activities of daily living.

*Simple regression analysis with 95% confidence intervals.

### Table 4. Barthel Index Scores and Wallerian Degeneration in Groups B and C

<table>
<thead>
<tr>
<th>Barthel Index</th>
<th>Wallerian Degeneration, %</th>
</tr>
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<tbody>
<tr>
<td>&gt;60 (n=5)</td>
<td>49.6±11.3</td>
</tr>
<tr>
<td>61-100 (n=15)</td>
<td>21.1±13.4*</td>
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</table>

*P=.0005.
The extent of Wallerian degeneration on MRIs observed 3 months or longer after stroke has predictive value for the ADL of the patient 1 year after stroke and can be a good index for the assessment of rehabilitation goals.

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References
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