Evaluation of Brain Dysfunction in Hypertensive Putaminal Hemorrhage with Multimodality Evoked Potentials

Minoru Shigemori, Tatsuio Yuge, Kensaku Kawasaki, Takashi Tokutomi, Tomoyuki Kawaba, Hironori Nakashima, Mitsuo Watanabe, and Shinken Kuramoto

Changes in multimodality evoked potentials (MEP's), consisting of somatosensory evoked potentials (SEP's), visual evoked potentials (VEP's), and auditory evoked brainstem responses (AEBR's), were studied in 36 patients with hypertensive putaminal hemorrhage to ascertain the relation among areas and distribution of brain dysfunction, the size of hemorrhage on computerized tomographic scan, and the clinical outcome. Among MEP's, SEP's were most significantly involved in all patients. Abnormalities in VEP's and AEBR's remained mild or moderate when the hemorrhage did not extend to the diencephalon. If SEP's were normal or mildly abnormal, they improved early after the ictus. These patients did well clinically. If SEP's were absent, the patients had poor outcome even when the hemorrhage was small and located outside the internal capsule. In contrast, deterioration or persistence of MEP's indicated secondary insult to the brain and poor patient outcome. Early and serial MEP studies are useful in evaluating primary and secondary brain dysfunction and in predicting patient outcome in hypertensive putaminal hemorrhage. (Stroke 1987;18:72-76)

HYPERTENSIVE intracerebral hemorrhage commonly involves the putamen and frequently extends into the internal capsule or surrounding structures. Neuronal damage therefore depends primarily on the size of the hemorrhage, but the degree of perifocal edema around the hemorrhage or the presence of ventricular rupture of the hemorrhage also influence the neuronal function of the brain. The advent of computerized tomographic (CT) scan allows precise location of these lesions, but the correlation between structural damage on CT scan and neurological dysfunction or outcome of the patients is not always consistent. We studied changes in multimodality evoked potentials (MEP's) consisting of three different sensory evoked potentials (EP's) in 36 patients with hypertensive putaminal hemorrhage to ascertain the relation among areas of brain dysfunction, size of the hemorrhage, and patients' outcome.

Subjects and Methods

This series included 36 patients with hypertensive putaminal hemorrhage treated in our department within 3 days of onset of the attack. The 20 men and 16 women all suffered from long term hypertension; ages ranged from 34 to 76 years, with a mean 56 years. Of these patients, 22 (61.1%) had a hemorrhage in the dominant hemisphere and 28 (77.8%) were treated by craniotomy in the acute stage. All patients had a mild-to-severe hemiparesis contralateral to the hemorrhage with or without consciousness disturbance. In each case, the site and size of the hemorrhage were determined on the initial CT scan taken at admission and classified into 7 types on the basis of CT classification (CT-C) proposed by Kanaya et al in 1978. Patients were then divided into 4 groups according to CT-C: Group 1 with hemorrhage outside the internal capsule or extended to the anterior limb, Group 2 with hemorrhage extended to the posterior limb with or without massive ventricular hemorrhage, Group 3 with hemorrhage extended to the anterior and posterior limbs with or without massive ventricular hemorrhage, and Group 4 with hemorrhage extended to the thalamus or subthalamus.

MEP's consisted of cortical somatosensory evoked potential (SEP), visual evoked potential (VEP), and auditory evoked brainstem response (AEBR). The specific techniques used to record MEP’s have been described in detail elsewhere. Briefly, MEP's were recorded with a Neuropack (Nihonkhoden Co. MEP-3102) with a stimulating and recording apparatus (DAT-3200) from standard placement of 10-20 electrodes. SEP’s obtained by median nerve stimulation at 2 Hz for 0.1 msec were recorded simultaneously from each parietal electrode with mastoid reference. Voltage was increased until thumb twitching occurred. Two hundred responses were averaged. VEP’s were recorded from each occipital electrode with mastoid reference. Both eyes were stimulated with a flash at 2 Hz. Two hundred responses were averaged. AEBR's were recorded from an active electrode on the vertex with ipsilateral mastoid references. Clicks of 100 dB were delivered to the ears at 300 Hz; 2,500 responses were averaged. The initial study of MEP's was performed on the first day of admission in each patient, and the serial study was done in the early period following the attack in 20 surgical patients.

Each response was evaluated for presence or absence of abnormalities and assigned a grade: I (nor-
Table 1. Classification of Multimodality Evoked Potential (MEP)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Normal</td>
</tr>
<tr>
<td>II</td>
<td>Delays in the latency of wave P-3 are present.</td>
</tr>
<tr>
<td>III</td>
<td>Normal</td>
</tr>
<tr>
<td>IV</td>
<td>Nearly flat wave. (Only wave P-1 is present.)</td>
</tr>
</tbody>
</table>

Modified from Greenberg et al. \(^{3,4}\)

Results

Of 36 patients, 14 (38.9%) had a hemorrhage outside the posterior limb of the internal capsule (Group 1), 6 (16.7%) were in Group 2, 9 (25%) in Group 3, and 7 (19.4%) in Group 4. Neurological impairment was fairly well correlated with the size of the hemorrhage. Twelve of 14 patients (85.7%) in Group 1 and 3 of 6 (50%) in Group 2 were alert or somnolent. However, 8 of 9 (88.9%) in Group 3 and 5 of 7 (71.4%) in Group 4 were semicomatose with or without decerebrate posturing. The overall ADL outcome of the patients was 10 (27.8%) Good, 6 (16.7%) Fair, and 14 (38.9%) Poor, and the overall mortality rate was 16.6%. Functional recovery was favorable in Group 1: 9 Good (64.3%), 3 Fair (21.4%), and 2 Poor (14.3%). In Group 2, 3 of 6 (50%) had Good or Fair outcome and the others had Poor outcome. No patients died in these groups. On the other hand, all but 1 patient showed Poor outcome and mortality rate was 22.2% (2 cases) in Group 3. Only 3 patients (42.9%) in Group 4 survived, with Poor outcome.

Abnormalities in MEP's among the 3 modalities were more pronounced in the initial study. The severity of SEP abnormality depended on the size of the hemorrhage. SEP was normal (Grade I) or mildly abnormal (Grade II) in 10 of 14 patients (71.4%) in Group 1 (Table 2). Severe abnormal SEP's were recorded in 3 patients. No patient with normal SEP was found in Groups 2, 3, or 4. Grade IV abnormality was found in 44.4—57.1% of patients in these 3 groups. In this series, 12 patients overall (33.3%) had normal or mildly abnormal SEP's and the others had moderately or severely abnormal SEP's.

VEP abnormalities were milder than those of SEP's in all groups of patients, and there were no patients with Grade IV abnormality in Groups 1, 2, and 3. Grade II or less abnormality was found in 83.3% and 77.8% of patients in Groups 2 and 3, respectively, and Grade IV abnormality was found in only 1 patient in Group 4. The results of initial VEP study indicated that 28 of 36 (77.8%) remained normal or mildly abnormal.

The abnormalities of AEBR were also mild compared to those of SEP's and all AEBR's in Groups 1 and 2 remained Grades I or II (Table 4). Grade II or less abnormalities were found in 77.8 and 57.1% of patients in Groups 3 and 4, respectively, and Grade IV abnormality was found in only 2 patients (28.6%) in Group 4. Initial AEBR study, thus, indicated that 31 patients of 36 (86.1%) showed normal or mildly abnormal AEBR's and only 5 patients (13.9%) were Grade III or IV abnormality.

A reciprocal relation among the 3 modalities in each
group demonstrated that only mild changes in VEP's were recorded in 4 patients (28.6%) in Group I and no abnormality in VEP's or AEBR's was found in 8 patients (57.1%). Two patients had mild abnormalities in both VEP and AEBR. In AEBR and/or VEP, Grade II abnormality was found in 4 of 6 patients (66.7%) in Group 2, and both modalities were involved in 2 instances. For the other 2 patients, no change in VEP and AEBR was found in 1 and moderately abnormal VEP was found in the other. In Group 3, mild or moderate abnormality in AEBR and/or VEP was found in 4 of 9 patients (44.4%). In the other 5 patients, 3 had moderate abnormality in AEBR or VEP and 2 patients had abnormal SEP only. On the other hand, all 3 modalities were moderately or severely abnormal in 4 of 7 (57.1%) patients in Group 4, but AEBR and VEP were normal in 1 case (Tables 2-4).

The size of the hemorrhage correlated better with VEP and AEBR grades than with SEP grade, but graded SEP correlated well with the outcome of the patients irrespective of the size of the hemorrhage (Table 5). All 5 patients with normal SEP showed Good outcome. In patients with mildly abnormal SEP's, 5 of 7 (71.4%) had Good or Fair outcome and only 1 patient had Poor outcome. However, 6 of 10 patients (60%) with moderately abnormal SEP showed Poor functional recovery. There was no case with Good outcome in patients with severely abnormal SEP's, and 50% (7 cases) had Poor outcome.

Serial recordings of SEP's were done for 5-14 days after admission in 20 surgical cases. The initial grades of SEP's in Group 1 ranged from I to IV and improved in 3-14 days after the operation in 7 of 8 patients (87.5%). All 7 had Good outcome even when their preoperative grade was III. In 1 case with Grade IV abnormality, there was no improvement of the grade. This patient had a Fair outcome. The improvement in SEP grades was delayed in 7 patients of Groups 2 and 3 even when initial SEP grade was II or III. Only 1 patient with initial Grade II abnormality had normal SEP at 3 days after operation. Patients with Grade IV abnormality did not show any improvement. In 5 patients of Group 4 undergoing ICP monitoring, there was deterioration of the grades in all modalities irrespective of preoperative grade of MEP's (Figure 1). ICP rose to more than 30 mm Hg in 3 instances (cases 30, 31, and 32). Only 2 patients had low ICP (less than 20 mm Hg). They survived with high morbidity and deterioration of the grades of each modality. Ventricular rupture of the hemorrhage seen on CT scan had no significant influence on the grades of each modality in Groups 2, 3, and 4.

Discussion

Hypertensive intracerebral hemorrhage commonly occurs in the putamen near the internal capsule and sometimes extends to the diencephalon or the brainstem. Patients frequently have contralateral hemiparesis due to involvement of the posterior limb of the internal capsule where a close topographical association of the somatosensory and motor systems exists. Therefore, SEP has now been widely used in neurological investigations to evaluate the site and degree of neuronal dysfunction at or around the somatosensory pathways. Not only SEP, but also other sensory EP's, depend on neuronal vitality and it is possible to detect dysfunctions at or around these specific sensory systems. MEP's consisting of several sensory EP's can indicate functional activities in different sensory systems so that analysis of responses from each modality might be expected to provide a useful index of the global evaluation of brain dysfunction. The present study was done to ascertain the relation between location of the hemorrhage determined on CT scan and the outcome of patients with hypertensive putaminal hemorrhage. SEP's were the most frequently and severely altered MEP in the present study, but the other 2 modalities

### Table 3. VEP Grade and Groups of Patients Divided by CT Classification of the Hemorrhage

<table>
<thead>
<tr>
<th>Group (CT-C)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>Total cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (I, II)</td>
<td>9 (64.3)</td>
<td>5 (35.7)</td>
<td>0</td>
<td>0</td>
<td>14 (38.9)</td>
</tr>
<tr>
<td>2 (IIa, IIb)</td>
<td>1 (16.7)</td>
<td>4 (66.6)</td>
<td>1 (16.7)</td>
<td>0</td>
<td>6 (16.7)</td>
</tr>
<tr>
<td>3 (IVa, IVb)</td>
<td>3 (33.3)</td>
<td>4 (44.5)</td>
<td>2 (22.2)</td>
<td>0</td>
<td>9 (25)</td>
</tr>
<tr>
<td>4 (V)</td>
<td>1 (14.3)</td>
<td>1 (14.3)</td>
<td>4 (57.1)</td>
<td>1 (14.3)</td>
<td>7 (19.4)</td>
</tr>
<tr>
<td>Total cases</td>
<td>14 (38.9)</td>
<td>14 (38.9)</td>
<td>7 (19.4)</td>
<td>1 (2.8)</td>
<td>36 (100)</td>
</tr>
</tbody>
</table>

### Table 4. AEBR Grade and Groups of Patients Divided by CT Classification of the Hemorrhage

<table>
<thead>
<tr>
<th>Group (CT-C)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>Total cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (I, II)</td>
<td>12 (85.7)</td>
<td>2 (14.3)</td>
<td>0</td>
<td>0</td>
<td>14 (38.9)</td>
</tr>
<tr>
<td>2 (IIa, IIb)</td>
<td>3 (50)</td>
<td>3 (50)</td>
<td>0</td>
<td>0</td>
<td>6 (16.7)</td>
</tr>
<tr>
<td>3 (IVa, IVb)</td>
<td>4 (44.5)</td>
<td>3 (33.3)</td>
<td>2 (22.2)</td>
<td>0</td>
<td>9 (25)</td>
</tr>
<tr>
<td>4 (V)</td>
<td>3 (42.8)</td>
<td>1 (14.3)</td>
<td>1 (14.3)</td>
<td>2 (28.6)</td>
<td>7 (19.4)</td>
</tr>
<tr>
<td>Total cases</td>
<td>22 (61.1)</td>
<td>9 (25)</td>
<td>3 (8.3)</td>
<td>2 (5.6)</td>
<td>36 (100)</td>
</tr>
</tbody>
</table>
were also increasingly altered with an increase in size of the hemorrhage. Changes in SEP's may reflect dysfunction of the somatosensory pathways at the posterior limb of the internal capsule because of the close anatomical relation with the hemorrhagic foci. When the hemorrhage was located outside the internal capsule (Group 1), 71.4% of the patients had nearly normal or mildly abnormal SEP's without changes in the other modalities. For these patients, abnormal SEP's improved within 7 days after onset irrespective of treatment, and a high degree of functional recovery was obtained. Therefore, neuronal dysfunction at the posterior limb of the internal capsule may be caused by compression of the somatosensory fibers by the hemorrhage or by perifocal edema without irreversible damage. Moderately or severely abnormal SEP's observed in the other patients of Group 1 and in most of the other groups persisted without improvement for more than 7 days or deteriorated. Functional recovery of these patients was not good. These results may signify that neuronal damage to the somatosensory pathways was irreversibly severe. If the hemorrhage is large enough to involve the posterior limb of the internal capsule or the diencephalon, direct damage to the somatosensory tracts may be produced. The results seen in 28.6% of patients of Group 1 (those with SEP Grades III and IV) could be a secondary effect of the hemorrhage. It has been reported that abnormal SEP's were induced by changes in cerebral blood flow (CBF) or metabolism without direct injury to the somatosensory tracts. It is also demonstrated that CBF is generally decreased in both hemispheres, predominantly on the side of hemorrhage, in patients with a relatively small hemorrhage at the putamen. The larger the size of the hemorrhage, the more CBF decreases. Therefore, it is likely that the abnormal SEP's in these patients were secondary effects of ischemia or metabolic disturbance around the hemorrhagic foci. These results also indicate that early SEP study was of use clinically for patients with hypertensive putaminal hemorrhage. If SEP's were normal or mildly abnormal, patients improved early after the ictus, commonly within 1 week. These patients did well clinically and showed good functional recovery. But, if SEP's were moderately abnormal, 60% of the patients had poor functional recovery. If the SEP's were absent, the patients did not improve and had poor outcome.

With an increase in size of the hemorrhage, degrees of abnormalities in the other 2 modalities also increased. VEP and AEBR abnormalities remained of Grade III or less if the hemorrhage did not extend to the diencephalon. VEP and AEBR abnormalities were found to be of Grades I or II in 77.7-100% of the patients in Groups 2 or 3. It has been reported that changes in VEP's occurred with increased ICP, caused by either hydrocephalus or brain edema, and that there was a linear relation between them. The alteration of VEP's has been suggested to result from stretching of the optic radiations in the hemisphere or from decreased CBF. Wave V of AEBR's has been thought to generate from neural activity of the auditory path-
ways in the midbrain, and it is suppressed by central transtentorial herniation due to increased ICP. The optic radiation is located away from the hemorrhagic foci. It is possible, therefore, to estimate that the mild abnormalities seen in VEP's and AEBR's in the patients of Groups 2 and 3 were derived from the secondary effects of raised ICP or decreased CBF on their pathways. These effects were mild and reversible. On the other hand, abnormalities in the 2 modalities were generally severe and deteriorated in the patients of Group 4 even when the initial grade remained II or less. For these patients, not only primary damage in the diencephalon or upper brainstem, but also secondary damage probably due to perifocal edema were extremely severe since high sustained ICP was recorded in fatal cases.

Thus, it is possible to predict not only primary and secondary brain dysfunction following hypertensive putaminal hemorrhage but also functional outcome of patients by early and serial MEP studies. Mortality and ADL were better in surgically treated cases than in medically treated ones in Groups 2, 3, and 4, but mortality and morbidity were still high in the latter 2 groups. Therefore, intensive medical management to control ICP and brain edema and to prevent secondary brain damage are mandatory especially when initial MEP study shows mild abnormality for a large hemorrhage.

References


KEY WORDS • hypertensive putaminal hemorrhage • multimodality evoked potentials • computerized tomography • outcome
Evaluation of brain dysfunction in hypertensive putaminal hemorrhage with multimodality evoked potentials.
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*Stroke*. 1987;18:72-76
doi: 10.1161/01.STR.18.1.72

*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0039-2499. Online ISSN: 1524-4628

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