



## Novel Anatomic Classification of Spontaneous Thalamic Hemorrhage Classified by Vascular Territory of Thalamus

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■ **BACKGROUND:** Spontaneous thalamic hemorrhage has increased in incidence in recent years. Analysis of the characteristics of thalamic hemorrhage was based on the vascular territories of the thalamus.

■ **METHODS:** Retrospective analysis included 303 consecutive patients with spontaneous thalamic hemorrhage. Thalamic hemorrhage was classified into 4 types: anterior type (supplied mainly by the tuberothalamic artery), medial (mainly paramedian thalamic-subthalamic artery), lateral (mainly thalamogeniculate artery), and posterior (mainly posterior choroidal artery). The baseline characteristics, complications, and functional outcomes were assessed.

■ **RESULTS:** The anterior type was found in 10 patients (3.3%), the medial type in 47 (15.5%), the lateral type in 230 (75.9%), and the posterior type in 16 (5.3%). Intracerebral hemorrhage volume was smallest in the anterior type, and significantly smaller than in the medial ( $P = 0.002$ ) and lateral types ( $P < 0.001$ ). Intraventricular hemorrhage (IVH) or acute hydrocephalus was significantly associated with the medial type ( $P < 0.01$  or  $P < 0.01$ , respectively). Non-IVH or non-acute hydrocephalus was significantly associated with the anterior ( $P < 0.05$  or  $P < 0.05$ , respectively) and lateral ( $P < 0.05$  or  $P < 0.05$ , respectively) types. Emergency surgery was correlated only with the medial type ( $P < 0.01$ ). The independent predictors of poor outcome were age (odds ratio [OR], 1.07;  $P = 0.002$ ), admission National Institutes of Health Stroke Scale score (OR, 1.32;  $P < 0.001$ ), and type of thalamic hemorrhage (OR, 2.08;  $P = 0.038$ ).

■ **CONCLUSIONS:** The present study proposed a novel anatomic classification of thalamic hemorrhage according to the major thalamic vascular territories.

### INTRODUCTION

Spontaneous intracerebral hemorrhage (ICH) is a severe disease associated with high frequencies of morbidity and mortality. Further clinical study is essential because ICH is less understood compared with ischemic stroke and aneurysmal subarachnoid hemorrhage.<sup>1</sup> A prospective Japanese cohort study of ICH in 2014 revealed increasing incidence of thalamic hemorrhage in contrast to decreasing incidence of putaminal hemorrhage with time, especially in older patients.<sup>2</sup> As a result, thalamic hemorrhage may be characteristic of the progression of population aging.

The distribution of thalamic arteries varies between individuals depending on the variation of the parent vessel from which each artery arises.<sup>3</sup> The 4 major arteries were reported to form complex vascular networks within the thalamus.<sup>3</sup> Their major thalamic arteries are originated from the posterior communicating artery (PCOM), posterior cerebral artery (PCA), and basilar artery (BA) as follows: the tuberothalamic artery arising from the PCOM and mainly supplying the anterior part of thalamus including the anterior and ventral anterior nuclei; the paramedian thalamic-subthalamic artery arising from the P<sub>1</sub> portion of the PCA and the top of the BA and mainly supplying the medial part of thalamus including the dorsomedial, lateral dorsal, intralaminar, and centromedial nuclei; the thalamogeniculate artery arising from the

#### Key words

- Anatomical classification
- Prognostic predictor
- Spontaneous thalamic hemorrhage
- Thalamic vascular territory

#### Abbreviations and Acronyms

- ANOVA:** Analysis of variance  
**BA:** Basilar artery  
**CI:** Confidence interval  
**CT:** Computed tomography  
**ICH:** Intracerebral hemorrhage  
**IQR:** Inventory quality ratio  
**IVH:** Intraventricular hemorrhage  
**mRS:** modified Rankin Scale  
**NIHSS:** National Institutes of Health Stroke Scale

**OR:** Odds ratio

**PCA:** Posterior cerebral artery

**PCOM:** Posterior communicating artery

**VP:** Ventriculoperitoneal

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P<sub>2</sub> portion of the PCA and mainly supplying the lateral part of thalamus including the ventral lateral, ventral posterolateral, ventral posteromedial, and lateral posterior nuclei; and the posterior choroidal artery arising from the P<sub>2</sub> portion of the PCA and mainly supplying the posterior part of thalamus including the pulvinar nucleus.<sup>3</sup> Hemorrhage is more common than infarction in thalamic stroke.<sup>4</sup> Thalamic hemorrhage is generally treated with conservative therapy, whereas serious intraventricular hemorrhage (IVH) or acute hydrocephalus caused by expansion of thalamic hemorrhage requires surgical treatment. Various studies of the symptoms and prognoses of thalamic hemorrhage have been reported,<sup>4-10</sup> but no large-scale clinical studies with appropriate statistical analysis.

The present study classified thalamic hemorrhage into 4 types according to the major thalamic vascular territories for statistical analysis, and the prognostic predictors of thalamic hemorrhage were investigated with logistic regression analysis.

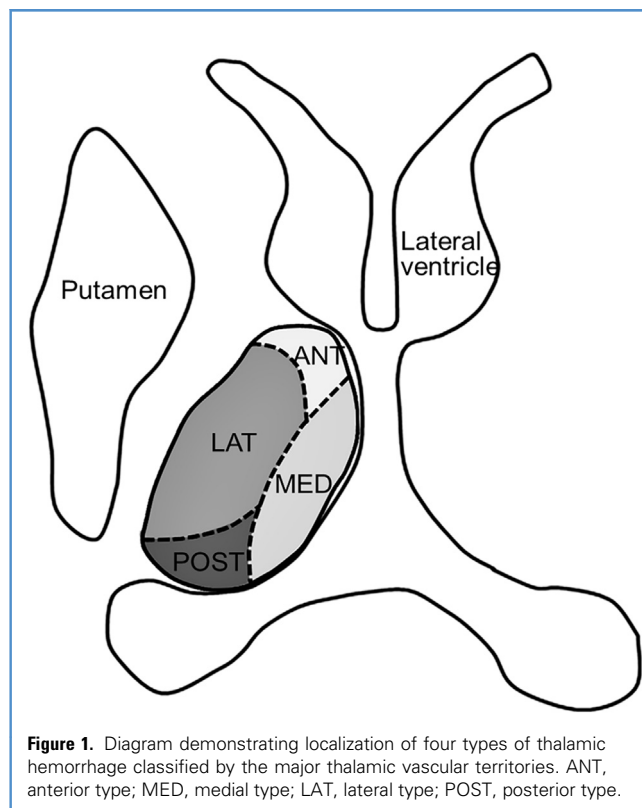
## MATERIALS AND METHODS

This study retrospectively examined 303 consecutive patients—178 men and 125 women with mean age of  $70.1 \pm 10.7$  years—with spontaneous thalamic hemorrhage located on the left in 162 cases and on the right in 141 cases, admitted to Juntendo University Shizuoka Hospital from January 2004 to December 2013. Patients with thalamic hemorrhage were treated in accordance with the Japanese Guidelines for the Management of Stroke 2004 and 2009. We reviewed the medical records and brain computed tomography (CT) scans for all patients. All clinical investigations were conducted according to the principles of the Declaration of Helsinki.

Thalamic hemorrhage was classified into 4 types based on the vascular territories of the four major thalamic arteries: anterior type (supplied mainly by the tuberothalamic artery), medial (supplied mainly by the paramedian thalamic-subthalamic artery), lateral (supplied mainly by the thalamogeniculate artery), and posterior (supplied mainly by the posterior choroidal artery; **Figure 1**). The classification of thalamic hemorrhage was based on the examination of CT scans (**Figure 2**). ICH volume was measured using the ABC/2 method<sup>11</sup> or computed planimetric technique.<sup>12</sup> The Graeb score is the most common scale of IVH that is useful for predicting short-term prognosis.<sup>13</sup> The severity of IVH was assessed in the range of Graeb scores of 0–12 according to the blood volume in each ventricle.<sup>14</sup>

The relationship between each type of thalamic hemorrhage and the rupture point of the ventricle was investigated. The rupture point of the ventricle was classified as body of the lateral ventricle, trigone of the lateral ventricle, third ventricle, body and trigone of the lateral ventricle, body of the lateral ventricle and third ventricle, and trigone of the lateral ventricle and third ventricle. Hydrocephalus was defined as an Evans' index greater than 0.35.<sup>7</sup>

Emergency surgery for normalization of increased intracranial pressure, reversal of ventricular enlargement, and removal of intraventricular blood clot were performed by either external ventricular drainage or endoscopic hematoma evacuation. Endoscopic surgery was selected for patients with massive IVH. Patients with delayed hydrocephalus related to thalamic hemorrhage underwent ventriculoperitoneal (VP) shunt surgery. Assessment of clinical outcomes used the National Institutes of Health Stroke



**Figure 1.** Diagram demonstrating localization of four types of thalamic hemorrhage classified by the major thalamic vascular territories. ANT, anterior type; MED, medial type; LAT, lateral type; POST, posterior type.

Scale (NIHSS) and modified Rankin Scale (mRS). Because improvement in NIHSS score of 4 and greater is associated with good outcome,<sup>15</sup> NIHSS improvement of 4 or greater at discharge was defined as neurologic improvement. mRS score at discharge was divided into favorable (score 0–2) and poor (score 3–6) functional outcome.

All statistical analyses were conducted using the SPSS version 22 (IBM Corporation, Armonk, New York, USA). Values for groups are given as mean and standard deviation or as median and interquartile range. Data were analyzed with the  $\chi^2$  test, unpaired *t* test, Mann-Whitney *U* test, one-way analysis of variance (ANOVA), or Kruskal-Wallis test. Statistical difference identified in the one-way ANOVA or Kruskal-Wallis test was confirmed with the appropriate post hoc test for multiple comparisons. Univariate and multivariate logistic regression analyses were applied to identify the independent factors associated with the functional outcome of thalamic hemorrhage. Statistical significance was defined as  $P < 0.05$ .

## RESULTS

The clinical characteristics of each type of thalamic hemorrhage are summarized in **Table 1**. The anterior type of thalamic hemorrhage was found in 10 patients (3.3%), the medial type in 47 patients (15.5%), the lateral type in 230 patients (75.9%), and the posterior type in 16 patients (5.3%). The lateral type occurred most frequently. No significant differences were found

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