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Analysis of the association between location and patient prognosis in spontaneous intracerebral hemorrhage in the basal ganglia and thalamus

A retrospective single-center study

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Abstract

Spontaneous intracerebral hemorrhage (ICH) causes profound neurological sequelae in survivors. The patient's prognosis is closely linked to the location and amount of hemorrhage. Therefore, we explored the relationship between the hemorrhage location within the basal ganglia, including the thalamus, and its clinical outcomes in patients with spontaneous intracerebral hemorrhage. A retrospective analysis of consecutively enrolled patients with basal ganglia and thalamic intracerebral hemorrhage treated conservatively at a single tertiary neurosurgical center was conducted between January 2014 and December 2020. Patients were divided into 2 groups according to the lateralization of the right or left hemisphere hemorrhage. Furthermore, baseline patient demographics, hematoma volume, location of the hemorrhage (i.e., caudate nucleus, globus palidus, putamen, internal capsule anterior limb, internal capsule posterior limb, thalamus), and clinical outcomes were evaluated. Clinical outcomes were assessed using the modified Rankin scale at the 1-year follow-up. An modified Rankin scale score between 3 and 6 was considered a poor outcome. In the analysis according to location, the prognosis was poor when the ICH was localized to the posterior limb of the internal capsule ($P < .000$) and globus palidus ($P = .001$) in the right hemisphere. Similarly, the prognosis was also poor when the ICH was localized to the posterior limb of the internal capsule ($P < .000$), globus palidus ($P < .000$), putamen ($P = .018$), and thalamus ($P < .000$) of the left hemisphere. In the spontaneous intracerebral hemorrhages of the basal ganglia and thalamus, hemorrhaging within the internal capsule and the left thalamus's bilateral posterior limbs is associated with a poor prognosis.

Multivariable logistic analysis showed that hematoma volume (odds ratio [OR] = 70.85, 95% confidence interval [CI]: 1.95–60.53, $P = .007$) and the posterior limb of the internal capsule (OR = 10.98, 95% CI:1.02–118.49, $P = .048$) were independent predictors of poor outcomes in the right hemisphere, while hematoma volume (OR = 70.85, 95% CI: 1.95–60.53, $P = .007$), the posterior limb of the internal capsule (OR = 10.98, 95% CI:1.02–118.49, $P = .048$) and thalamus (OR = 10.98, 95% CI:1.02–118.49, $P = .048$) were independent predictors of poor outcomes in the left hemisphere.

Abbreviations: CI = confidence interval, CT = computed tomography, ICH = intracerebral hemorrhage, mRS = modified Rankin scale, OR = odds ratio.

Keywords: basal ganglia hemorrhage, internal capsule, intracranial hemorrhage, thalamus

1. Introduction

Intracerebral hemorrhage (ICH) is a significant public health problem with an annual incidence of 10 to 30 per 100,000 people, accounting for 2 million (10%–15%) of approximately 15 million strokes worldwide.[1] Most ICHs (78%–88% of cases) are caused by the abrupt rupture of small blood vessels damaged by chronic hypertension or amyloid angiopathy leading to spontaneous ICH.[2] Spontaneous intracerebral hemorrhages can occur anywhere, mainly in the basal ganglia (50%) and thalamus (15%).[3] ICH has different clinical characteristics depending on the location of the hemorrhage. The basal ganglia and thalamus are

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

Our institutional review board approved this retrospective study.

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responsible for motor function and consciousness. Hemorrhaging in these structures can lead to impaired motor function and impaired consciousness in patients, resulting in a poor prognosis.[4] Although many studies have reported spontaneous intracerebral hemorrhage in the basal ganglia and thalamus, studies subdividing the prognosis according to the regions constituting the basal ganglia and thalamus are rare and insufficient. This study evaluated the relationship between hemorrhage location within the basal ganglia, including the thalamus, and clinical outcomes of patients with spontaneous intracerebral hemorrhage.

2. Materials and methods

2.1. Patient's populations

Our institutional review board approved this retrospective study. The requirement for informed consent to review patient records and images was waived. Based on a prospective hospital registry, we initiated a retrospective analysis including patients with spontaneous ICH who were admitted to the Department of Neurosurgery between January 2014 and December 2020 using the following inclusion criteria: presence of basal ganglia and thalamic ICH confirmed by computed tomography (CT); conservative management without surgical treatment; a hematoma volume less than 30 mL[5]; the patient must have pure ICH; patients with concomitant intravascular hemorrhage or other vascular diseases such as arteriovenous malformations or ruptured aneurysms were excluded.

Analysis was conducted on 172 patients with basal ganglia and thalamic ICH (Fig. 1).

2.2. Baseline and imaging data acquisition

Patient age, sex, neurological status at admission measured by the modified Rankin scale (mRS) score, and risk factors were obtained from medical records. Hematoma volume and location were assessed using brain CT with a multi-slice CT scanner (SOMATOM Sensation 16; Siemens, Erlangen, Germany). Basal ganglia ICH lesions were subdivided according to the anatomic sites where hemorrhage occurred, such as the caudate nucleus, globus palidus, putamen, internal capsule anterior limb, internal capsule posterior limb, and thalamus (Fig. 2).

2.3. Outcome assessment

The clinical outcome was assessed using the mRS at a 1-year follow-up. An mRS score of 3 to 6 indicated a poor outcome.

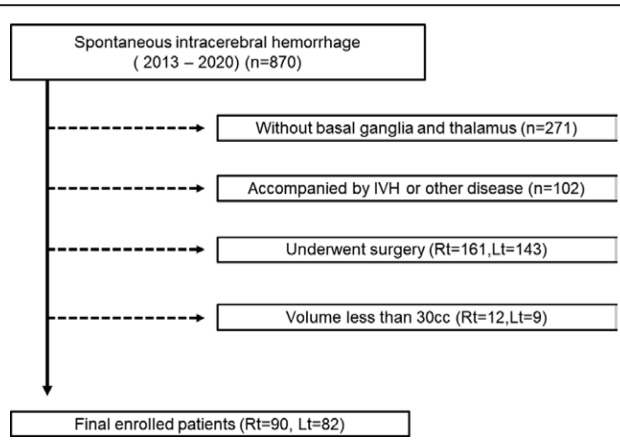

Figure 1. A total of 172 patients with basal ganglia and thalamic ICH were analyzed.

2.4. Statistical analysis

Statistical analysis was performed using SPSS software (version 26.0; IBM SPSS, Chicago, IL). Patients were divided into 2 groups according to the hemispheric location of the ICH, right or left. Baseline patient demographics, hematoma volume, and the location of the hemorrhaging as separated by the caudate nucleus, globus palidus, putamen, internal capsule anterior limb, internal capsule posterior limb, and thalamus, and clinical outcomes were evaluated.

We performed univariate comparisons of the groups using an independent *t*-test and Pearson's χ^2 test for categorical variables. Additionally, multivariable logistic regression analyses were performed to identify the variables as independent prognostic factors for poor prognosis at 1-year mRS. Statistical significance was set at a *P*-value < .05.

3. Results

The baseline characteristics of the patients are summarized in Table 1. Of the 172 eligible patients, 90 (52.32%) had right hemisphere ICH (mean age, 60.9 ± 12.3 years; men, 56 [65.6%]; volume 11.47 ± 7.55 mL; hospital days 14.99 ± 14.41) and 82 (47.67%) had left hemisphere ICH (mean age, 61.41 ± 12.58 years; men, 44 [53.7%]; volume 12.74 ± 6.43 mL; hospital days 15.49 ± 15.22).

There was no statistically significant difference between the right and left hemispheres for the above factors.

Classified according to location, no statistical significance in the incidence rates of ICH for the right and left hemispheres was found at each location.

In analyzing the relationship between hematoma volume and prognosis (1-year mRS score), left hemisphere hematomas had no statistical significance (*P* = .234). However, right hemisphere hematomas were statistically significant (*P* < .001) (Table 2).

In analysis prognosis according to location, the results showed that ICHs in the posterior limb of the right internal capsule (53.3%, *P* < .000) and right globus palidus (68.9%, *P* = .001) were associated with a poor prognosis, and this association was statistically significant. Similarly, ICHs localized to the posterior limb of the left internal capsule (39.0%, *P* < .000), left globus palidus (57.3%, *P* < .000), left putamen (59.8%, *P* = .018), and left thalamus (43.9%, *P* < .000) resulted in poor prognoses which were also statistically significant. Conversely, the prognosis was not statistically significant according to the presence or absence of ICH at other locations.

In summary, a comparison of the effects of ICH hemispheric location on patient prognosis demonstrated that ICH in the posterior limb of the internal capsule and thalamus in the left hemisphere was significantly associated with a poor prognosis. Other locations yielded no statistical significance (Table 3).

Multivariable logistic analysis indicated that hematoma volume (odds ratio [OR] = 70.85, 95% confidence interval [CI]: 1.95–60.53, *P* = .007) and ICH in the posterior limb of the internal capsule (OR = 10.98, 95% CI: 1.02–118.49, *P* = .048) were independent predictors of poor outcomes at 1-year follow-up in the right hemisphere. Comparably, hematoma volume (OR = 70.85, 95% CI: 1.95–60.53, *P* = .007) and ICH in the posterior limb of the internal capsule (OR = 10.98, 95% CI: 1.02–118.49, *P* = .048) and thalamus (OR = 10.98, 95% CI: 1.02–118.49, *P* = .048) were independent predictors of poor outcomes at 1-year follow-up in the left hemisphere (Table 4).

4. Discussion

Patients with ICH exhibit different clinical features depending on the hemorrhage location.[6] Patients with large hematomas typically have reduced levels of consciousness because of increased intracranial pressure and direct compression or distortion of the thalamus and reticular activation systems.[7]

Figure 2. Basal ganglia ICH lesions were subdivided according to the anatomic sites where hemorrhage occurred such as the caudate nucleus, globus palidus, putamen, internal capsule anterior limb, internal capsule posterior limb, and thalamus. C = caudate nucleus, G = globus palidus, P = putamen, ICa = internal capsule anterior limb, ICp = internal capsule posterior limb, T = thalamus.

Patients with supratentorial intracerebral hemorrhages involving the putamen, caudate, and thalamus have varying severity of contralateral sensorimotor deficits because of the involvement of the internal capsule.[8]

When deciding to treat an ICH patient conservatively, predicting the prognosis is very important crucial in managing the patient in the future. An accurate prediction of the patient's prognosis can lead to the implementation of customized treatment or specialized rehabilitation for individual patients.

Spontaneous intracerebral hemorrhage mainly occurs in the thalamus and basal ganglia.[3]

This study was conducted based on the hypothesis that the patient's prognosis will vary depending on the location of the hematoma within the basal ganglia and thalamus.

Patients with hemorrhages in the basal ganglia were identified by subdividing the hemorrhage sites anatomically into the caudate nucleus, globus pallidus, putamen, and anterior and posterior limbs of the internal capsule. The patient's prognosis for each hemorrhage location was then confirmed using the 1-year mRS score.

Therefore the multivariate analysis of the location of the hematoma as a prognostic factor, it was confirmed that a hemorrhagic lesion in the right hemisphere, particularly in the posterior limb of the right internal capsule, had a significant effect on the patient's poor prognosis. In the left hemisphere, ICH lesions in the posterior limb of the internal capsule and thalamus were identified as prognostic factors leading to poor prognoses.

In many previous studies, hematoma volume in ICH patients was mentioned as an important prognostic factor. Although we limited the volume of hematoma to 30 mL or less to exclude the effect of volume on prognosis, our analysis confirmed that hematoma volume also had a significant predictive value.[5]

The most critical factor in a patient's independent daily life performance is the degree of motor function recovery after ICH. Therefore, an accurate prediction of motor function outcomes in the early stages of cerebral hemorrhage is vital for the rehabilitation and management of patients. The corticospinal tract, an anatomical structure passing through the internal capsule, is a major pathway mediating voluntary movement. Previous studies have confirmed that damage to the posterior limb of the internal capsule included in this pathway adversely affects the recovery of motor function.[9,10] In our study, hemorrhage in the posterior limb of the internal capsule was found to affect patient prognosis adversely.

Another critical factor influencing a patient's prognosis and exercise ability is the patient's cognitive status after ICH. One of the main processes that the thalamus regulates is the regulation of consciousness, which also plays a vital role in performing higher functions.[11] Previous studies have reported that coma and stupor are associated with fatal outcomes of thalamic hemorrhage. In particular, these studies have shown that the left thalamus is involved in language function.[12] Damage, resulting in left paramedian and left tuberothalamic lesions, with ventrolateral nucleus involvement, can affect language function.[13] Furthermore, this can be considered the reason why left thalamic lesion lateralization affects the patient's prognosis more than a right thalamic lesion. Likewise, our findings showed that thalamic hemorrhaging was associated with a poor prognosis, especially in the left dominant hemisphere.

Our study had several limitations. First, this study had a small sample size and was conducted at a single center. Second, in each patient, the boundaries of the actual hematoma overlapped with 2 or more lesions, so it may be difficult to pinpoint which exact

Table 1

Baseline characteristics.

	Overall, n = 172		*P*
	ICH Right (n = 90)	ICH Left (n = 82)	
Mean age, y	60.32 ± 11.56	61.41 ± 12.58	.248
Men, no (%)	59 (65.6)	44 (53.7)	.112
Volume, cc	11.47 ± 7.55	12.74 ± 6.43	.233
Hospital Day	14.99 ± 14.41	15.49 ± 15.22	.826
Initial mRS. (%)			
Poor	54 (60.0)	58 (70.7)	.140
mRS after 3-month (%)			
Poor	27 (30.0)	35 (42.7)	.083
Location			
C (%)	3 (3.3)	6 (7.3)	.313
Ica (%)	2 (2.2)	3 (3.7)	.670
ICp (%)	48 (53.3)	32 (39.0)	.060
G (%)	62 (68.9)	47 (57.3)	.116
P (%)	50 (55.6)	49 (59.8)	.578
T (%)	42 (46.7)	36 (43.9)	.716

C = caudate nucleus, G = globus palidus, P = putamen, ICa = internal capsule anterior limb, ICp = internal capsule posterior limb, T = thalamus.

Table 2

Prognosis versus location (1-year mRS score).

	Overall, n = 172			
	CH Right (n = 90)	CH Left (n = 82)	*p*	*P*
Volume, cc	11.47 ± 7.55	0.000	12.74 ± 6.43	.234
C (%)	3 (3.3)	0.249	6 (7.3)	.244
ICa (%)	2 (2.2)	0.349	3 (3.7)	.837
ICp (%)	48 (53.3)	0.000	32 (39.0)	.000
G (%)	62 (68.9)	0.001	47 (57.3)	.000
P (%)	50 (55.6)	0.165	49 (59.8)	.018
T (%)	42 (46.7)	0.268	36 (43.9)	.000

C = caudate nucleus, G = globus palidus, P = putamen, ICa = internal capsule anterior limb, ICp = internal capsule posterior limb, T = thalamus.

Table 3

Comparing the prognosis between the right and left same locations.

	Overall, n = 172				
	ICH Right (n = 90)	pPoor (n)	`ICH Left (n = 82)	poor(n)	*P*
C (%)	3 (3.3)	0 (0)	6 (7.3)	1 (16.7)	.887
ICa (%)	2 (2.2)	0 (0)	3 (3.7)	1 (33.3)	.361
ICp (%)	48 (53.3)	22 (45.8)	32 (39.0)	26 (81.2)	.004
G (%)	62 (68.9)	25 (40.3)	47 (57.3)	27 (57.4)	.090
P (%)	50 (55.6)	18 (36.0)	49 (59.8)	14 (28.5)	.389
T (%)	42 (46.7)	15 (35.7)	36 (43.9)	24 (66.6)	.001

C = caudate nucleus, G = globus palidus, P = putamen, ICa = internal capsule anterior limb, ICp = internal capsule posterior limb, T = thalamus.

Table 4

Multivariable logistic analysis.

	Rt Multivariate analysis		Lt Multivariate analysis	
	OR (95% CI)	*p*	OR (95% CI)	*P*
Volume	1.186 (1.084–1.297)	0.000	1.108 (1.002–1.225)	.046
ICp	10.240 (2.583–40.600)	0.001	9.319 (2.016–43.081)	.004
T			4.690 (1.033–21.300)	.045

CI = confidence interval, ICp = internal capsule posterior limb, OR =odds ratio, T = thalamus.

cortical area affected the prognosis. However, this limitation was corrected through multivariate analysis, and the potential of each site as a prognostic factor was confirmed. Third, objective data on cognitive ability through quantified motor grading and specific tests were lacking, as the patient's prognosis was evaluated only with mRS.

5. Conclusion

In our study, when the prognostic interrelationships between the location of each hemorrhage site were explored through multivariate analysis, we found that in spontaneous intracerebral hemorrhages of the basal ganglia and thalamus, hemorrhaging within the bilateral posterior limbs of the internal capsule and left thalamus are associated with a poor prognosis. Therefore, in such cases, it is necessary to properly ascertain the patient's long-term prognosis to facilitate early rehabilitation therapy.

Author contributions

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Visualization: Hyoung Gyu Jang.
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