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Integral neuroimaging criteria for predicting the outcome of the acute period of spontaneous supratentorial intracerebral hemorrhage on the background of conservative therapy

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article

The aim of the study was to develop criteria for predicting the outcome of the acute period of spontaneous supratentorial intracerebral hemorrhage (SSICH) on the background of conservative therapy, taking into consideration the lesion localization in conjunction with neuroimaging parameters of the quantitative severity assessment of the damage to cerebral structures.

Materials and methods. Prospective cohort examination of 314 patients in acute period of SSICH on the ground of conservative treatment. Clinical and neurological examination consisted of using the Full Outline of Unresponsiveness coma scale and NIHHS, neuroimaging with the help of computed tomography with detection of SSICH localization, volume of intracranial hemorrhage, secondary intraventricular hemorrhage and midline shift. Disease acute period outcome was evaluated on the 21st day by the Rankin scale.

Results. It was detected that integrated neuroimaging SSICH's type considering its localization and quantitative severity estimation of cerebral structure injury was closely associated with the disease acute period outcome on the ground of conservative therapy (χ^2 Pearson = 308.6, P < 0.0001). Thus, mortality rate was the highest in patients with posteromedial type of thalamic hemorrhage (50.0 %), global type of thalamic hemorrhage (91.7 %) and massive type of striatocapsular hemorrhage (89.8 %). Unfavorable functional outcome as the modified Rankin scale score 4–5 on 21st disease day predominated among patients with posterolateral types of thalamic hemorrhage (76.5 %) and striacapsular hemorrhage (64.3 %). Whereas the frequency of favorable outcome was the highest among patients with anterior/dorsal type of thalamic hemorrhage (100.0 %), posteromedial (88.0 %), middle (95.0 %), lateral types of striatocapsular hemorrhage (61.9 %) and lobar (74.5 %) hemorrhage.

Conclusions. Posteromedial type of thalamic hemorrhage, global type of thalamic hemorrhage and massive type of striatocapsular hemorrhage are the predictors of lethal outcome of the acute period of SSICH on the background of conservative therapy. Criteria for unfavorable short-term functional outcome are posterolateral types of thalamic and striatocapsular hemorrhage, while anterior/dorsal type of thalamic hemorrhage, posteromedial/middle type of striatocapsular hemorrhage and lobar hemorrhage are associated with favorable outcome of the acute period of the disease.

Key words: cerebral hemorrhage, neuroimaging, prognosis.

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Інтегральні нейровізуалізаційні критерії прогнозування наслідку гострого періоду спонтанного супратенторіального внутрішньомозкового крововиливу на тлі консервативної терапії

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Мета роботи – розробити критерії прогнозування наслідку гострого періоду спонтанного супратенторіального внутрішньомозкового крововиливу (ССВМК) на тлі консервативної терапії, що враховують локалізацію осередку ураження разом із нейровізуалізаційними параметрами кількісного оцінювання тяжкості ушкодження церебральних структур.

Матеріали та методи. Здійснили проспективне, когортне дослідження 314 пацієнтів у гострому періоді ССВМК на тлі консервативної терапії. Клініко-неврологічне обстеження передбачало оцінювання за шкалою коми Full Outline of Unresponsiveness і шкалою інсульту Національного інституту здоров'я США; нейровізуалізаційне дослідження здійснили методом комп'ютерної томографії головного мозку з визначенням локалізації осередку ураження, об'єму внутрішньомозкового крововиливу, об'єму вторинного внутрішньошлуночкового крововиливу та латеральної дислокації серединних структур мозку. Наслідок гострого періоду захворювання оцінювали на 21 добу за модифікованою шкалою Ренкіна.

Результати. Встановили, що інтегральний нейровізуалізаційний тип ССВМК, який враховує його локалізацію та параметри кількісного оцінювання тяжкості ушкодження церебральних структур, тісно асоційований із наслідком гострого періоду захворювання на тлі консервативної терапії (χ^2 Пірсона = 308,6, p < 0,0001). Так, рівень летальності найвищий у групах пацієнтів із задньомедіальним (50,0 %), глобальним типами таламічного крововиливу (91,7 %) та масивним типом стріатокапсулярного крововиливу (89,8 %). Несприятливий функціональний наслідок, а саме значення 4–5 балів за модифікованою шкалою Ренкіна на 21 добу захворювання, домінував у групах пацієнтів із задньолатеральними типами таламічного (76,5 %) та стріатокапсулярного крововиливу (64,3%), тоді питома вага сприятливого функціонального наслідку найбільша в пацієнтів із переднім/заднім типом таламічного крововиливу (100,0 %), задньомедіальним (88,0 %), серединним (95,0 %), латеральним типами стріатокапсулярного крововиливу (61,9 %) та лобарним крововиливом (74,5 %).

Висновки. Предикторами летального наслідку гострого періоду ССВМК на тлі консервативної терапії є задньомедіальний, глобальний типи таламічного крововиливу і масивний тип стріатокапсулярного крововиливу. Критерії несприятливого короткострокового функціонального прогнозу – задньолатеральні типи таламічного та стріатокапсулярного крововиливу, а передній/задній тип таламічного крововиливу, задньомедіальний/серединний тип стріатокапсулярного крововиливу та лобарний крововилив асоційовані зі сприятливим функціональним наслідком гострого періоду захворювання.

Ключові слова: мозковий крововилив, нейровізуалізація, прогноз.

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Cerebral hemorrhagic stroke, namely, its most common form – spontaneous supratentorial intracerebral hemorrhage (SSICH) is the most severe type of acute cerebrovascular disorders from the point of view of the medical and social aspects [1–3]. The modern paradigm of the specialized medical care provision to this group of patients primarily involves the use of a personalized approach to the determination of the optimal treatment tactics. The most important basis for making appropriate decisions is to undertake an immediate verification of a short-term prognosis on the background of the conservative therapy [4–6].

Routine clinical practice allows carrying out a verification of short-term period prognosis in this group of patients primarily on the basis of neuroimaging data [7,8]. Quantitative parameters are used to assess the severity of damage to cerebral structures (intracerebral hemorrhage volume, midline shift severity, secondary intraventricular hemorrhage volume) [9–11]. The information on the localization of a lesion is also taken into consideration [12–15]. At the same time, the localization of SSICH and quantitative neuroimaging indicators are closely associated with each other, which determines the feasibility of their assessment along with the definition of integrated neuroimaging patterns. The validity of a comprehensive assessment of these data was shown in our previous study, which identified the appropriate assessment gradations of the cerebral damage severity in patients with SSICH based on clustering of observations with exclusively quantitative neuroimaging criteria. The informative value of these criteria as for the determination of the acute period outcome of the disease was also proven [16].

Therefore, the consideration of the lesion localization in addition to the indicators of quantitative assessment of damage to cerebral structures in patients with SSICH may improve the accuracy of neuroimaging verification of short-term prognosis on the background of conservative therapy.

Aim

The aim of the study was to develop criteria for predicting the outcome of the acute period of spontaneous supratentorial intracerebral hemorrhage on the background of conservative therapy, taking into consideration the lesion localization in conjunction with neuroimaging parameters of the quantitative severity assessment of the damage to cerebral structures.

Materials and methods

In order to achieve this goal, a prospective, cohort study involving 314 patients (178 men and 136 women, mean age – 65.2 ± 0.6 years) with the first case of hypertensive SSICH was conducted at the Department of Acute Disorders of Brain Circulation of the Municipal Non-Profit Enterprise "City Hospital No. 6" of the Zaporizhzhia City Council. The diagnosis was verified on the basis of a comprehensive clinical and neuroimaging examination within 24 hours of the disease onset. The required informed consent to participate in the study was signed by each patient.

The level of neurological deficit was determined at the time of hospitalization and in the dynamics of the acute period of the disease, using the Full Outline of Unresponsiveness (FOUR) Coma score and the National Institute of Health Stroke Scale (NIHSS). According to the computed tomography brain examination, which was conducted using a scanner Siemens Somatom Spirit (Germany) or Toshiba Astelion (Japan), we detected the localization, linear size of intracerebral hemorrhage, midline shift severity (by the average displacement of the pellucid septum and the pineal gland), the presence of a blood breakthrough into the brain ventricular system. The intracerebral hemorrhage volume (ICHV) was calculated using the ellipsoid formula. The secondary intraventricular hemorrhage volume (IVHV) was determined by the exponential formula, based on the value of the total score on the Intraventricular Hemorrhage (IVH) scale [11]. The sum of ICHV and IVHV were calculated as the intracranial hemorrhage total volume (ICHTV). Depending on the location, thalamic, striatocapsular and lobar hemorrhages were determined.

The types of thalamic and striatocapsular hemorrhages were identified according to the relevant classifications of Chin-Sang Chun et al. (1996, 2000). Thus, thalamic haematomas were classified into four regional types and one global type. The regional types were anterior, dorsal, posterolateral and posteromedial. The anterior type was defined as a haematoma mainly located in the anterior thalamic region supplied by the polar or tuberothalamic artery. The dorsal type was defined as a haematoma located in the dorsal aspect of the thalamus with the main haematoma best seen at a higher level of the computed tomography scans than other types. The posterolateral type was defined as a haematoma located in the territory of the thalamogeniculate arteries. The posteromedial type was defined as a haematoma located in the medial thalamic region supplied by the thalamic-subthalamic paramedian arteries. The global type was defined as a large whole-thalamus haematoma and its bleeding focus was difficult to assess in the brain images [16].

Striatocapsular hemorrhages were divided into five types (four regional and one massive) according to the major vascular territories:

1. the posteromedial type in the anterior choroidal artery territory;
2. the middle type in the medial lenticulostriate artery territory;
3. the posterolateral type in the posteromedial branches of the lateral lenticulostriate artery territory;
4. the lateral type in the subinsular region supplied by the most lateral branches of the lateral lenticulostriate artery;
5. the entire striatocapsular area haematomas were defined as the massive type [17].

All patients were consulted by a neurosurgeon. Conservative therapy was recommended as an optimal treatment tactic, which was carried out according to the Unified Protocol for the provision of medical care to patients with cerebral hemorrhagic stroke, approved by the order of the Ministry of Health of Ukraine No. 275 dated 17.04.2014 [18].

The study did not include patients who corresponded to the following criteria: acute disorders of brain circulation in the anamnesis; intracerebral hemorrhage due to cerebral infarction, brain tumor, receiving anticoagulants; the presence of a confirmed aneurysm or arteriovenous malformation of cerebral vessels; somatic pathology in the stage of decompensation; malignant neoplasms;

Table 1. Comparative analysis of clinical and neuroimaging indicators in patients with thalamic, striatocapsular and lobar hemorrhage

Parameters, units	Localization of SSICH			P
	Thalamic (n = 100)	Striatocapsular (n = 167)	Lobar (n = 47)	
FOUR score	14 (12; 16)	15 (11; 16)	16 (15; 16)	0.0023
NIHSS score	15 (11; 20)	16 (10; 24)	7 (5; 13)	<0.0001
ICHV, mL	8.9 (5.6; 13.1)	23.2 (9.2; 66.3)	10.7 (2.6; 34.5)	<0.0001
MS, mm	2.5 (0.0; 4.0)	2.5 (0.0; 8.0)	0.0 (0.0; 2.0)	<0.0001
IVHV, mL	11.0 (4.7; 30.0)	2.2 (0.0; 30.0)	0.0 (0.0; 0.0)	<0.0001
ICHTV, mL	9.8 (6.6; 14.1)	23.3 (9.2; 67.3)	10.7 (2.6; 35.0)	<0.0001

FOUR: Full Outline of UnResponsiveness Scale; **NIHSS:** National Institute of Health Stroke Scale; **ICHV:** intracerebral hemorrhage volume; MS: midline shift; **IVHV:** intraventricular hemorrhage volume; **ICHTV:** intracranial hemorrhage total volume; **P:** statistical significance of intergroup differences according to the Kruskal–Wallis test.

Table 2. Comparative analysis of clinical and neuroimaging indicators in patients with different types of thalamic hemorrhage, Me (Q1; Q3)

Parameters, units	Type of thalamic hemorrhage				P
	Anterior/dorsal (n = 17)	Posterolateral (n = 51)	Posteromedial (n = 20)	Global (n = 12)	
FOUR score	16 (15; 16)	15 (14; 16)	12 (6; 15)	8 (4; 11)	<0.0001
NIHSS score	9 (7; 10)	15 (12; 18)	19 (12; 30)	30 (23; 30)	<0.0001
ICHV, mL	4.7 (3.4; 7.4)	10.4 (6.5; 12.3)	7.5 (4.5; 10.1)	36.1 (30.2; 58.5)	<0.0001
MS, mm	0.0 (0.0; 2.0)	2.5 (1.5; 3.5)	0.0 (0.0; 3.3)	7.5 (6.3; 9.1)	<0.0001
IVHV, mL	1.8 (0.0; 3.3)	11.0 (6.0; 16.4)	23.2 (9.0; 36.1)	54.6 (30.0; 54.6)	<0.0001
ICHTV, mL	4.8 (3.4; 8.4)	11.4 (7.5; 13.1)	8.3 (5.5; 11.1)	37.1 (31.2; 59.5)	<0.0001

FOUR: Full Outline of UnResponsiveness Scale; **NIHSS:** National Institute of Health Stroke Scale; **ICHV:** intracerebral hemorrhage volume; **MS:** midline shift; **IVHV:** intraventricular hemorrhage volume; **ICHTV:** intracranial hemorrhage total volume; **P:** statistical significance of intergroup differences according to the Kruskal–Wallis test.

the presence of indications for surgical treatment prescribed by a neurosurgeon.

The following were considered as endpoints: lethal outcome within 21 days from the disease onset; unfavorable functional outcome of the acute period of SSICH in the form of 4–5 points value on the modified Rankin Scale (mRS) on the 21st day of the disease. The value of ≤3 points on the mRS was considered as a favorable functional outcome.

Statistical processing of the results was performed using Statistica 13.0 (StatSoft Inc., USA, serial number JPZ804I382130ARCN10-J) and MedCalc (version 18.2.1). The form of descriptive statistics (median and interquartile range) and tools for studying null hypotheses on the absence of intergroup differences in quantitative indicators (the Mann–Whitney criterion – for two unrelated samples, the Kruskal–Wallis test – for three or more unrelated samples) were chosen based on the results of the studied indicators distribution (using the Shapiro–Wilk test). Pearson's chi-square test was used to assess the relationship between qualitative (discrete) indicators. We also used logistic regression analysis, calculated the odds ratio (OR), relative risk (RR), as well as indicators of sensitivity (Se) and specificity (Sp). The significance level $P < 0.05$ was considered critical for rejecting the null hypotheses.

Results

Depending on the localization of SSICH, patients were divided into 3 groups: the 1st group consisted of 100 (31.8 %) patients with thalamic hemorrhage, the 2nd group – 167 (53.2 %) patients with striatocapsular hemorrhage, the 3rd group included 47 (15.0 %) patients with lobar hemorrhage. The results of comparison between these groups as for clinical and neuroimaging indicators are shown in *Table 1*.

So, in the group of patients with thalamic hemorrhage, the median ICHV was the lowest, midline shift was detected in 70 (70.0 %) patients, blood breakthrough into the ventricular system – in 84 (84.0 %) patients, which demonstrated the highest value of the median IVHV and the greatest severity of cerebral syndrome according to the FOUR score. In the group of patients with striatocapsular hemorrhage, the median ICHV was the highest, lateral displacement of the medial structures were detected in 111 (66.5 %) patients, the prevalence of blood breakthrough into the ventricular system was slightly lower (52.1 %). The value of the median ICHV was respectively lower and the cerebral syndrome was less pronounced. The median ICHV values in the group of patients with lobar hemorrhage were 2.2 times lower in comparison to patients with the hemorrhage located in the striatocapsular areas, and only 20.2 % higher than in the group of patients with thalamic hemorrhages, while midline shift and blood breakthrough into the ventricular system were detected in only 14 (29.3 %) and 11 (23.4 %) patients, respectively, which resulted in the lowest severity of cerebral syndrome and the lowest level of neurological deficit.

The structure of thalamic hemorrhages was presented as follows: anterior type – 2 (2.0 %) patients, posterior type – 15 (15.0 %) patients, posterolateral type – 51 (51.0 %) patients, posteromedial type – 20 (20.0 %) patients, global type – 12 (12.0 %) patients. On the basis of a comparative analysis of clinical and neuroimaging indicators, it was found that the group of patients with anterior/dorsal thalamic hemorrhage had the lowest levels of median ICHV and IVHV. Respectively, the severity of cerebral syndrome and neurological deficit were the lowest. The medians of ICHV, IVHV and NIHSS in the group of patients with posterolateral thalamic hemorrhage were 2.2, 6.1 and 1.7 times higher, respectively, in the group of patients with posteromedial thalamic hemorrhage – 1.6, 12.9 and 2.1 times higher, respectively, and in the group with the global type of thalamic hemorrhage – 7.7, 30.3 and 3.3 times, respectively, with a greater severity of cerebral syndrome. The FOUR score in groups of patients with posterolateral, posteromedial and global types of thalamic hemorrhage on comparison to

Table 3. Comparative analysis of clinical and neuroimaging parameters in patients with different types of striato-capsular hemorrhage

Parameters, units	Type of striatocapsular hemorrhage					P
	Posteromedial (n = 25)	Middle (n =20)	Lateral (n = 21)	Posterolateral (n = 42)	Massive (n = 59)	
FOUR score	16 (16; 16)	16 (16; 16)	15 (14; 16)	16 (14; 16)	6 (5; 13)	<0.0001
NIHSS score	7 (6; 8)	10 (7; 13)	15 (13; 18)	16 (12; 18)	30 (21; 30)	<0.0001
ICHV, mL	1.5 (0.7; 3.4)	6.2 (4.1; 11.8)	20.1 (17.7; 29.6)	19.9 (12.6; 25.1)	80.3 (61.6; 121.1)	<0.0001
MS, mm	0.0 (0.0; 0.0)	0.0 (0.0; 0.4)	1.5 (0.0; 3.5)	2.5 (0.0; 3.5)	10.0 (7.3; 13.5)	<0.0001
IVHV, mL	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)	0.0 (0.0; 1.2)	8.2 (0.0; 16.4)	30.0 (16.4; 54.6)	<0.0001
ICHTV, mL	1.5 (0.7; 3.4)	6.2 (4.1; 11.8)	20.1 (18.5; 29.6)	20.4 (13.3; 26.1)	81.3 (62.1; 122.1)	<0.0001

FOUR: Full Outline of UnResponsiveness Scale; **NIHSS:** National Institute of Health Stroke Scale; **ICHV:** intracerebral hemorrhage volume; **MS:** midline shift; **IVHV:** intraventricular hemorrhage volume; **ICHTV:** intracranial hemorrhage total volume; **P:** statistical significance of intergroup differences according to the Kruskal–Wallis test.

Table 4. The structure of the options for the outcome of the acute period of the disease on the background of conservative therapy in patients with different types of SSICH

Type of SSICH	Acute period outcome on the background of conservative therapy		
	FFO (n = 130)	uFFO (n = 92)	LO (n = 92)
Anterior/dorsal thalamic hemorrhage (n = 17)	17 P_1: 100.0 % P_2: 13.0 % P_3: 5.4 %	0 P_1: 0.0 % P_2: 0.0 % P_3: 0.0 %	0 P_1: 0.0 % P_2: 0.0 % P_3: 0.0 %
Posterolateral thalamic hemorrhage (n = 51)	7 P_1: 13.7 % P_2: 5.4 % P_3: 2.2 %	39 P_1: 76.5 % P_2: 42.4 % P_3: 12.4 %	5 P_1: 9.8 % P_2: 5.4 % P_3: 1.6 %
Posteromedial thalamic hemorrhage (n = 20)	6 P_1: 30.0 % P_2: 4.6 % P_3: 1.9 %	4 P_1: 20.0 % P_2: 4.3 % P_3: 1.3 %	10 P_1: 50.0 % P_2: 10.9 % P_3: 3.2 %
Global thalamic hemorrhage (n = 12)	0 P_1: 0.0 % P_2: 0.0 % P_3: 0.0 %	1 P_1: 8.3 % P_2: 1.1 % P_3: 0.3 %	11 P_1: 91.7 % P_2: 12.0 % P_3: 3.5 %
Posteromedial striatocapsular hemorrhage (n = 25)	22 P_1: 88.0 % P_2: 16.9 % P_3: 7.0 %	3 P_1: 12.0 % P_2: 3.3 % P_3: 1.0 %	0 P_1: 0.0 % P_2: 0.0 % P_3: 0.0 %
Middle striatocapsular hemorrhage (n = 20)	19 P_1: 95.0 % P_2: 14.6 % P_3: 6.1 %	1 P_1: 5.0 % P_2: 1.1 % P_3: 0.3 %	0 P_1: 0.0 % P_2: 0.0 % P_3: 0.0 %
Lateral striatocapsular hemorrhage (n = 21)	13 P_1: 61.9 % P_2: 10.0 % P_3: 4.1 %	6 P_1: 28.6 % P_2: 6.5 % P_3: 1.9 %	2 P_1: 9.5 % P_2: 2.2 % P_3: 0.6 %
Posterolateral striatocapsular hemorrhage (n = 42)	10 P_1: 23.8 % P_2: 7.7 % P_3: 3.2 %	27 P_1: 64.3 % P_2: 29.3 % P_3: 8.6 %	5 P_1: 11.9 % P_2: 5.4 % P_3: 1.6 %
Massive striatocapsular hemorrhage (n = 59)	1 P_1: 1.7 % P_2: 0.8 % P_3: 0.3 %	5 P_1: 8.5 % P_2: 5.4 % P_3: 1.6 %	53 P_1: 89.8 % P_2: 57.6 % P_3: 16.9 %
Lobar hemorrhage (n = 47)	35 P_1: 74.5 % P_2: 26.9 % P_3: 11.1 %	6 P_1: 12.8 % P_2: 6.5 % P_3: 1.9 %	6 P_1: 12.8 % P_2: 6.5 % P_3: 1.9 %

FFO: favorable functional outcome; **uFFO:** unfavorable functional outcome; **LO:** lethal outcome; **P_1:** the prevalence of this outcome in cohort of patients with specific type of SSICH; **P_2:** the prevalence of this type of SSICH in cohort of patients with specific outcome of the acute period of the disease on the background of conservative therapy; **P_3:** the prevalence of these patients in general cohort.

patients with anterior/dorsal type of thalamic hemorrhage were 6.3 %, 25.0 % and 50.0 % lower, respectively (*Table 2*).

The structure of striatocapsular hemorrhages was presented as follows: posteromedial type – 25 (15.0 %) patients, middle type – 20 (12.0 %) patients, lateral type – 21 (12.6 %) patients, posterolateral type – 42 (25.1 %) patients, massive type – 59 (35.3 %) patients. Based on a comparative analysis of clinical and neuroimaging indicators, it was determined that groups of patients with posteromedial and middle types of striatocapsular hemorrhage had the lowest ICHV (1.5 (0.7; 3.4) ml and 6.2 (4.1; 11, 8) ml, respectively), low prevalence of midline shift (20.0 % and 25.0 %, respectively) and no blood breakthrough into the ventricular system, which was registered in only 1 (5.0 %) patient with middle type of striatocapsular hemorrhage (*Table 3*).

Levels of neurological deficit in the groups of patients with posteromedial and middle types of striatocapsular hemorrhage were 7 (6; 8) and 10 (7; 13) NIHSS score, respectively, while in groups with lateral, posterolateral and massive types of striatocapsular hemorrhage values this indicator constituted 15 (13; 18), 16 (12; 18) and 30 (21; 30) points, which was due to the significantly larger volume of the lesion (20.1 (17.7 (29.6)) ml, 19.9 (12.6; 25.1) ml and 80.3 (61.6; 121.1) ml, respectively) and greater midline shift severity (1.5 (0.0; 3.5) mm, 2.5 (0.0; 3.5) mm and 10.0 (7.3; 13.5) mm, respectively). The blood breakthrough into the ventricular system was recorded in 27 (64.3 %) and 53 (89.8 %) patients with posterolateral and massive types of striatocapsular hemorrhage, respectively, and only 6 (28.6 %) patients with lateral type, so ICHV median was higher in the groups of patients with posterolateral and massive types of striatocapsular hemorrhage. In the studied cohort, lethal outcome was registered in 92 (29.3 %) cases, unfavorable functional outcome – in the same quantity of 92 (29.3 %) patients, favorable functional outcome occurred in 130 (41.4 %) patients. The structure of the options for the outcome of the acute period of the disease on the background of conservative therapy in patients with different types of SSICH is shown in *Table 4*.

It was determined that the type of SSICH was associated with the outcome of the acute period of the disease on the background of conservative therapy (Pearson's chi-square = 308.6, P < 0.0001). Thus, in all patients with anterior/posterior type of thalamic hemorrhage, the acute period of the disease had a favorable functional outcome. Unfavorable functional outcome predominated in the group of patients with posterolateral type of thalamic hemorrhage (76.5 %), while favorable functional outcome was recorded in only 13.7 % of cases, lethal outcome – in 9.8 % of cases. Patients with posteromedial and global types of thalamic hemorrhage had a high proportion of unfavorable outcomes of the acute period of the disease on the background of conservative therapy, with lethal outcome in 50.0 % and 91.7 % of patients, respectively. We did not report any deaths in the groups of patients with posteromedial and middle types of striatocapsular hemorrhage, the share of favorable functional outcome was the highest (88.0 % and 95.0 %, respectively). Mortality rates in patients with lateral and posterolateral types

Table 5. Prognostic value of the type of spontaneous supratentorial intracerebral hemorrhage as a predictor of unfavorable outcome of the acute period of the disease on the background of conservative therapy (results of univariate logistic regression analysis and determination of relative risk)

Type of SSICH	Univariate logistic regression model		Relative risk	
	OR (95 % CI)	P	RR (95 % CI)	P
Anterior/dorsal thalamic hemorrhage	0.02 (0.00–0.30)	0.0050	0.05 (0.00–0.70)	0.0261
Posterolateral thalamic hemorrhage	5.52 (2.34–12.71)	0.0001	1.62 (1.39–1.90)	<0.0001
Posteromedial thalamic hemorrhage	1.70 (0.64–4.55)	0.2895	1.21 (0.89–1.64)	0.2165
Global thalamic hemorrhage	18.91 (1.11–322.38)	0.0422	1.76 (1.59–1.94)	<0.0001
Posteromedial striatocapsular hemorrhage	0.08 (0.02–0.28)	0.0001	0.19 (0.07–0.56)	0.0024
Middle striatocapsular hemorrhage	0.03 (0.00–0.24)	0.0009	0.08 (0.01–0.54)	0.0098
Lateral striatocapsular hemorrhage	0.41 (0.16–1.02)	0.0545	0.63 (0.36–1.10)	0.1066
Posterolateral striatocapsular hemorrhage	2.53 (1.19–5.34)	0.0153	1.36 (1.12–1.66)	0.0023
Massive striatocapsular hemorrhage	59.38 (8.10–435.28)	0.0001	1.99 (1.75–2.26)	<0.0001
Lobar hemorrhage	0.19 (0.09–0.38)	<0.0001	0.39 (0.24–0.65)	0.0003

OR: odds ratio; **RR:** relative risk; **CI:** confidence interval.

Table 6. Prognostic value of spontaneous supratentorial intracerebral hemorrhage as a predictor of lethal outcome of the acute period of the disease on the background of conservative therapy (results of univariate logistic regression analysis and determination of relative risk)

Type of SSICH	Univariate logistic regression model		Relative risk	
	OR (95 % CI)	P	OR (95 % CI)	P
Anterior/dorsal thalamic hemorrhage	0.06 (0.00–1.07)	0.0555	0.09 (0.01–1.38)	0.0841
Posterolateral thalamic hemorrhage	0.22 (0.08–0.57)	0.0019	0.30 (0.13–0.69)	0.0050
Posteromedial thalamic hemorrhage	2.58 (1.04–6.44)	0.0414	1.79 (1.11–2.88)	0.0161
Global thalamic hemorrhage	30.01 (3.81–236.17)	0.0012	3.42 (2.65–4.40)	<0.0001
Posteromedial striatocapsular hemorrhage	0.04 (0.00–0.70)	0.0269	0.06 (0.00–0.94)	0.0453
Middle striatocapsular hemorrhage	0.05 (0.00–0.89)	0.0414	0.08 (0.00–1.18)	0.0656
Lateral striatocapsular hemorrhage	0.24 (0.05–1.04)	0.0566	0.31 (0.08–1.17)	0.0843
Posterolateral striatocapsular hemorrhage	0.39 (0.11–0.76)	0.0116	0.37 (0.16–0.86)	0.0212
Massive striatocapsular hemorrhage	48.92 (19.68–121.60)	<0.0001	5.87 (4.35–7.94)	<0.0001
Lobar hemorrhage	0.31 (0.13–0.75)	0.0099	0.40 (0.18–0.85)	0.0181

OR: odds ratio; **RR:** relative risk; **CI:** confidence interval.

Table 7. Prognostic value of the SSICH type of as a predictor of unfavorable functional outcome of the acute period of the disease on the background of conservative therapy (results of univariate logistic regression analysis and determination of relative risk)

Type of SSICH	Univariate logistic regression model		Relative risk	
	OR (95 % CI)	P	OR (95 % CI)	P
Anterior/dorsal thalamic hemorrhage	0.03 (0.00–0.59)	0.0201	0.06 (0.00–0.96)	0.0463
Posterolateral thalamic hemorrhage	12.93 (5.44–30.76)	<0.0001	2.82 (2.18–3.64)	<0.0001
Posteromedial thalamic hemorrhage	0.94 (0.26–3.43)	0.9246	0.96 (0.44–2.09)	0.9254
Global thalamic hemorrhage	4.28 (0.17–106.21)	0.3750	2.43 (2.07–2.84)	<0.0001
Posteromedial striatocapsular hemorrhage	0.17 (0.05–0.57)	0.0044	0.27 (0.09–0.78)	0.0154
Middle striatocapsular hemorrhage	0.06 (0.01–0.49)	0.0080	0.11 (0.02–0.75)	0.0246
Lateral striatocapsular hemorrhage	0.63 (0.23–1.72)	0.3649	0.75 (0.38–1.47)	0.3978
Posterolateral striatocapsular hemorrhage	4.98 (2.27–10.94)	0.0001	2.08 (1.57–2.74)	<0.0001
Massive striatocapsular hemorrhage	7.41 (0.85–64.56)	0.0696	2.07 (1.40–3.06)	0.0003
Lobar hemorrhage	0.19 (0.08–0.47)	0.0004	0.31 (0.14–0.66)	0.0022

OR: odds ratio; **RR:** relative risk; **CI:** confidence interval.

of striatocapsular hemorrhage were 9.5 % and 11.9 %, while the first subcohort had a relatively higher proportion of favorable functional outcome (61.9 % vs. 23.8 %) and the largest share of unfavorable functional outcome (64.3 % vs. 28.6 %) in the second subcohort. The mortality rate in the group of patients with massive type of striatocapsular hemorrhage was 89.8 %, and among the surviving patients the acute period of the disease had an unfavorable functional outcome in 83.3 % of cases. In the structure of variants of the acute period of the disease in patients with lobar hemorrhage, the prevalence of favorable functional outcome was the largest (74.5 %), while unfavorable variants occurred in 25.0 % (unfavorable functional outcome 12.5 %, lethal outcome – 12.5 %).

On the basis of a logistic regression analysis, types of thalamic (posterolateral, global) and striatocapsular hemorrhage (posterolateral, massive) were identified, which were predictors of unfavorable outcomes of the acute period and associated with increased risk of recurrence on the background of conservative therapy. The risk was increases by 1.6 ($P < 0.0001$), 1.8 ($P < 0.0001$), 1.4 ($P = 0.0023$) and 2.0 times ($P < 0.0001$), respectively (*Table 5*).

It was determined that the criteria for unfavorable vital prognosis on the background of conservative therapy were posteromedial type of thalamic hemorrhage (OR (95 % CI) = 2.58 (1.04–6.44), $P = 0.0414$; Se = 10.9 %, Sp = 95.5 %), global type of thalamic hemorrhage (OR

(95 % CI) = 30.01 (3.81–236.17), P = 0.0012; Se = 12.0 %, Sp = 99.6 %) and massive type of striatocapsular hemorrhage (OR (95 % CI) = 48.92 (19.68–121.60), P < 0.0001, Se = 57.6 %, Sp = 97.3 %). They were associated with a risk of death increased by 1.8 (P = 0.0161), 3.4 (P < 0.0001) and 5.9 times (P < 0.0001), respectively (*Table 6*).

It was proved that in patients with other types of thalamic hemorrhage (anterior/posterior, posterolateral), striatocapsular hemorrhage (posteromedial, middle, posterolateral), as well as with lobar hemorrhage, the vital prognosis on the background of conservative therapy was favorable. The prognosis was relatively favorable in patients with lateral type of striato-capsular hemorrhage and depended on the further course of the disease.

On the basis of a logistic regression analysis, the results of which are shown in *Table 7*, it was found that predictors of unfavorable functional outcome of the acute period of the disease on the background of conservative therapy were posterolateral type of thalamic hemorrhage (OR (95 % CI) = 12.93 (5.44–30.76), P < 0.0001; Se = 42.4 %, Sp = 94.6 %) and posterolateral type of striatocapsular hemorrhage (OR (95 % CI) = 4.98 (2.27–10.94), P = 0.0001; Se = 29.4 %, Sp = 92.5 %). The above-mentioned types of SSICH were associated with an increased risk of the endpoint by 2.8 (P < 0.0001) and 2.1 times (P < 0.0001), respectively. The criteria of favorable functional outcome were anterior/dorsal type of thalamic hemorrhage (OR (95 % CI) = 0.03 (0.00–0.59), P = 0.0201), posteromedial type of striatocapsular hemorrhage (OR (95 % CI) = 0.17 (0.05–0.57), P = 0.0044), middle type of striatocapsular hemorrhage hemorrhage (OR (95 % CI) = 0.06 (0.01–0.49), P = 0.0080), as well as lobar hemorrhage (OR (95 % CI) = 0.19 (0.08–0.47), P = 0.0004).

Discussion

As a result, we studied in detail the structure of options of the acute period outcome after hemorrhagic hemispheric stroke on the background of conservative therapy in patients with different integrated neuroimaging types, taking into consideration the localization of SSICH and the parameters for quantifying the severity of cerebral damage. It was determined that posteromedial type of thalamic hemorrhage, global type of thalamic hemorrhage and massive type of striatocapsular hemorrhage were associated with the increased risk of lethal outcome of the acute period of SSICH on the background of conservative therapy. The presence of global type of thalamic hemorrhage and massive type of striatocapsular hemorrhage in the spectrum of predictors of lethal outcome, confirmed the leading role of lesion volume in thanatogenesis, because the largest volume of SSICH (regardless of location) in integration with perifocal edema initiated the dislocation of caudal directions with the further development of the temporal-tentorial wedge and/or wedge in the cervical-dural funnel. Under these circumstances, the development of secondary (dislocation) hemorrhages in the brain stem was quite common. The above data are consistent with the results of our previous studies [11,19], as well as with the works of other researchers [20,21], demonstrating the diagnostic informative value of such quantitative neuroimaging indicators as intracerebral hemorrhage and lateral displacement of midbrain in the verification of short-term vital signs.

Patients with global thalamic hemorrhage demonstrated that an additional factor in thanatogenesis was the blood breakthrough into the ventricular system with the development of massive secondary intraventricular hemorrhage and the resulting cerebrospinal fluid disorders (including internal occlusive hydrocephalus), which is also consistent with our previous studies [11,19] and the works of other researchers who showed that the volume of secondary intraventricular hemorrhage was an independent predictor of unfavorable outcomes in patients with SSICH [9,10]. Thus, despite the lower volume of intracerebral hemorrhage in comparison with the subcohort of patients with massive type of striatocapsular hemorrhage (36.1 (30.2; 58.5) ml vs. 80.3 (61.6; 121.1) ml), the level of mortality in the group of patients with global thalamic hemorrhage was also quite high (91.7 % vs. 89.8 %) due to a significantly higher volume of secondary intraventricular hemorrhage (54.6 (30.0; 54.6) ml vs. 30.0 16.4; 54.6) ml).

Based on the study of the acute period of the disease structure on the background of conservative therapy depending on the type of thalamic hemorrhage, it was found that patients with posterior medial type had the highest mortality (50.0 % vs. 9.8 % and 0.0 % in groups with posterolateral and anterior/dorsal types), because the specified contingent of patients (taking into account anatomical features) had the largest volume of secondary intraventricular hemorrhage (23.2 (9.0; 36.1) ml vs. 11.0 (6.0; 16.4) ml and 1.8 (0.0; 3.3) ml, respectively). Thus, the informative value of thalamic localization of SSICH as one of the criteria for unfavorable vital prognosis should be assessed differently based on the type of thalamic hemorrhage.

In accordance with the logistic regression analysis, posterolateral type of thalamic hemorrhage and posterolateral type of striatocapsular hemorrhage were associated with unfavorable functional outcome of the acute period of the disease. Both of these types of SSICH were characterized by lesions of posterior limb of internal capsule which caused the severe motor deficit in combination with severe disorders of sensitivity (including proprioception) explaining the negative impact on functional recovery after stroke, while the short-term functional prognosis on the background of conservative therapy in patients with anterior/dorsal type of thalamic hemorrhage, posteromedial/middle type of striatocapsular hemorrhage, lobar hemorrhage was favorable. The results are consistent with the data of C. Delcourt et al. (2017), according to which thalamic localization of intracerebral hemorrhage was a predictor of lethal outcome of the acute period of the disease, lesion of posterior limb of internal capsule was associated with unfavorable functional outcome, while lobar hemorrhage was a criterion for favorable functional prognosis [15]. However, the above-mentioned study did not apply a differentiated definition of the thalamic hemorrhage type, that, in our opinion, may reduce the accuracy of verification of a short-term prognosis in this group of patients.

However, the results of logistic regression analysis showed that the neuroimaging verification of short-term prognosis in patients with lateral striatocapsular hemorrhage was the most difficult. The vital prognosis in this group of patients could be considered relatively favorable while the functional prognosis was ambivalent and required

the comparison of the neurological deficit level, as well as further dynamic monitoring of both – quantitative neuroimaging parameters (volume of intracerebral hemorrhage, shift of the median brain structures) and clinical and neurological parameters.

Thus, the study proved the relation between the integrated neuroimaging type SSICH, which takes into account not only the location but also the parameters of quantitative assessment of the severity of damage to cerebral structures, and the outcome of the acute period of the disease, demonstrating high prognostic value for neuroimaging type, and proved the viability of the determination of the short-term prognosis on the background of conservative therapy as a part of the basis for choosing the optimal treatment tactics in this group of patients.

Conclusions

1. Integral neuroimaging type of SSICH, which takes into account its location and parameters of quantitative assessment of the severity of damage to cerebral structures, is closely associated with the outcome of the acute period of the disease on the background of conservative therapy (Pearson's chi-square = 308.6, P < 0.0001) and is an informative criterion for the verification of the short-term prognosis in this group of patients. Posteromedial type of thalamic hemorrhage (OR (95 % CI) = 2.58 (1.04–6.44), P = 0.0414), global type of thalamic hemorrhage (95 % CI) = 30.01 (3.81–236.17), P = 0.0012) and massive type of striatocapsular hemorrhage (OR (95 % CI) = 48.92 (19.68–121.60), P < 0.0001) are highly specific predictors of lethal outcome of the acute period of SSICH.

2. Highly specific criteria of unfavorable short-term functional prognosis in patients with SSICH on the background of conservative therapy are posterolateral types of thalamic hemorrhage (OR (95 % CI) = 12.93 (5.44–30.76), P < 0.0001) and striatocapsular hemorrhage CI) = 4.98 (2.27–10.94), P = 0.0001), while anterior/dorsal type of thalamic hemorrhage, posteromedial/middle type of striatocapsular hemorrhage and lobar hemorrhage are associated with the favorable functional outcome of the acute period of the disease.

The prospect of further research is to develop a differentiated approach to determination of the optimal treatment tactics in patients with SSICH, based on the results of integrated neuroimaging verification of a short-term prognosis on the background of conservative therapy.

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