Check for updates

Оригинальное исследование | Original study article
DOI: https://doi.org/10.35693/SIM623623

A multivariate weighted assessment model for the course of ischemic stroke accompanied by carotid stenosis of varying severity

Anastasiya S. Tkachenko[1], Irina E. Poverennova[1], Tatyana V. Romanova[1], Natalya P. Persteneva[2]

[1]Samara State Medical University (Samara, Russian Federation)
[2]Samara State University of Economics (Samara, Russian Federation)

Abstract

Aim – to develop a multivariate weighted assessment model for analyzing the influence of individual risk factors for acute ischemic cerebrovascular accidents on the course of ischemic stroke with concurrent carotid stenosis of varying severity.

Material and methods. The study involved 606 in-patients receiving treatment for the acute ischemic stroke. The patients were divided into three groups according to the NASCET scale for severity of carotid stenosis. In all patients, we identified the risk factors for the stroke development, the size of the ischemic locus according to the CT imaging, the patient's condition at admission and discharge from the hospital using the NIHSS, Rankin, and Rivermead scales.

Results. The estimated indicators were represented by different measurement scales, so there was a need to bring them to the universal basis. A weighted assessment model required assigning weights for each component of the new index. A multivariate weighted assessment was modeled in order to identify the main factors influencing its variation. We selected the risk factors for acute ischemic cerebrovascular accidents, built the regression models, performed the statistical analysis and assessed their quality.

Conclusion. The regression models are helpful in covering a wide range of factors and mathematically expressing their relationship with performance indicators. The developed logistic regression models demonstrated the degree of positive or negative influence of various risk factors on the course of ischemic stroke in the studied groups of patients.

Keywords: carotid stenosis, ischemic stroke, risk factors, logistic regression analysis, multivariate weighted assessment.

Conflict of interest: nothing to disclose.

Citation
Tkachenko AS, Poverennova IE, Romanova TV, Persteneva NP. A **multivariate weighted assessment model for the course of ischemic stroke accompanied by carotid stenosis of varying severity.** *Science and Innovations in Medicine*. 2025;10(1):30-36.
DOI: https://doi.org/10.35693/SIM623623

Information about authors
Anastasiya S. Tkachenko – MD, a postgraduate student of the Department of Neurology and Neurosurgery.
ORCID: 0000-0002-1081-7140
E-mail: tka4enko.n777@yandex.ru
Irina E. Poverennova – MD, Dr. Sci. (Medicine), Professor, Head of the Department of Neurology and Neurosurgery.
ORCID: 0000-0002-2594-461X
E-mail: i.e.poverennova@samsmu.ru
Tatyana V. Romanova – MD, Dr. Sci. (Medicine), Professor, Department of Neurology and Neurosurgery.
ORCID: 0000-0003-2851-8672
E-mail: t.v.romanova@samsmu.ru
Natalya P. Persteneva – Cand. Sci. (Economy), Associate professor, Department of Statistics and Econometrics.
ORCID: 0000-0003-3845-5011
E-mail: persteneva_np@mail.ru

Corresponding Author
Irina E. Poverennova
Address: Samara State Medical University, 89 Chapaevskaya st., Samara, Russia, 443099.
E-mail: i.e.poverennova@samsmu.ru

Abbreviations
ACVA – acute cardiovascular accident; IS – ischemic stroke; RS – Rankin Scale; RMI – Rivermead Mobility Index; MWA – multivariate weighted assessment.

Received: 20.11.2023
Accepted: 24.03.2024
Published: 10.04.2024

Многомерная взвешенная оценка в анализе течения ишемического инсульта на фоне каротидного стеноза различной степени выраженности

А.С. Ткаченко[1], И.Е. Повереннова[1], Т.В. Романова[1], Н.П. Перстенева[2]

[1]ФГБОУ ВО «Самарский государственный медицинский университет» Минздрава России (Самара, Российская Федерация)
[2]ФГАОУ ВО «Самарский государственный экономический университет» Министерства науки и высшего образования России (Самара, Российская Федерация)

Аннотация

Цель – разработать многомерную взвешенную оценку влияния факторов риска острого нарушения мозгового кровообращения (ОНМК) на течение ишемического инсульта, развившегося на фоне каротидного стеноза различной степени выраженности.

Материал и методы. Исследовано 606 больных, находившихся в отделении для больных с ОНМК в остром периоде ишемического инсульта, которые были разделены на три группы по степени выраженности каротидного стеноза согласно NASCET. У всех больных выявляли факторы риска развития ОНМК, определяли размер очага ишемии по КТ головного мозга, оценивали состояние пациента и его изменения по шкалам NIHSS, Рэнкина, Ривермид.

Результаты. Оценочные показатели представлены различными измерительными шкалами, поэтому их необходимо привести к одному основанию. Методика построения взвешенной оценки предполагает формирование весовых коэффициентов для каждого компонента нового индекса. Произведено моделирование многомерной взвешенной оценки для выявления основных факторов, влияющих на ее вариацию. Был проведен отбор факторов риска ОНМК у исследованных больных, построены регрессионные модели, выполнен их статистический анализ и оценено их качество.

Выводы. Регрессионные модели позволяют охватить большой круг факторов и математически выразить их связь с результативными показателями. Разработанные логистические модели показывают степень положительного или отрицательного влияния различных факторов риска на течение ишемического инсульта в исследованных группах больных.

Ключевые слова: каротидный стеноз, ишемический инсульт, факторы риска, логистический регрессионный анализ, многомерная взвешенная оценка.

Конфликт интересов: не заявлен.

Для цитирования:
Ткаченко А.С., Поверennова И.Е., Романова Т.В., Перстенева Н.П. **Многомерная взвешенная оценка в анализе течения ишемического инсульта на фоне каротидного стеноза различной степени выраженности.** *Наука и инновации в медицине.* 2025;10(1):30-36. DOI: https://doi.org/10.35693/SIM623623

Сведения об авторах
Ткаченко А.С. – аспирант кафедры неврологии и нейрохирургии.
ORCID: 0000-0002-1081-7140
E-mail: tka4enko.n777@yandex.ru
Поверennова И.Е. – д-р мед. наук, профессор, заведующая кафедрой неврологии и нейрохирургии.
ORCID: 0000-0002-2594-461X
E-mail: i.e.poverennova@samsmu.ru
Романова Т.В. – д-р мед. наук, профессор кафедры неврологии и нейрохирургии.
ORCID: 0000-0003-2851-8672
E-mail: t.v.romanova@samsmu.ru
Перстенева Н.П. – канд. экон. наук, доцент кафедры статистики и эконометрики.
ORCID: 0000-0003-3845-5011
E-mail: persteneva_np@mail.ru

Автор для переписки
Поверennова Ирина Евгеньевна
Адрес: Самарский государственный медицинский университет, ул. Чапаевская, 89, г. Самара, Россия, 443099.
E-mail: i.e.poverennova@samsmu.ru

Список сокращений
ИИ – ишемический инсульт; КТ – компьютерная томография; МВО – многомерная взвешенная оценка; ОНМК – острые нарушения мозгового кровообращения; NASCET – North American Symptomatic Carotid Endarterectomy Trial; NIHSS – National Institutes of Health Stroke Scale; RS – Rankin Scale, шкала Рэнкина; RMI – Rivermead Mobility Index, индекс мобильности Ривермид.

Получено: 20.11.2023
Одобрено: 24.03.2024
Опубликовано: 10.04.2024

INTRODUCTION

Among the causes of death and disability worldwide, cardiovascular diseases are leading. With every decade, the frequency of strokes among patients aged 50–55 increases by 1.8–2.0 times [1]. Loss of working capacity after an acute cardiovascular accident (ACVA) reaches 3.2 per 10000 adults and leads among the causes of disability. A great number of patients with ACVA are people of productive age: 23.6% from 41 up to 50 years, and 12.3% of the total number of patients are below 40 [2]. After the vascular accident, 40-45% patients die within 12 months, and every fifth patient develops a second stroke in the subsequent years [3]. It is for that reason that contemporary neurology focuses on prevention of ischemic stroke (IS) and post-stroke patient rehabilitation.

Constrictive lesion of the major arteries of the head and the neck are one of the principal causes for development of the brain ischemia [4, 5]. There is a classification of carotid stenosis depending on the degree of vessel constriction, which identified mild (0–29%), mild to moderate (30–49%), moderate (50–69%) and severe stenosis (70–99%), and full occlusion of the vessel (100%) [6, 7]. In the recent years, there were published many papers on the assessment of the major factor of risk of IS development [8, 9]. Thus, important roles in the onset and progress of ACVA belong to arterial hypertension – like the carotid stenosis, it is a type of a macrovascular disease [10], – and the decrease of just the diastolic arterial blood pressure by 5 mmHg leads to the decrease of risk of cerebral stroke by 34% [11]. Atrial fibrillation is the supraventricular tachycardia. According to several sources, in 15–20% of patients it is the atrial fibrillation that is the major reason of vascular accidents [12]. Studying the influence of these factors on the progress and prognosis of the acute period of ischemic stroke may open a possibility of lowering the risk of development of recurrent ACVAs and reduce the severity of the neurological deficiency in the acute period of ischemic stroke [13, 14]. In this regard, the analysis of the impact of risk factors on the progress of IS with concurrent carotid stenosis, seems an important task.

AIM

To develop a multivariate weighted assessment model for analyzing the influence of individual risk factors for acute ischemic cerebrovascular accidents on the course of ischemic stroke with concurrent carotid stenosis of varying severity.

MATERIAL AND METHODS

The paper is based on the results of an open prospective observation study involving 606 in-patients receiving treatment for the acute ischemic stroke. The studies patients included 292 women (48.2%) and 314 men (51.8%) aged between 39 and 89. The median age of the patients was 67.4 (81.75; 52.9) years.

Depending on the severity of stenosis of the major arteries of the head and the neck measured by duplex Doppler ultrasound inspection of the brachiocephalic trunk upon admission for ACVA treatment as per the NASCET (North American Symptomatic Carotid Endarterectomy Trial) classification, the patients were divided into three groups. The first group of hemodynamically mild/mild to moderate stenosis (below 49%) included 446 patients (73.6%). The second group (moderate stenosis of 50–69%) included 85 (14.0%) patients. The third group (hemodynamically severe stenosis of 70–100%) included 75 patients (12.4%).

In all of the examined patients, risk factors for the ACVA development were identified: degree of arterial hypertension, cardiac pathology, history of acute vascular accidents, diabetes mellitus, dyslipidemia, etc. The size of IS lesion was measured by the data of brain CT performed upon patient admission for treatment: lacunar, up to 10 mm, mini, up to 15 mm, medium, 20–50 mm, and large, over 50 mm. To ensure a complex evaluation of changes in the patient's condition from admission to (examination 1) to discharge from the in-patient facility (examination 2), three evaluation scales were used: National Institutes of Health Stroke Scale (NIHSS), Rankin Scale (RS), and Rivermead Mobility Index (RMI).

RESULTS

The results of examination of patients from the three groups on admission to (examination 1) and on discharge (examination 2) from the ACVA in-patient facility are shown in **Table 1**.

The initial data array consists of scores registered under each scale and every examination. The greater the difference (delta) between the scores of the same patient under both examination, the greater is the change in their condition during in-patient treatment. Undoubtedly, scores under separate indices provide vital information for the planning of therapy and control of its efficiency, yet the greatest prognostic value lies in the combination of all three separate indices represented in the single multivariate assessment. Since

Group / Scale	Group I (n = 446)		Group II (n = 85)		Group III (n = 75)	
	Ex. 1	Ex. 2	Ex. 1	Ex. 2	Ex. 1	Ex. 2
Lacunar stroke						
NIHSS	7.2 (4; 8)	3.0 (1; 3)	9.2 (6; 12)	3.1 (1; 6)	9.1 (5; 12)	6.9 (2; 8)
p-value	p < 0.001		0.001		0.142	
Rankin	3.0 (2; 3)	2.0 (1; 2)	4.0 (3; 5)	2.0 (1; 2)	3.0 (3; 4)	2.5 (2; 4)
p-value	p < 0.001		0.002		0.091	
Rivermead	6.2 (2: 7)	12.3 (9; 13)	2.0 (1; 4)	10.0 (9; 12)	3.0 (1; 6)	8.0 (5; 12)
p-value	p < 0.001		0,001		0.013	
Mini stroke						
NIHSS	10.0 (7.5; 12.5)	4.0 (3; 5)	8.5 (5.0; 8.0)	4.6 (2.0; 6.0)	10.2 (5; 15)	8.4 (3; 11)
p-value	p < 0.001		0.011		0.075	
Rankin	4.0 (3.0; 4.5)	2.0 (1; 3)	3.0 (3; 3)	2.0 (1; 3)	3.0 (3; 4)	3.0 (2; 3)
p-value	p < 0.001		0.028		0.310	
Rivermead	3.0 (1; 6)	8.0 (6; 12)	4.5 (1.0; 6.0)	9.5 (7.0; 13.0)	2.0 (1; 6)	6.0 (3; 10)
p-value	p < 0.001		0.005		0.043	
Medium stroke						
NIHSS	7.0 (4; 11)	3.5 (3.0; 8.0)	9.5 (6.0; 15.0)	6.0 (2; 9)	11.5 (7.0; 18.0)	9.0 (3; 10)
p-value	p < 0.001		p < 0.001		p < 0.001	
Rankin	3.0 (3; 4)	2.0 (2; 4)	4.0 (3; 5)	3.0 (2; 4)	4.0 (3.0; 4.0)	3.0 (1.0; 4.0)
p-value	p < 0.001		p < 0.001		0.002	
Rivermead	3.0 (1; 6)	8.0 (4; 12)	2.5 (1.0; 5.0)	7.0 (4; 12)	2.0 (1; 6)	4.5 (3; 11)
p-value	p < 0.001		p < 0.001		0.001	
Large stroke						
NIHSS	10.0 (8.5; 13.0)	5.5 (5.0; 11.0)	11.0 (10; 16)	6.5 (5; 6)	13.0 (5; 16)	10.0 (4; 11)
p-value	p < 0.001		0.043		0.176	
Rankin	4.2 (4; 5)	3.4 (3; 4)	4.1 (4; 5)	3.0 (2; 4)	4.3 (3; 5)	4.0 (3; 4)
p-value	0.002		0.109		0.178	
Rivermead	2.0 (1.0; 3.5)	4.8 (2.5; 6.5)	1.8 (1; 2)	5.0 (3; 8)	1.0 (1; 1)	3.0 (3; 8)
p-value	p < 0.001		0.068		0.028	

Table 1. *Indicators of neurological deficit at the admission (Study 1) and at the discharge from the hospital (Study 2) depending on the degree of atherosclerotic lesions and the volume of the stroke lesion (median, quartile 1; quartile 3)*

Таблица 1. *Показатели неврологического дефицита при поступлении (исследование 1) и при выписке из стационара (исследование 2) в зависимости от степени атеросклеротического поражения и объема очага инсульта (медиана, квартиль 1; квартиль 3)*

the evaluation indicators (components) of the multivariate assessment are represented by different evaluation scales, there arises a need of bringing them together to a universal basis. Each scale has its own specifics related not only to the nature of the assessed phenomenon, but to the difference in the evaluated parameters as well:

– The NIHSS scale evaluates the neurological status; it has an interval from 0 to 42, the "0" meaning "No stroke symptoms", and "42" meaning "Severe stroke";

– The Rankin scale measures degree of disability, i.e. to what extent the patient depends on assistance. The scale runs from 0 to 6, where "0" means "No symptoms", and "5" means "Severe disability";

– The Rivermead mobility index assesses functional mobility in gait and transfers. The range of scores is from "0" ("inability to independently perform any arbitrary movements") to "15" ("ability to run 10 meters in 4 seconds").

While forming the data array, it is very important to meet two requirements: single direction and normalization of scales. Single direction implies unified interpretation of all three specific indices, i.e. the increase of values of each index is to be interpreted in the same way: only either as 'improvement' or only as 'impairment'. Normalization means that all three indices are to have the same range of values.

In order to meet these requirements, we based our research on the Rivermead index. Its scale is 'ascending', i.e. the increase of its values represents improvement of the patient's mobility. Such a scale is intuitively perceived as a logical and adequate. The maximum score is 15 (the range of values being larger than that of the Rankin scale and smaller than that of the NIHSS scale). It is in the range of the Rivermead index that we will normalize the values of the other two scales that are 'descending', i.e. the increase of values represents the decline in the patient's condition.

To address the task of normalization, we will introduce correction factors, based on which we will recalculate all the scores obtained. For the NIHSS scale, all scores will be proportionately decreased with respect to the factor 15/42 = 0.357. E.g., the score of 12 will decrease after recalculation to 4.284 (12*0.357), however, in its essence the normalized score will remain the same: prior to normalization, it was 12 out of 42, after normalization it became 4.284 out of 15, i.e. it decreased proportionately. At the same time, the scale will still remain 'descending'; therefore, to 'turn over' the scale, to make it 'ascending', we will subtract each obtained normalized score from the maximum possible score of 15:

$$NIHSS_{\_norm}=15-NIHSS_{act},$$

where $NIHSS_{norm}$ – is the normalized score; $NIHSS_{act}$ – is the actual score.

Next, we will calculate the score difference (Δ_{NIHSS}):

$$\Delta_{NIHSS}=NIHSS_{norm2}-NIHSS_{norm1},$$

where $NIHSS_{norm1}$ and $NIHSS_{norm2}$ – are the scores after the first and the second examinations, respectively.

Index / Scale	Scale type	Value range
Specific indices (non-normalized scales)		
NIHSS Scale	'descending' – from better to worse	0 … 42
Rankin Scale	'descending' – from better to worse	0 … 5
Mobility Index	'ascending' – from worse to better	0 … 15
MWA		
Normalized scale	'ascending' – from worse to better	0 … 15

Table 2. *Scales of private MWA indices*
Таблица 2. *Шкалы частных индексов МВО*

Now, the plus sign "+" of the difference will mean the positive change in the neurological status, and the minus sign "–", the negative change.

We will apply the same procedure to the Rankin scale. All scores will be proportionately increased with the factor of 15/5 = 3. For example, the score of 2 after normalization will become greater: 6 (2*3). Transferring to the 'ascending' scale, we will subtract each obtained score from the maximum possible score of 15:

$$RS_{norm}=15–RS_{act},$$

where RSnorm – is the normalized score; RS_{act} – actual score.

Next, we will calculate the score difference (Δ_{RS})

$$\Delta RS=RS_{norm2}–RS_{norm1},$$

where RS_{norm1} and RS_{norm2} – are the scores after the first and the second examinations, respectively.

Thus, we are turning to the 'ascending' scale. Now, the plus sign "+" of the difference will mean the positive change in the total disability, and the minus sign "–", the negative change. The Rivermead index, taken as the reference, will remain unchanged. The difference in scores after the first and the second examination of the patient will provide information about the changes in the patient's mobility. The «+» plus sign "+" of the difference will mean the positive change in the mobility, and the minus sign "–", the negative change.

Number	Variable	Scale
X_1	Sex	nominal, binary
X_2	Age (years)	Quantitative
X_3	Arterial hypertension (140–160 mmHg)	nominal, binary
X_4	Arterial hypertension (161–180 mmHg)	nominal, binary
X_5	Arterial hypertension (181 mmHg and higher)	nominal, binary
X_6	Arrhythmia	nominal, binary
X_7	Ischemic changes on the ECG	nominal, binary
X_8	Stage 1 chronic heart failure	nominal, binary
X_9	Stage 2a chronic heart failure	nominal, binary
X_{10}	Stage 2b chronic heart failure	nominal, binary
X_{11}	Stage 3 chronic heart failure	nominal, binary
X_{12}	Second stroke in the same territory	nominal, binary
X_{13}	Second stroke in a different territory	nominal, binary
X_{14}	Stroke history	nominal, binary
X_{15}	Lacunar ischemic stroke	nominal, binary
X_{16}	Mini ischemic stroke	nominal, binary
X_{17}	Medium ischemic stroke	nominal, binary
X_{18}	Large ischemic stroke	nominal, binary
X_{19}	Acute cerebrovascular accident in the territory of the left middle cerebral artery	nominal, binary

Table 3. *Composition of factor variables for MWA modeling*
Таблица 3. *Состав факторных переменных для моделирования МВО*

The next stage will be the calculation of the multivariate weighted assessment (MWA) of the changes in the patient's condition. The multivariate array comprises a complex of differences (delta) of the abovementioned indices. The method of calculation of the weighted assessment implies formation of weight factors for each component of the new scale. There exist different approaches to the selection of weights, and the simples and most effective of these is the expert approach. The weight factors are assigned based on an intuitive recognition of comparative importance of components. In our case, it is suggested to determine the weights as follows (with the fixed sum of 1):

$\Delta NIHSS – 0,6;$
$\Delta RS – 0,2;$
$\Delta RMI – 0,2.$

We believe that the NIHSS is the universal tool to assess the patient's condition, whereas the two other factors serve auxiliary, albeit quite important, roles. The equation for the calculation of the MWA of the changes in the condition of a specific patient is as follows:

$$MBO = \Delta NIHSS_{norm}*0,6+\Delta RS_{norm}*0,2+\Delta RMI*0,2.$$

We will consider the proposed method on an example. Let patient A have 10 and 13 points (respectively in the first and second examinations) on the normalized NIHSS scale, 9 and 10 points on the normalized RS index, 13 and 15 points on the RMI index. Thus, the differences (deltas) will have the following values: 3 points on the normalized NIHSS scale, 1 point on the normalized RS index, 2 points on the RMI scale. Below is the calculation of the MWA for patient A:

$$MBO = 3*0.6+1*0.2+2*0.2 =2,4.$$

The MWA was calculated for each patient. We will provide brief data for all private indices (MWA components) and for the normalized scale (**Table 2**).

The algorithm for building the MWA is as follows: selection of components (private indices) for the MWA; normalization of private indices (bringing to the unified scale); recalculation of scores of each private index to normalized scores; calculation of normalized differences (deltas) of assessments for each private index; selection and assignment of weight factors; calculation of MWA.

The next stage of the research was the modeling of the multivariate weighted assessment to identify the major factors influencing its variation. Regression models allow for encompassing a vast variety of factors and for a mathematical expression of their correlation with resultative indicators. We selected the ACVA risk factors in the studied patients, constructed regression models, performed their statistical analysis and evaluated their quality. The models were built specifically for each patient group. The multivariate weighted assessment served as the dependent variable Y. The

Groups	Better condition	Worse condition
Group I	Lacunar ischemic stroke	Stage 2a chronic heart failure Large ischemic stroke
Group II	Mini stroke	Medium stroke
Group III	Stage 1 chronic heart failure	Second stroke in the same territory

Table 4. *The results of multivariate weighted assessment modelling*
Таблица 4. *Результаты моделирования с использованием многомерной взвешенной оценки*

numbering of factored variables was single for all models. The list of cardiovascular risk factors for the modeling is given in **Table 3**.

The major array of factors is represented by nominal binary variables that are included in the models as dummies if needed. For each group of patients, a minimum of two coupled regression models of comparable quality were built with the aim of identifying and qualitatively expressing the multi-directional impact increasing the multivariate assessment or decreasing it, respectively. All models are significant by the F-test, and their parameters are significant by the t-test. The regression model 1 for the Group I is as follows:

$$\hat{Y}_1=2{,}678–0{,}422X_9.$$
$$(0{,}114)\quad(0{,}182)$$

Explanation of the regression factor. Patients with Stage 2a chronic heart failure have a multivariate weighted assessment approx. 0.422 points lower than that of patients without chronic heart failure.

Regression model 2 for Group I is as follows:

$$\hat{Y}_1=2{,}575–0{,}571X_{18}.$$
$$(0{,}095)\quad(0{,}287)$$

The diagnosis of 'large ischemic stroke' is a factor aggravating the patient's condition; its multivariate weighted assessment will be 0.571 points lower, on average, than that of patients with less severe forms of stroke.

Regression model 3 for Group I is as follows:

$$\hat{Y}_1=2{,}388+0{,}466X_{15}.$$
$$(0{,}104)\quad(0{,}201)$$

If the patient had a lacunar ischemic stroke, their multivariate weighted assessment will be approx. 0.466 points higher, on average, than that of patients with more severe forms of stroke.

Thus, from the perspective of a more favorable condition of a patient from Group I, the presence of lacunar ischemic stroke is significant, and adverse effects on the patient's condition will be expected from Stage 2a chronic heart failure and history of a large ischemic stroke.

Regression model 1 for the Group II is as follows:

$$\hat{Y}_12=3.065-0.572X_{17}.$$
$$(0.239)\quad(0.263)$$

Patients with a medium ischemic stroke have a multivariate weighted assessment that is 0.572 points lower, on average, than that of patients with other types of stroke.

Regression model 2 for the Group II is as follows:

$$Y_2=2.530+1.115X_{16}.$$
$$(0.200)\quad(0.393)$$

Patients diagnosed with mini ischemic stroke, when compares to patients with other types of stroke, have a multivariate weighted assessment that is on average 1.115 points higher. It can be concluded that for the patients of Group II two types of stroke have a varied impact on their overall condition: medium stroke in the decline of their condition, mini stroke in the improvement.

Regression model 1 for the Group III is as follows:

$$Y_3=2.206-3.235X_{12}.$$
$$(0.274)\quad(1.858)$$

Second stroke in the same territory reduces the patient's multivariate weighted assessment by approx. 3.235 versus patients without the second stroke or with the second stroke in a different territory.

Regression model 2 for the Group III is as follows:

$$Y_3=1.852+1.305X_8.$$
$$(0.303)\quad(0.650)$$

The diagnosis of Stage 1 chronic heart failure was a factor of a better condition of a patient by an average of 1.305 points (vs. patients with other stages of CHF). In this way, the modeling results showed that for the patients from Group III the most negative influence on their condition was caused by the second stroke in the same territory, and the favorable influence, by Stage 1 chronic heart failure as compared to more severe stages of CHF. The results of our modeling follow in **Table 4**.

DISCUSSION

Constrictive lesion of the major arteries of the head and the neck per se is a significant risk factor of ACVA development [15, 16]. The risk increases depending on the decree of vessel constriction [6]. The onset and progress of ischemic strokes are influenced by other adverse risk factors of ACVA, mainly of vascular nature: arterial hypertension of various severity, chronic heart failure of various severity, cardiac arrhythmia, history of ACVA, etc. [8, 10, 12]. In analyzing the problem of interrelation of carotid stenosis and ischemic stroke, contemporary studies mainly focus on the surgical aspect only, viz. carotid endarterectomy and its role in the post-stroke prognosis and rehabilitation [17, 18].

To evaluate the condition of a stroke patient, clinical scales (indices) are used and changes of their values over time are considered; without doubt, this provides information for the planning of treatment and control of its efficiency. Much interest lies in the combination of all three private indices in a single multivariate assessment and in the analysis of its values for the selected groups of patients. Regression models enable involvement of a wide variety of factors and mathematical representation of their connection with resultative values. When analyzing the available literature, we could not find similar studies. At the same time, this aspect of studying the results and prognosis of the progress of ischemic stroke with concurrent carotid stenosis of various severity seems vital and requiring more effort.

CONCLUSION

Mathematical modeling involving development of a multivariate weighted assessment facilitates the determination of the influence of one or another risk factor for stroke on the course of ischemic stroke in patients with varying degrees of carotid stenosis.

Regression models enable involvement of a wide variety of factors and a mathematical representation of their connection with resultative values. The developed logistic models show the degree of positive or negative impact of various risk factors on the course of ischemic stroke in the studies groups of patients.

ADDITIONAL INFORMATION	ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ
Ethical expertise. Minutes No. 202 of the meeting of the Committee on Bioethics at SamSMU dated October 09, 2019.	***Этическая экспертиза.*** Протокол №202 заседания комитета по биоэтике при СамГМУ от 09 октября 2019 г.
Study funding. The study was the authors' initiative without external funding.	***Источник финансирования.*** Работа выполнена по инициативе авторов без привлечения финансирования.
Conflict of Interest. The author declares that there are no obvious or potential conflicts of interest associated with the content of this article.	***Конфликт интересов.*** Автор декларирует отсутствие явных и потенциальных конфликтов интересов, связанных с содержанием настоящей статьи.
Contribution of individual authors. I.E. Poverennova, T.V. Romanova – developed the study concept, performed detailed manuscript editing and revision; A.S. Tkachenko, N.P. Persteneva – has been responsible for scientific data collection, its systematization and analysis, wrote the first draft of the manuscript; manuscript editing. All authors gave their final approval of the manuscript for submission, and agreed to be accountable for all aspects of the work, implying proper study and resolution of issues related to the accuracy or integrity of any part of the work.	***Участие авторов.*** И.Е. Поверенннова, Т.В. Романова – разработка концепции исследования, редактирование текста. А.С. Ткаченко, Н.П. Перстенева – сбор и обработка научного материала, написание текста, редактирование текста. Все авторы одобрили финальную версию статьи перед публикацией, выразили согласие нести ответственность за все аспекты работы, подразумевающую надлежащее изучение и решение вопросов, связанных с точностью или добросовестностью любой части работы.

REFERENCES / ЛИТЕРАТУРА

1. *Stroke: A Guide for Doctors*. Eds. Stakhovskaya LV, Kotov SV. M., 2013. (In Russ.). [*Инсульт: Руководство для врачей*. Под ред. Стаховской Л.В., Котова С.В. М., 2013]. ISBN 978-5-6040008-6-1

2. Kandyba DV. Stroke. *Russian Family Doctor*. 2016;20(3):5-15. (In Russ.). [Кандыба Д.В. *Инсульт. Российский семейный врач*. 2016;20(3):5-15]. DOI: 10.17816/rfd201635-15

3. Gusev EI, Skvortsova VI, Krylov VV. Reducing mortality and disability from vascular diseases of the brain in the Russian Federation. *Nevrologicheskij vestnik*. 2007;1:128-133. (In Russ.). [Гусев Е.И., Скворцова В.И., Крылов В.В. Снижение смертности и инвалидности от сосудистых заболеваний мозга в Российской Федерации. *Неврологический вестник*. 2007;1:128-133].

4. Fedorina MA, Davydkin IL, Germanova OA. Atherosclerosis of the carotid arteries: clinical significance (literature review). *Bulletin of the Medical Institute «REAVIZ» (rehabilitation, doctor and health)*. 2023;13(3):41-46. [Федорина М.А., Давыдкин И.Л., Германова О.А. Атеросклероз сонных артерий: клиническое значение (обзор литературы). *Вестник медицинского института «РЕАВИЗ»: реабилитация, врач и здоровье*. 2023;3:41-46]. DOI: 10.20340/vmi-rvz.2023.3.CLIN.2

5. Vishnyakova AYu, Berdalin AB, Golovin DA, et al. Echographic features of the structure of atherosclerotic plaques in carotid ischemic stroke. *Neurology, neuropsychiatry, psychosomatics*. 2020;2:23-29. [Вишнякова А.Ю., Бердалин А.Б., Головин Д.А., и др. Эхографические особенности структуры атеросклеротических бляшек при каротидном ишемическом инсульте. *Неврология, нейропсихиатрия, психосоматика*. 2020;2:23-29]. DOI: 10.14412/2074-2711-2020-2-23-29

6. Vishnyakova AYu, Berdalin AB, Golovin DA, et al. Similarities and differences in echographic signs of atherosclerotic lesions of the extracranial sections of the brachiocephalic arteries in carotid and vertebrobasilar ischemic stroke. *Cardiovascular Therapy and Prevention*. 2021;1:28-34. [Вишнякова А.Ю., Бердалин А.Б., Головин Д.А., и др. Сходства и различия эхографических признаков атеросклеротического поражения экстракраниальных отделов брахиоцефальных артерий при каротидном и вертебрально-базилярном ишемическом инсульте. *Кардиоваскулярная терапия и профилактика*. 2021;1:28-34]. DOI: 10.15829/1728-8800-2021-2437

7. Kargiotis O, Safouris A, Magoufis G, et al. The Role of Neurosonology in the Diagnosis and Management of Patients with Carotid Artery Disease: A Review. *J Neuroimaging*. 2018;3:239-251. DOI: 10.1111/jon.12495

8. Fei H, Fei-Fei Z, Wang Q, et al. Prevalence and Risk Factors of Cerebral Small Vessel Disease in a Chinese Population-based Sample. *J Stroke*. 2018;20(2):239-246. DOI: 10.5853/jos.2017.02110

9. van Dam-Nolen DHK, Truijman MTB, van der Kolk AG. Carotid Plaque Characteristics Predict Recurrent Ischemic Stroke and TIA: The PARISK (Plaque At RISK) Study. *JACC Cardiovasc Imaging*. 2022;15(10):1715-1726. DOI: 10.1016/j.jcmg.2022.04.003

10. Fedin AI, Starykh EV, Baranova OA, et al. Endothelial dysfunction, vascular inflammation and oxidative stress in patients with chronic cerebral ischemia with stenosis of the internal carotid arteries. *Medical Affairs*. 2018;1:66-71. (In Russ.). [Федин А.И., Старых Е.В., Баранова О.А., и др. Дисфункция эндотелия, сосудистое воспаление и окислительный стресс у пациентов с хронической ишемией мозга при стенозах внутренних сонных артерий. *Лечебное дело*. 2018;1:66-71].

11. Chang RW, Tucker LY, Rothenberg KA, et al. Incidence of Ischemic Stroke in Patients With Asymptomatic Severe Carotid Stenosis Without Surgical Intervention. *JAMA*. 2022;327(20):1974-1982. DOI: 10.1001/jama.2022.4835

12. Gimaev RKh, Krestyaninov MV, Lankov VA, et al. Features of morphofunctional parameters of the heart in patients in the acute stage of ischemic stroke of various localization. *Neurological Bulletin. Journal named after V.M. Bekhterev*. 2018;1:93. [Гимаев Р.Х., Крестьянинов М.В., Ланков В.А., и др. Особенности морфофункциональных параметров сердца у больных в острой стадии ишемического инсульта различной локализации. *Неврологический вестник. Журнал им. В.М. Бехтерева*. 2018;1:93]. DOI: 10.17816/nb119904

13. Riganello F, Chatelle C, Schnakers C, et al. Heart Rate Variability as an Indicator of Nociceptive Pain in Disorders of Consciousness? *J Pain Symptom Manage*. 2019;57(1):47-56. DOI: 10.1016/j.jpainsymman.2018.09.016

14. Abbott AL. Extra-Cranial Carotid Artery Stenosis: An Objective Analysis of the Available Evidence. *Front Neurol*. 2022;13:739999. DOI: 10.3389/fneur.2022.739999

15. Bir SC, Kelley RE. Carotid atherosclerotic disease: A systematic review of pathogenesis and management. *Brain Circ*. 2022;8(3):127-136. DOI: 10.4103/bc.bc_36_22

16. Yaghi S, de Havenon A, Rostanski S, et al. Carotid Stenosis and Recurrent Ischemic Stroke: A Post-Hoc Analysis of the POINT Trial. *Stroke*. 2021;52(7):2414-2417. DOI: 10.1161/strokeaha.121.034089

17. Kazantsev AN, Porkhanov VA, Khubulava GG. Comparative results of emergency carotid endarterectomy and emergency carotid angioplasty with stenting in the acute period of ischemic stroke. Results of a multicenter study. *Emergency medical care. Journal named after N.V. Sklifosovsky*. 2021;10(1):33-47. (In Russ.). [Казанцев А.Н., Порханов В.А., Хубулава Г.Г. Сравнительные результаты экстренной каротидной эндартерэктомии и экстренной каротидной ангиопластики со стентированием в острейшем периоде ишемического инсульта. Результаты многоцентрового исследования. *Неотложная медицинская помощь. Журнал им. Н.В. Склифосовского*. 2021;10(1):33-47]. DOI: 10.23934/2223-9022-2021-10-1-33-47

18. Chang RW, Tucker L, Rothenberg KA, et al. Incidence of Ischemic Stroke in Patients With Asymptomatic Severe Carotid Stenosis Without Surgical Intervention. *JAMA*. 2022;327(20):1974-1982. DOI: 10.1001/jama.2022.4835