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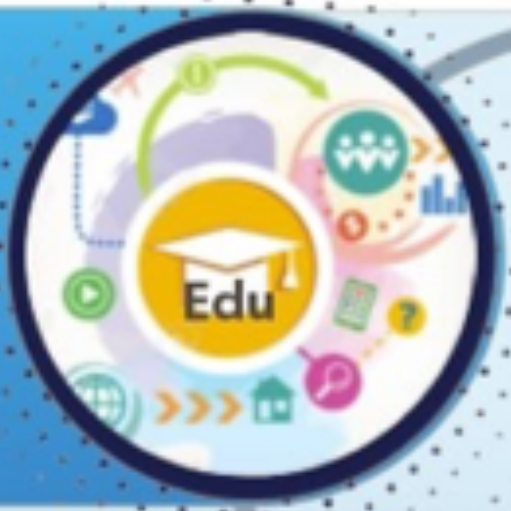

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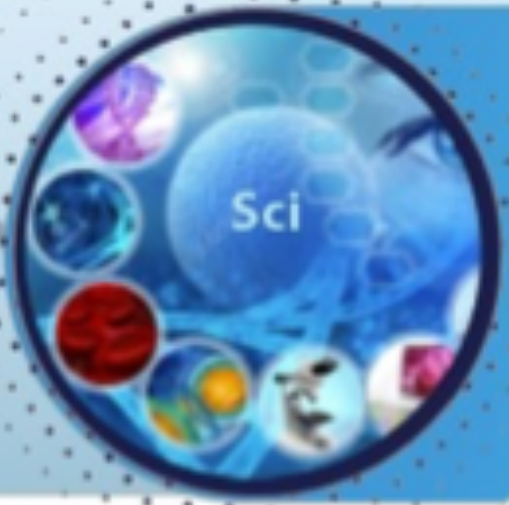

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Correlations of Carotid Artery Stenosis and Contralateral Compensatory Mechanisms in Ischemic Stroke Subtypes: hemodynamic analysis

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ABSTRACT

Background: *Carotid artery stenosis significantly affects the risk of IS by affecting cerebral blood flow. Narrowing of the carotid arteries may lead to decreased perfusion of the brain, which may provoke neurological deficits. Moreover, the body may activate compensatory mechanisms to maintain adequate cerebral blood flow despite significant narrowing of the arteries. Understanding the relationship between carotid artery stenosis and cerebral blood flow velocity is important for effective clinical decision making and patient management.*

Material and methods: *We collected clinical and instrumental data from patients with IS admitted clinic over a period of 1 year (n=240). All patients included in the study underwent ultrasound duplex scanning of the carotid arteries and spine (mean age 62.3±11.2 years), which was performed during their stay in the intensive care unit of neurology. All patients underwent NIHSS and mRankin score, computed tomography and ultrasound examination of the carotid arteries. Carotid plaques were defined by the presence of intimal thickening ≥1 mm. The severity of carotid stenosis was assessed using the NASCET method 1st day of hospitalization. NIHSS and mRankin scales were estimated first, third, seventh and 12 days.*

Results: *There were no significant differences between the 2 groups in terms of clinical characteristics of the patients included in the study. The average clinical score in patients with two subtypes of IS first day of hospitalization*

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was 17.8±3.2 on the NIHSS scale and 4,5±0,5 on the modified Rankin scale, which corresponds to moderate to severe level of the disease. The mRankin scale and NIHSS scale showed similar results that, in patients with significant atherosclerotic stenosis, the highest score were revealed in high degree carotid stenosis groups. Although there was a positive change in the indicators over time, in patients with significant stenosis these figures remained high even after 12 days of analysis and it should be noted that the difference between the groups was very notable.

Conclusion: *According to our study, patients with carotid artery stenosis that is not hemodynamically significant have a more positive prognosis. However, even with standard treatment, patients with high carotid artery stenosis have a recovery process that is as dynamically significant as those with hemodynamically insignificant stenosis. This study highlights the complex relationship between carotid artery stenosis and cerebral hemodynamics, which has important implications for the management and treatment of these patients.*

Key words: *IS, carotid artery stenosis, blood flow velocity, NIHSS, mRankin scale, NASCET criteria.*

INTRODUCTION

Stroke remains the second leading cause of death and the third leading cause of disability.

From 1990 to 2019, stroke increased substantially 70.0% increase in stroke incidence, 43.0% increase in stroke deaths, 102.0% increase in common stroke subtypes, with the bulk of the global stroke burden occurring in low- and middle-income countries [1].

Secondary prevention of ischemic stroke (IS) is based on accurate definition of the underlying etiology of stroke, which in a meta-analysis the risk of recurrent stroke/TIA in patients with non-stenotic carotid plaques was 2.6/100 person-years and increased to 4.9/100 person-years in the presence of intraplaque hemorrhage.

Furthermore, even in cardioembolic strokes (CS), non-stenotic carotid artery disease (<50%) has been shown to be present as a competing source of stroke in 9–12% [2].

Cerebral autoregulation is an internal protective mechanism that maintains cerebral blood flow at a relatively constant level despite fluctuations in cerebral perfusion pressure or arterial pressure [3].

In particular, the carotid arteries are a critical source of stroke due to their susceptibility to atherosclerotic plaque accumulation and associated thromboembolic events that can lead to stroke [5].

Collateral circulation involves the opening of alternative vascular channels located distal to the occluded artery, resulting in massive vasodilation, representing a more important compensatory mechanism that maintains the viability of the ischemic penumbra [6].

Ultrasound examination of the carotid and vertebral arteries is now routinely performed and the main functions are the detection of significant stenosis of the carotid arteries and the etiologic classification of stroke according to the TOAST criteria [7].

Despite the fact that the results of ultrasound examination of the carotid vascular system in patients with IS have been studied in many studies, the analysis of the characteristics of contralateral vessels and compensatory changes in the disease has not yet been resolved.

The aim of the study: to analyze the relationship between the compensatory features of ipsilateral and transhemispheric extracranial blood vessels and the severity of the disease in groups of atherothrombotic and cardioembolic subtypes of IS.

MATERIALS AND METHODS

We collected clinical and instrumental data from patients with IS admitted to the intensive neurology department of the Tashkent Medical Academy clinic over a period of 1 year (N=240).

All patients included in the study underwent ultrasound duplex scanning of the carotid arteries and spine (mean age 62.3±11.2 years), which was performed during their stay in the intensive care unit of neurology. All patients underwent a standardized neurological examination on admission, and the National Institutes of Health Stroke Scale (NIHSS) score was obtained to quantify stroke severity, and computed tomography (CT or MRI) was performed after hospitalization to identify the ischemic lesion and its extent. Regarding the etiopathogenetic mechanism of stroke, patients were classified into five categories according to the definitions of the ORG 10172 TOAST Classification system; patients in our study were predominantly of atherothrombotic and cardioembolic subtype of IS. All patients underwent ul-

trasound examination of the carotid arteries and vertebrae using a conventional ultrasound system (equipped with a multifrequency (7.5–13 MHz) linear transducer). Carotid plaques were defined by the presence of intimal thickening ≥1 mm. Plaque structure was assessed in B-mode and defined according to its echogenicity: hypoechoic (soft), hyperechoic (dense), calcifying, or mixed/heterogeneous [14].

The severity of carotid stenosis was assessed using the NASCET method 1 day of hospitalization. NIHSS and mRankin scales were estimated first, third, seventh and 12 days.

RESULTS

Of the 240 patients included in the registry, 144 (55%) patients were classified as having atherothrombotic stroke and 108 (45%) were patients with CS. Of these, internal carotid artery (ICA) was able to be assessed bilaterally in all patients who were included in the analysis (Table 1).

Table 1

Clinical and hemodynamic characteristics of patients with IS and its subtypes

Indicators	All patients (n=240)	Atherothrombotic subtype (n=132)	Cardioembolic subtype (n=108)	p
Age, years	62,3±11,2	66±11	58±14	0,168
Males, n (%)	160 (53,3%)	103 (57,3%)	49 (41,2%)	0,057
BWI, kg/m^2	24,1±3,1	24,0±3,0	24,3±3,1	0,911
Hypertension, n (%)	197 (82,1%)	105 (79,6%)	92 (85,2)	0,066
SBP, mm Hg	137,6±21,2	138.5±17,4	136,4±15.4	0,543
DBP, mm Hg	81,4±9,6	82.3±10,2	80.1±8.3	0,256
Smokers, n (%)	40 (16,7%)	23 (17,4%)	17 (15,7%)	0,355
Diabetes mellitus, n (%)	56 (23,3%)	32 (24,2%)	24 (22,2%)	0,799
Lesion location (n (%) Frontal lobe Occipital lobe Temporal lobe Parietal lobe Cerebellum	48 (20%) 54 (22,5%) 56 (23,3%) 46 (19,2%) 36 (15%)	28 (21,2%) 31 (23.5%) 33 (25%) 26 (19,7%) 14 (10,6%)	20 (18,5%) 23 (21,3%) 23 (21,3%) 20 (18,5%) 22 (20,4%)	0,156 0,237 0,566 0,433 0,04

There were no significant differences between the 2 groups in terms of clinical characteristics of the patients included in the study. It can only be seen that the stroke pool was higher in CS group (p-0.04).

To objectify the condition of patients in subtypes with IS, an assessment of their neurological status was carried out using two complementary scales - the modified Rankin scale and NIHSS. The average clinical score upon admission in patients with two subtypes of IS first day of hospitalization was 17.8±3.2 on the NIHSS scale and 4,0±0,5 on the modified Rankin scale, which corresponds to moderate to severe level of the disease (Table 2).

The dynamics of both scales decreased without statistical differences between groups.

For both carotid arteries in each patient, the degree of stenosis was measured according to the NASCET criteria. The ICA could be assessed bilaterally in all patients with atherothrombotic and CS (Table 3).

Table 2

Assessment of neurological status in the dynamics of the disease in patients in the acute period of stroke according to clinical scales and stroke subtypes (n=240)

	Atherothrombotic subtype n =132	Cardioembolic subtype n=108		Atherothrombotic subtype n =132	Cardioembolic subtype n=108	
	NIHSS scale		p-value	mRankin scale		p-value
1 day	18,1±3,1	17,5±3,4	0,211	4,1±0,6	3,9±0,4	0,256
3 day	14,9±1,3	15,2±1,2	0,424	3,6±0,4	3,4±0,7	0,116
7 day	10,1±0,9	9,1±1,1	0,665	2,8±0,5	2,4±0,5	0,07
12 day	7,6±1,1	6,7±0,8	0,103	2,5±0,4	2,2±-0,3	0,09

Table 3

Ultrasound indices of the carotid and vertebral arteries on both sides according to subtypes of IS.

	Atherothrombotic (n = 132)	Cardioembolic (n = 108)	P value <
Carotid plaques (on both sides)	107 (81%)	89 (82%)	0.89
Carotid artery stenosis 0%-50%	56 (35.5%)	57 (48%)	0.034
Carotid artery stenosis 50%-70%	40 (43.8%)	28 (15%)	0.004
Carotid artery stenosis ≥70%	11 (8.3%)	4 (3,7%)	0.023
Uneven surface	46 (34.8%)	13 (12.1%)	0.028
Calcified echostructure	40 (16.6%)	11 (10.2%)	0.043
Mixed echostructure	29 (16%)	55 (34.8%)	0.053
Carotid artery anomaly	10 (7.6%)	9 (8.3%)	0.178
Vertebral artery anomaly	12 (9.1%)	7 (6.5%)	0.07

All patients underwent statistical analysis based on the development of atherosclerotic plaque (ASP) in the carotid basin. The prevalence of non-stenotic hemodynamically insignificant carotid plaque on both sides was 196/240 (82%) without intergroup differentiation. The prevalence of hemodynamic significantly nonstenotic carotid plaques in the atherothrombotic and cardioembolic subgroups was 107/132 (81%) and 89/108 (82%), respectively, whereas 4/108 (3.7%) patients with CS and 11/132 (8.3%) with atherothrombotic stroke had bilateral stenotic hemodynamically significant carotid plaques, that were referred for angiosurgical interventions. In the comparative analysis of the degree of stenosis of the carotid arteries, we can see that in patients with IS, the degree of stenosis is significantly higher in the 2 groups,

especially in the proportion of patients with 50-70% and more than 70% (p-0.04, p-0.023). There are also differences in the structure of atherosclerotic plaques according to echocardiography (EchoCG). The prevalence of bilateral atherosclerotic plaques in atherothrombotic subgroups was 107/132, of which 56/132 patients had lesions up to 50% of the right and left carotid basin stenosis and peak systolic velocity >125 m/sec, 40 (43.8%) patients had stenosis of the distal internal carotid artery (50%-70%). Of all these patients, local thickening of the intima media thickness in the common carotid artery up to 1.25±0.25 mm was analyzed. In 2 (2.7%) patients, pathological changes in the wall of extracranial vessels were not detected. All patients had local thickening of the IMT up to 1.2±0.5 mm; in 6 patients (8.9%) no pathological changes in the wall of extracranial vessels were detected. In patients with CS, non-stenotic carotid plaques were significantly more common ipsilateral to the stroke than contralateral (57/108 [48%] P = 0.034). In patients with atherothrombotic stroke, nonstenotic carotid plaques were also nominally more common ipsilateral to the stroke side (31/132 [23.9%] (P = 0.99). When plaque features were analyzed, none was significantly associated with ipsilateral stroke in the cardioembolic subgroup. In the atherothrombotic subgroup, plaque irregularity, plaque hypodense were significantly associated with ipsilateral stroke (Table 4).

Table 4

The main indicators of linear blood flow velocity and stenosis level are shown

	Atherotrombotic subtype n=132		Cardioembolic subtype n=108		
Degree of stenosis of carotid artery	Amount of patients	Speed of blood flow	Amount of patients	Speed of blood flow	P value
0%	29 (19%)	42,4±4,6	19 (18%)	48,6±4,1	0,09
0-50%	56 (35.5%)	66,2±6,1	57 (48%)	78,2±5,7	0,08
50-70%	40 (43.8%)	82,4±4,1	28 (15%)	88,1±4,9	0,133
>70%	11 (1.6%)	108,2±3,4	4 (3%)	114,2±3,9	0,08

When assessing the blood flow velocity in the carotid artery in relation to the degree of stenosis, it can be observed that the blood flow velocity in the carotid vessels increases with the degree of stenosis in both groups of patients, although there is a difference in the number of patients, but no difference in blood flow in the carotid basin between groups was observed, regardless of the stroke subtype (Table 5).

Regardless of the type of stroke, when comparing the dynamic NIHHS scores of patients according to the degree of stenosis, it can be observed that with increasing stenosis, the severity of stroke in patients also increased, that is, the lowest score was recorded in the group without stenosis - 12.5±2.1, and the highest score was recorded in the group with hemodynamically significant stenosis (70%) - 24.6±3.9, and the difference in results was statistically significant (p-0.011). The dynamics show a positive improvement in the results in all groups. At 12 days after the stroke, the lowest NIHSS score was recorded in the group with no stenosis, while the highest score was recorded in the group with significant stenosis. The differences in NIHSS scores at all time points were statistically significant (Table 6).

Table 5

Relationship between stenosis degree of carotid artery and NIHHS scale

Days of stroke	Degree of stenosis of carotid artery				P value
	No stenosis n=48	0-50% n=113	50-70% n=68	>70% n=15	
1 day	12,5±2,1	16,5±3,2	19,5±4,5	24,6±3,9	0,011
3 day	10,9±1,8	12,9±2,9	16,9±2,8	21,9±4,8	0,009
7 day	5,1±1,6	9,1±3,1	13,1±2,6	17,1±4,1	0,016
12 day	2,4±1,6	7,6±2,6	9,2±2,4	12,6±3,2	<0,001

Table 6

Relationship between stenosis degree of carotid artery and mRankin scale

Days of stroke	Degree of stenosis of carotid artery				P value
	No stenosis n=48	0-50% n=113	50-70% n=68	>70% n=15	
1 day	2,9±0,8	3,5±0,7	4,5±0,7	5,1±0,4	<0,001
3 day	2,4±0,5	3,0±0,8	3,9±0,8	4,6±0,5	<0,001
7 day	2,0±0,6	2,8±0,5	3,2±0,6	3,9±0,6	<0,001
12 day	1,6±0,4	2,3±0,6	2,7±0,4	3,3±0,4	<0,001

The mRankin scale indicators also showed similarities with the NIHSS scale indicators, and in patients with significant atherosclerotic stenosis, the highest score on the scale between the groups was 5.1±0.4 points (p<0.001). Although there was a positive change in the indicators over time, in patients with significant stenosis these figures remained high even after 12 days of analysis (3.3±0.4), and it should be noted that the difference between the groups was very notable (p-<0.001).

DISCUSSION

The results of this study provide crucial insight into the hemodynamic consequences of carotid artery stenosis in stroke patients. Our results show that a significant increase in blood flow velocity is associated with a higher degree of stenosis of the right and left carotid arteries, as well as the contralateral left

internal carotid artery in patients with both types above mentioned stroke, as well as suggested another investigations too [8]. These data suggest that the body initiates compensatory mechanisms to maintain adequate cerebral perfusion when arteries are significantly narrowed. Increased velocity in these arteries may reflect an adaptive response aimed at ensuring sufficient blood flow to the brain despite the obstruction caused by stenosis. Such compensatory mechanisms are of great importance to clinicians when assessing stroke risk and developing personalized treatment strategies [9].

Our study results show that a high degree of stenosis is associated with a more severe stroke, and since atherosclerosis is a common phenomenon, the severity of the disease is inextricably linked to the severity of the stroke, which are Jusufovich M. et al. also confirmed this kind of findings by their study results [10].

However, it should be noted that, regardless of the degree of stenosis, the NIHSS and Rankin scales, which assess the patient's general condition and stroke severity, changed positively against the background of standard treatment in groups [11].

Interestingly, the lack of significant differences in blood flow velocity at different levels of stenosis in patients with atherothrombotic stroke indicates a more complex hemodynamic response that is not as simple as that seen in patients with CS. This variability highlights the importance of individual assessment rather than relying solely on the severity of stenosis to make clinical decisions [12].

The study also highlights the utility of advanced ultrasound techniques in monitoring these hemodynamic changes, offering a noninvasive and accurate method to inform clinical practice. These methods are critical to assess the dynamic response to stenosis and adapt therapeutic approaches accordingly [13].

CONCLUSION

According to our study, patients with carotid artery stenosis that is not hemodynamically significant have a relatively mild stroke course. However, even with standard treatment, patients with high carotid artery stenosis have a recovery process that is as dynamically significant as those with hemodynamically insignificant stenosis. This study highlights the complex relationship between carotid artery stenosis and cerebral hemodynamics, which has important implications for the management and treatment and to optimize stroke prevention of these patients.

Consent for publication – The study is valid, and recognition by the organization is not required. The author agrees to open publication.

Availability on data and material – available.

Competing interest – no.

Financing – no financial support has been provided for this work.

Conflict of interests – The authors declare that there is no conflict of interest.

ABBREVIATION

IS - Ischemic Stroke
CES - Cardioembolic stroke
NIHSS - National Institute Health Stroke Scale
TOAST - Trial of Original Acute Stroke Treatment
mRankin – modified Rankin scale
MRI – Magnetic Resonance Imaging
CT - Computed Tomography
NASCET – North American Symptomatic Carotid Endarterectomy Trial
ICA – Internal Carotid Artery
ASP – atherosclerotic plaque
EchoCG - Echocardiography

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ISHEMIK INSULT PODTIPLARIDA KAROTID ARTERIYALAR STENOZI VA KONTRALATERAL KOMPENSATOR MEHANIZMLARNING O'ZARO BOG'LIQLIGI: GEMODINAMIK TAHLIL

EGAMNAZAROVA Z.R., MUSAYEVA Y.A.

1TOSHKENT TIBBIYOT AKADEMIYASI

ABSTRAKT

Kirish: Karotid arteriya stenozi miya qon oqimiga ta'sir qilish orqali ishemik insult rivojlanish xavfini sezilarli darajada oshiradi. Uyqu arteriyalarning torayishi miya perfuziyasining pasayishiga olib kelib, nevrologik yetishmovchilikning kuchayishiga va kasallikni klinik jihatdan og'ir kechishini yuzaga keltiradi. Bundan tashqari, tomirlarning sezilarli torayishiga qaramay, organizm miya qon oqimini etarli darajada ushlab turish uchun kompensator mexanizmlarni faollashtirishi mumkin. Karotid arteriya stenozi va miya qon oqimi tezligi o'rtasidagi munosabatni tushunish samarali klinik qaror qabul qilish va bemorni keying bosqichda boshqarish uchun muhimdir.

Material va metodlar: 1 yil davomida TTA klinikasiga ishemik insult tashxisi bilan yotqizilgan bemorlardan (n=240) klinik va instrumental ma'lumotlar to'plandi. Tadqiqotga kiritilgan barcha bemorlar (o'rtacha yoshi 62,3 ± 11,2) intensiv nevrologiya bo'limida bo'lish paytida uyqu va umurtqa arteriyalari ultratovushli dupleks tekshiruvidan o'tkazilib, stenoz og'irlik darajasi NASCET kriteriyasi asosida baholandi. Bemorlar kasallik og'irlik darajasini aniqlash uchun NIHSS va mRankin shkalalari, kompyuter tomografiyasi va laborator tahlillar yordamida baholandi. Karotid intima media qalinligi ≥1 mm qalinlashuv mavjudligi bilan o'lchandi. Nevrologik yetishmovchilik NIHSS va mRankin shkalasi orqali 1-chi, 3-chi, 7-chi va 12-chi sutkalarda baholandi.

Natija: Tadqiqotga kiritilgan bemorlarning klinik xususiyatlari bo'yicha 2 guruh o'rtasida sezilarli farq topilmadi. Ishemik insultning 1-chi sutkasida ikkala podtip guruhi bemorlarida o'rtacha klinik ko'rsatkich NIHSS shkalasi bo'yicha 17,8±3,2 va modifikatsiyalangan Rankin shkalasi bo'yicha 4,5±0,5 ni tashkil etdi, bu kasallikning o'rta va og'ir darajasiga to'g'ri kelib, stenoz darajasi yuqori bo'lgan bemorlar guruhlarida aniqlangan. Vaqt o'tishi bilan ko'rsatkichlarda ijobiy o'zgarishlar bo'lsada, sezilarli stenozli bemorlarda bu ko'rsatkichlar 12 kunlik tahlildan keyin ham yuqori bo'lib qoldi va guruhlar o'rtasidagi farq juda sezilarli ahamiyat kasb etdi.

Kalit so'zlar: II, uyqu arteriyasi stenozi, qon oqish tezligi, NIHSS, mRankin shkalasi, NASCET kriteriyasi.

КОРРЕЛЯЦИИ МЕЖДУ СТЕНОЗОМ СОННОЙ АРТЕРИИ И КОНТРАЛАТЕРАЛЬНЫМИ КОМПЕНСАТОРНЫМИ МЕХАНИЗМАМИ ПРИ ПОДТИПАХ ИШЕМИЧЕСКОГО ИНСУЛЬТА: ГЕМОДИНАМИЧЕСКИЙ АНАЛИЗ

ЭГАМНАЗАРОВА З.Р., МУСАЕВА Ю.А.

ТАШКЕНТСКАЯ МЕДИЦИНСКАЯ АКАДЕМИЯ

Введение: Стеноз сонной артерии значительно влияет на риск ИИ, влияя на мозговой кровоток. Сужение сонных артерий может привести к снижению перфузии мозга, что может спровоцировать неврологический дефицит.

Материалы и методы: Мы собирали клинические и инструментальные данные у пациентов с ИИ, поступивших в клинику в течение 1 года (n=240). Всем пациентам, включенным в исследование, было проведено ультразвуковое дуплексное сканирование сонных артерий и позвоночника, которое проводилось во время их пребывания в отделении интенсивной терапии неврологии.

Результаты: не было выявлено значимых различий между 2 группами с точки зрения клинических характеристик пациентов, включенных в исследование. Средний клинический балл у пациентов с двумя подтипами ИИ в первый день госпитализации составил 17,8±3,2 по шкале NIHSS и 4,5±0,5 по модифицированной шкале Рэнкина, что соответствует умеренной и тяжелой степени заболевания.

Заключение: согласно нашему исследованию, пациенты со стенозом сонной артерии, который не является гемодинамически значимым, имеют более позитивный прогноз. Однако даже при стандартном лечении у пациентов с высоким стенозом сонной артерии процесс восстановления является таким же динамически значимым, как и у пациентов с гемодинамически незначимым стенозом. Это исследование подчеркивает сложную взаимосвязь между стенозом сонной артерии и церебральной гемодинамикой, что имеет важные последствия для ведения и лечения этих пациентов.

Ключевые слова: ИИ, стеноз сонной артерии, скорость кровотока, NIHSS, шкала mRankin, критерии NASCET.