

DOI: 10.34921/amj.2024.1.001

**İŞEMİK İNSULT OLAN XƏSTƏLƏRDƏ YUXU ARTERİYASI ATEROSKLEROZUNUN
SONOQRAFİK XÜSUSİYYƏTLƏRİ****R.Ya.Abdullayev¹, A.S.Yefimenko¹, L.A.Sysun¹, A.V.Loqvinenko¹,
N.F.Posoxov², R.R.Abdullayev¹, T.A.Dudnik³, A.Q.Kiriçenko⁴, N.V.Tomax⁴**¹*Xarkov Milli Tibb Universiteti, Xarkov, Ukrayna;*²*Ukrayna Milli Tibb Elmləri Akademiyası Nevrologiya, Psixiatriya və Narkologiya İnstitutunun
Neyrocərrahlik şöbəsi, Xarkov, Ukrayna;*³*Poltava Dövlət Tibb Universiteti, Poltava, Ukrayna;*⁴*Ukrayna Səhiyyə Nazirliyinin Tibbi və Sosial Əlillik Problemləri üzrə Ukrayna Dövlət Tədqiqat
İnstitutu, Dnepr, Ukrayna*

Xülasə. Məqalədə gənc, orta və ahıl yaşda işemik insult (İİ) keçirən 127 xəstənin (orta yaş 56 ± 7 il) yuxu arteriyası aterosklerozunun sonografik xüsusiyyətlərinin araşdırılmasına dair məlumat verilir. Müqayisə qrupunu 51 nəfər ürək-damar xəstəliyi riski müəyyən edilmiş, lakin anamnezində insult qeyd edilməyən şəxs təşkil etmişdir.

Müəyyən edilmişdir ki, əsas qrupun xəstələrində arterial hipertenziyaya və 2-ci tip şəkərli diabetə müqayisə qrupundakına nisbətən statistik etibarlı şəkildə çox rast gəlinir. Yuxu arteriyalarında aterosklerotik düyünlərin lokalizasiya etməsinin insultun gedişindən asılılığı müəyyənləşdirilmişdir. Xəstələrdən 79 nəfərdə ($62,2 \pm 4,3\%$) insultun gedişi ağır, 27 nəfərdə ($21,3 \pm 3,6\%$) orta, 21 nəfərdə ($16,5 \pm 3,3\%$) yüngül olmuşdur.

Tədqiqat göstərmişdir ki, ağır gedişli insult keçirən xəstələrdən $73,4 \pm 5,0\%$ -də yuxu arteriyası bifurkasiyasından 2 sm aralıda yerləşən 3-cü segmentdə aterosklerotik düyün olur. Ağır gedişli insult olan xəstələrdə 2 ($62,0 \pm 5,5\%$) və 3 ($48 \pm 5,6\%$) segmentdə birlikdə aterosklerotik düyünə rast gəlinmiş, intima-media qışalarının qalınlığı $2,41 \pm 0,34$ mm və aterosklerotik düyünlərin diametri $3,62 \pm 4,3$ mm olmuş, həmçinin yuxu arteriyasının stenozu ($62,5 \pm 6,7\%$) daha çox yayılmışdır.

Açar sözlər: sonografiya, işemik insult, yuxu arteriyasının ateroskleroza

Ключевые слова: сонография, ишемический инсульт, каротидный атеросклероз

Key words: ultrasonography, ischemic stroke, carotid atherosclerosis

**SONOGRAPHIC CHARACTERISTICS OF CAROTID ATHEROSCLEROSIS
IN PATIENTS WITH ISCHEMIC STROKE****R.Ya.Abdullaiev¹, A.S.Yefimenko¹, L.A.Sysun¹, A.V.Logvinenko¹,
N.F.Posokhov², R.R.Abdullaiev¹, T.A.Dudnik³, A.Q.Kyrychenko⁴, N.V.Tomakh⁴**¹*Kharkiv National Medical University, Kharkiv, Ukraine;*²*Institute of Neurology, Psychiatry and Narcology of the National Academy of Medical Sciences of
Ukraine" State Institution, Kharkiv, Ukraine;*³*Poltava State Medical University, Poltava, Ukraine;*⁴*Ukrainian State Research Institute of Medical and Social Disability Problems of the Ministry of
Health of Ukraine; Dnipro, Ukraine*

Summary. The article presents the results of sonographic diagnosis of carotid atherosclerosis in 127 patients with ischemic stroke (IS) aged 38-74 year (average age 56 ± 7 years). The comparison group (CG) consisted of 51 people with risk factors for cardiovascular diseases without a history of stroke. It has been

established that arterial hypertension and type 2 diabetes mellitus are significantly more common among patients with IS than in patients of CG. The frequency of localization of atherosclerotic plaques on the walls of the carotid arteries was determined depending on the course of the stroke. Severe stroke was observed in 79 (62.2±4.3%), moderate – in 27 (21.3±3.6%) and mild – in 21 (16.5±3.3%) patients, respectively.

It was found that in 73.4±5.0% of patients with severe stroke, atherosclerotic plaques were noted in the 3rd segment of the carotid artery, corresponding to 2 cm distal from the bifurcation. Combined atherosclerotic lesion of 2 (62.0±5.5%) and 3 (48.1±5.6%) segments, the greatest thickness of intima-media (2.41±0.37 mm) and atherosclerotic plaque (3.62±0.43 mm), as well as carotid stenosis (62.5±6.7%) were significantly more often recorded in patients with severe stroke.

Stroke, with its high morbidity, mortality, and disability rates, represents one of the leading causes of death worldwide [1]. The tactics of secondary prevention and treatment of stroke depend on the accuracy of determining its cause. In almost a third of cases, there is no apparent cause for the stroke. Often, the nature of changes in the carotid arteries determines the likelihood of developing an ischemic stroke. It is assumed that the uneven surface of the carotid arteries is one of the pathogenetic mechanisms leading of the formation of blood clots and the development of stroke [2].

Previous studies have shown that carotid lesions extending 2 cm proximal and distal to the bifurcation with an increase in intima-media thickness of more than 3 mm, are important in the development of stroke [3]. In addition, a number of authors have identified a relationship between the nature of the atherosclerotic plaque and the course of ipsilateral ischemic stroke [4, 5]. Ulceration of the medial layer of carotid plaques can create additional conditions for the formation of thrombotic masses, thereby increasing the degree of stenosis and the risk of thromboembolic complications [6].

Angiography is a gold standard for examining the great vessels of the neck and brain. It allows you to visualize the lumen of vessels along their entire length, including distal part with a diameter of up to 1 mm, and accurately determine the location and degree of stenosis [7, 8]. However, angiography does not allow assessing the nature of changes in the vessel wall, in particular the structure of atherosclerotic plaques, or determining the hemodynamic parameters of blood flow in the area of stenosis. Recently, sonography has become an integral part of the instrumental

study of the great vessels of the neck and head in patients with cerebrovascular accidents [9]. Transcranial Doppler and ultrasonic examination of the extracranial internal carotid artery may provide additional diagnostic information to assist in the management of patients with acute ischemic stroke [10, 11].

It is of interest to study the relationship between atherosclerotic lesions of the carotid arteries and the course of ischemic stroke.

The purpose of the study is an echographic assessment of the features of atherosclerotic changes in the carotid arteries in patients with ischemic stroke.

Material and methods. The analysis included the results of echography of 127 patients with ischemic stroke **aged 38-74 year (average age 56±7 years)**. Among the subjects, 69 (54.3±4.4%) were men and 58 (45.7±4.4%) women. The comparison group consisted of 51 people with lipid metabolism disorders and the presence of other risk factors for cardiovascular diseases, without a history of stroke (Table 1). Echography was carried out using linear and microconvex sensors in the frequency range 5-10 and 4-9 MHz on a Philips HD-11 ultrasound machine.

The reliability of differences in average values was assessed using a two-sample independent t-test for average values in groups with a non-parametric distribution (Mann-Whitney method) after determining the nature of the distribution. Differences were considered significant at $p<0.05$.

Results and discussion. As can be seen from Table 1, the number of young patients (up to 44 years) was 17 (13.4±3.0%), middle-aged (45–59 years) – 47 (37.0±4.3%) and elderly aged (60–74 years) – 63 (49.6±4.3%) people, respectively. The number of elderly patients was significantly greater than that of young ($p<0.001$) and middle-aged ($p<0.05$) patients. In all age groups there were not significantly more men than women.

Table 1. Distribution of those examined taking into account their gender and age

Пол	Ischemic stroke (n=127)			Comparison group (n=51)		
	< 44 лет	45-60 лет	61-74 лет	< 44 лет	45-60 лет	61-74 лет
Man	9 (7,1%)	26 (20,5%)	34 (26,8%)	8 (15,7%)	12 (23,5%)	9 (17,6%)
Women	8 (6,3%)	21 (16,5%)	29 (22,8%)	5 (9,8%)	9 (17,6%)	8 (15,7%)
Total	17 (13,4±3,0%)	47 (37,0±4,3%)	63 (49,6±4,3%) p<0,05 p<0,001	13 (25,5±6,1%)	21 (41,1±6,9%)	17 (33,3±6,6%)

Note: P1 – difference between age ranges 61-74 years and 45-60 years; difference between age ranges 61–74 years and <44 years

Table 2. Risk factors for cardiovascular disease

Risk factors	Ischemic stroke (n=127)	Comparison group (n=51)
Arterial hypertension	91 (71,6±4,0%) p<0,001	12 (23,5±5,9%)
Non-alcoholic fatty liver disease	41 (32,3±4,1%)	13 (25,5±6,1%)
Diabetes mellitus type 2	32 (25,2±3,9%) p<0,01	5 (9,8±4,2%)

The leading risk factors for cardiovascular diseases, which include arterial hypertension, non-alcoholic fatty liver disease, diabetes mellitus type 2, are presented in Table 2. Arterial hypertension and diabetes mellitus in ischemic stroke were recorded significantly often, than in the comparison group.

To assess the hemodynamic significance of atherosclerotic plaques on the walls of the common and internal carotid arteries (CCA and

ICA), we designated 4 segments: 1st segment - proximally 2 cm from the bifurcation of the CCA; 2nd segment – a section of the CCA with a length of 2 cm from the bifurcation; The 3rd segment occupies a section of the ICA extending up to 2 cm from the bifurcation; The 4th segment is the distal section of the extracranial section of the ICA, which begins at a distance of 2 cm from the bifurcation of the CCA (Fig. 1A, B).

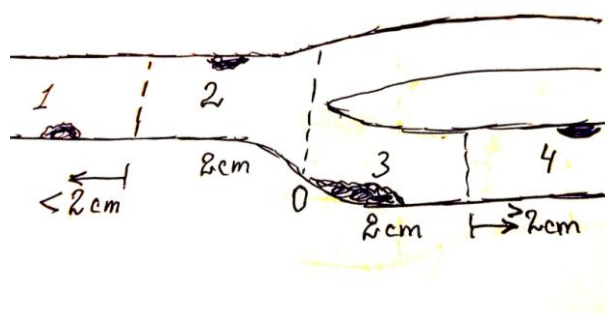
**A****B**

Fig. 1. Scheme and echogram of conditional segments of the CCA and ICA to determine the localization of atherosclerotic plaques. 1 – proximal segment of the CCA ≥ 2 cm from the bifurcation; 2 – segment of the CCA up to 2 cm from the bifurcation; 3 – segment of the ICA up to 2 cm from the bifurcation; 4 – distal segment of the ICA ≥ 2 cm from the bifurcation.

Neurological status in the acute period of the disease was assessed using the Scandinavian stroke severity scale. According to this scale, severe ischemic stroke was recorded in 79 (62.2±4.3%), moderate in 27 (21.3±3.6%) and mild in 21 (16.5±3.3%) patients, respectively. The number of patients with severe severity of ischemic stroke with high confidence ($p<0.001$) was greater than patients with moderate and mild severity.

Table 3 presents data on the frequency of occurrence of atherosclerotic plaques in different segments of the carotid arteries depending on the severity of ischemic stroke (IS). In the 1st segment of CCA, with a mild degree of IS, atherosclerotic plaques were observed in 11 (52.4±10.9%) cases, with a moderate degree of IS - in 13 (48.1±9.6%), with a severe degree of IS - in 45 (57.0±5.6%), in the comparative group – in 16 (31.4±6.5%) cases, respectively.

In the second segment, plaques were recorded in 8 (38.1±3.4%), 11 (40.7±9.5%), 41 (51.2±5.6%) and 7 (13.7±4.8%) cases; in the 3rd segment – in 5 (23.8±9.3%), in

14 (51.4±9.6%), in 58 (73.4±5.0%) and in 3 (5.9±3.3%) cases; in the 4th segment – in 2 (9.5±6.4%), in 5 (18.5±7.5%), in 37 (46.8±5.6%) cases, respectively. In severe stroke, atherosclerotic plaques in the 3rd and 4th segments of the carotid arteries were recorded significantly more often than in mild ($P<0.001$) and moderate ($P<0.05$) stroke severity, as well as in comparative ($P<0.001$) group.

Atherosclerotic plaques in 2 segments at once with mild stroke were recorded in 5 (23.8±9.3%), moderate in 11 (40.7±9.5%), severe in 49 (62.0±5.5%) and in the comparative group – in 3 (5.9±3.3%) cases, respectively. Atherosclerotic lesions of 3 segments of the carotid arteries were observed in 1 (4.8±4.7%), 7 (25.9±8.4%) and 38 (48.1±5.6%) cases, respectively. As can be seen from the table, with severe stroke, combined damage to 2 and 3 segments was significantly more common than with mild ($P<0.001$) and moderate ($P<0.05$) stroke severity.

Table 3. Distribution of the atherosclerotic plaques localization frequency of carotid arteries segments, depending on the severity of stroke

Carotid artery segments	Mild stroke	Moderate stroke	Severe stroke	Comparative group
	n=21	n=27	n=79	n=51
	1	2	3	4
1 segment, n%	11 (52.4±10.9%)	13 (48.1±9.6%)	45 (57.0±5.6%)	16 (31.4±6.5%)
2 segment, n%	8 (38.1±3.4)	11 (40.7±9.5%)	41 (51.2±5.6%)	7 (13.7±4.8%)
3 segment, n%	5 (23.8±9.3%)	14 (51.4±9.6%)	58 (73.4±5.0%) P3-2 <0,05 P3-1 <0,001 P3-4 <0,001	3 (5.9±3.3%)
4 segment, n%	2 (9.5±6.4%)	5 (18.5±7.5%)	37 (46.8±5.6%) P3-2 <0,01 P3-1 <0,001	-
Damage of 2 segments, n%	5 (23.8±9.3%)	11 (40.7±9.5%)	49 (62.0±5.5%) P3-2 <0,05 P3-1 <0,001	3 (5.9±3.3%)
Damage of 3 segments, n%	1 (4.8±4.7%)	7 (25.9±8.4%)	38 (48.1±5.6%) P3-2 <0,05 P3-1 <0,001	-

Note: P3-1 – difference between Severe stroke and Mild stroke;
P3-2 – difference between Severe stroke and Moderate stroke;
P3-4 – difference between Severe stroke and Comparative group.

Table 4 presents echographic parameters of atherosclerosis of the carotid arteries depending on the severity of stroke. The thickness of the intima-media complex in the range of 1.0-1.5 mm with mild stroke was observed in 12 (57.1±10.8%), with moderate - in 14 (51.9±9.6%), with severe stroke - in 16 (20.3±4.5%), in the comparative group - in 18 (35.3±6.7%) patients, respectively. The thickness of the intima-media complex within 1.6-2.0 mm was recorded in 8 (38.1±10.6%), in 11 (40.7±9.5%), in 42 (53.2±5.6%), in 4 (7.8±3.7%) patients, respectively. Intima-media thickness >2.0 mm was observed in 1 (4.8±10.6%), in 2 (7.4±5.0%) and in 21

(26.6±5.0%) patients, respectively (Fig. 2).

The intima-media thickness in the corresponding groups was 1.37±0.26 mm, 1.54±0.23 mm, 2.41±0.37 mm and 1.16±0.19 mm; plaque thickness – 1.64±0.32 mm, 2.28±0.36 mm, 3.62±0.43 mm and 1.37±0.34 mm; carotid stenosis – 31.2±4.6%, 42.8±5.3%, 62.5±6.7% and 23.8±1.9%, respectively. As can be seen from Table 4, intima-media thickness >2.0 mm in severe stroke was recorded significantly ($P<0.01$) more often than in mild and moderate stroke. The same trend was observed in intima-media thickness, carotid plaques and stenosis (Fig. 3).

Table 4. Echographic parameters of the carotid atherosclerosis depending on the severity of ischemic stroke

Echographic parameters of the carotid atherosclerosis	Mild stroke	Moderate stroke	Severe stroke	Comparative group
	n=21	n=27	n=79	n=51
	1	2	3	4
Intima-media thickness 1,0-1,5 mm, n%	12 (57,1±10,8%) P1-3 <0,01	14 (51,9±9,6%) P2-3 <0,01	16 (20,3±4,5%)	18 (35,3±6,7%)
Intima-media thickness 1,6-2,0 mm, n%	8 (38,1±10,6%)	11 (40,7±9,5%)	42 (53,2±5,6%)	4 (7,8±3,7%)
Intima-media thickness > 2,0 mm, n%	1 (4,8±4,7%)	2 (7,4±5,0%)	21 (26,6±5,0%) P3-2 <0,01 P3-1 <0,01	-
Mean intima-media thickness, mm	1,37±0,26 mm	1,54±0,23 mm	2,41±0,37 mm P3-2 <0,05 P3-1 <0,001 P3-4 <0,001	1,16±0,19 mm
Plaque thickness, mm	1,64±0,32 mm	2,28±0,36 mm	3,62±0,43 mm P3-2 <0,05 P3-1 <0,001 P3-4 <0,001	1,37±0,34 mm
Carotid stenosis, %	31,2±4,6%	42,8±5,3%	62,5±6,7% P3-2 <0,05 P3-1 <0,001 P3-4 <0,001	23,8±1,9%
Plaques with ulceration, n%	-	2 (7,4±5,0%)	17 (21,5±4,6%) P3-2 <0,05 P3-4 <0,001	1 (2,0±2,0%)

Note: P3-1 – difference between Severe stroke and Mild stroke;
P3-2 – difference between Severe stroke and Moderate stroke;
P3-4 – difference between Severe stroke and Comparative group

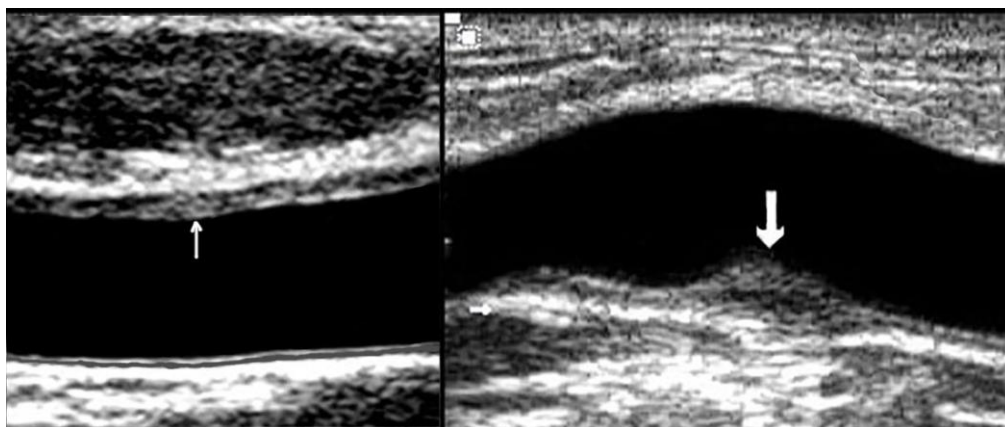


Fig. 2. On the left side of the echogram, the arrow shows a diffuse thickening of the intima-media complex on the anterior wall of the CCA (1st segment) up to 2 mm, on the right side - a local thickening of the intima-media complex of more than 3 mm with the formation of a soft plaque

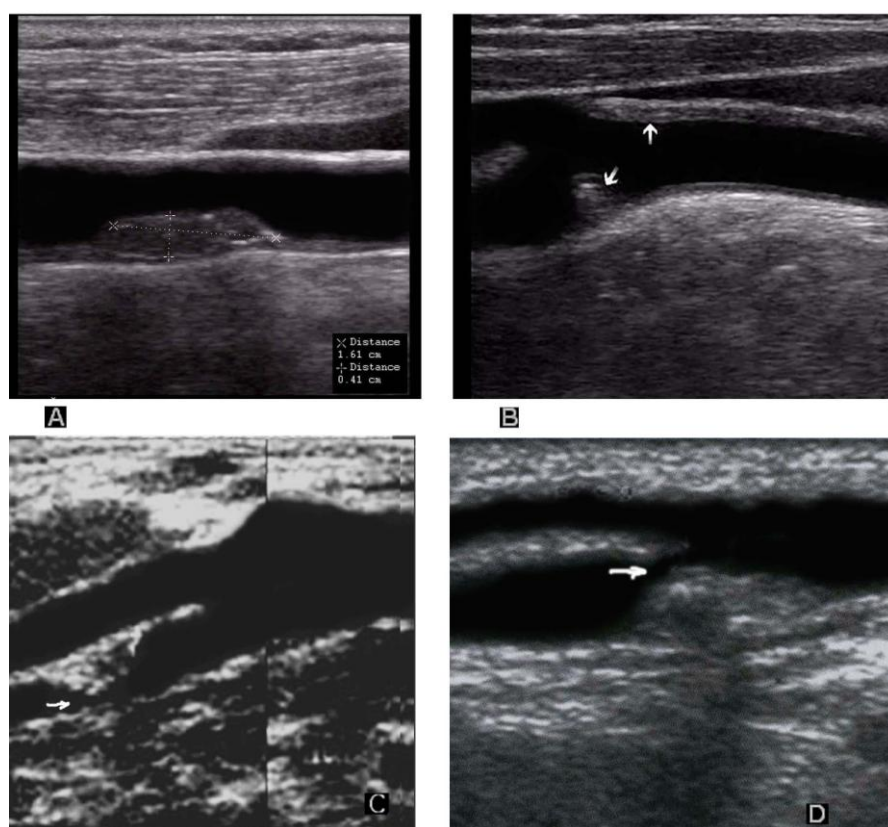


Fig. 3. Echograms of atherosclerosis of the carotid arteries: A – localization of a soft plaque on the posterior wall of the CCA (1st segment) with a height of 4.1 mm; B – soft plaque on the posterior wall of the CCA bifurcation (2nd segment) causing lumen stenosis about 50%; C – Large soft plaque on the anterior wall of the ICA (4th segment) causing lumen stenosis up to 75%; D – large soft plaque on the posterior wall of the CCA and ICA (segments 2 and 3) with lumen stenosis up to 80% (arrow).

Discussion

We carried out echography of the carotid arteries using high-frequency linear and micro-convex sensors, which made it possible to

visualize these vessels over a large extent. The thickness of the intima-media complex and atherosclerotic plaques was measured, and the degree of stenosis was calculated.

According to Gao T. et al. (2014) the nature of atherosclerotic lesions in the wall of the carotid arteries determines the risk of developing ischemic stroke [8]. Previous studies have shown that stenosing atherosclerosis of the extracranial part of the internal carotid artery is often the cause of large-focal stroke [7, 12].

One of the leading mechanisms of stroke is considered to be arterial embolism, hemodynamic disturbances, and vascular occlusion. Histological examination of the middle cerebral artery showed that luminal stenosis is often caused by rupture of ulcerated plaques, which include a large lipid-necrotic core covered by a thin fibrous cap infiltrated by macrophages and hemorrhage into the plaque [5]. Approximately 18–25% of all ischemic strokes are attributable to carotid plaque rupture [13, 14]. Gu, S. Y. et al. (2023) registration of vascular signals inside carotid plaques during contrast ultrasound examination is considered as a biomarker of the vulnerability of these plaques and the potential risk of developing ischemic stroke as a result of embolism [15]. Some researchers have found that the location and morphology of plaques determine their vulnerability. In this case, the main mechanism of plaque rupture is considered to be an increase in tension on their surface [16]

We studied the incidence of plaques with ulceration taking into account the severity of ischemic stroke. Among patients with severe stroke, plaques with ulceration were recorded in 17 (21.5±4.6%) cases, while in the group of patients with moderate stroke severity this figure was 2 (7.4±5.0%), the difference being this is statistically significant.

Previous publications on ultrasound examination of the carotid arteries in patients with ischemic stroke have not examined the relationship between the location of atherosclerotic plaques and the severity of ischemic stroke. The results of our studies showed that it is precisely when atherosclerotic plaques are localized distal to the bifurcation of the common carotid artery that the greatest stenosis occurs and a severe course of stroke is reliably often recorded. According to our data, among patients with severe stroke, stenosis had an average of $62.5 \pm 6.7\%$, while in the mild stroke group this figure was $31.2 \pm 4.6\%$.

Conclusion

1. A relationship has been established between the localization of atherosclerotic lesions of the carotid arteries and the course of ischemic stroke: carotid atherosclerosis distal to the bifurcation of the common carotid artery ($73.4 \pm 5.0\%$) and the combination of damage to several segments is significantly ($P < 0.001$) more often recorded in patients with severe course of ischemic stroke.

2. The greatest thickness of intima-media (2.41 ± 0.37 mm) and atherosclerotic plaque (3.62 ± 0.43 mm), the greatest stenosis ($62.5 \pm 6.7\%$) and plaques with ulceration in severe ischemic stroke is observed significantly ($P < 0.01$ and $P < 0.001$) more often.

Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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СОНОГРАФИЧЕСКАЯ ХАРАКТЕРИСТИКА КАРОТИДНОГО АТЕРОСКЛЕРОЗА У БОЛЬНЫХ ИШЕМИЧЕСКИМ ИНСУЛЬТОМ

**Р.Я.Абдуллаев¹, А.С.Ефименко¹, Л.А.Сысун¹, А.В.Логвиненко¹,
Н.Ф.Посохов², Р.Р.Абдуллаев¹, Т.А.Дудник³, А.Г.Кириченко⁴, Н.В.Томах⁴**

¹ *Харьковский национальный медицинский университет, Харьков, Украина;*

² *Отделение нейрохирургии «Института неврологии, психиатрии и наркологии Национальной академии медицинских наук Украины», Харьков, Украина;*

³ *Полтавский государственный медицинский университет, Полтава, Украина*

⁴ *Украинский государственный научно-исследовательский институт медико-социальных проблем инвалидности Министерства здравоохранения Украины*

Резюме. В статье представлены результаты сонографической диагностики каротидного атеросклероза у 127 больных ишемическим инсультом (ИИ) молодого, среднего и пожилого возраста (средний возраст 56±7 лет). Сравнительную группу (СГ) составили 51 человек с наличием факторов риска сердечно-сосудистых заболеваний без инсульта в анамнезе. Установлено, что артериальная гипертензия и сахарный диабет 2-го типа среди больных с ИИ встречается достоверно чаще, чем в СГ. Определена частота локализации атеросклеротических бляшек на стенках сонных артерий в зависимости от течения инсульта. Тяжелое течение инсульта отмечалось у 79 (62,2±4,3%), умеренное – у 27 (21,3±3,6%) и легкое – у 21 (16,5±3,3%) пациента, соответственно.

Установлено, что у 73,4±5,0% больных с тяжелым течением инсульта атеросклеротические бляшки отмечались в 3-м сегменте каротидной артерии, соответствующий на 2 см дистально от бифуркации. Сочетанное атеросклеротическое поражение 2-х (62,0±5,5%) и 3-х (48,1±5,6%) сегментов, наибольшая толщина интима-медиа (2,41±0,37 mm) и атеросклеротической бляшки (3,62±0,43 mm), а также каротидный стеноз (62,5±6,7%) достоверно чаще регистрировались у больных с тяжелым течением инсульта.

Correspondence author:

Abdullaiev Rizvan Yagubovich; *Department of Ultrasound Diagnostics, Kharkiv National Medical University, Kharkiv, Ukraine*

E-mail: rizvanabdullaiev@gmail.com