УДК 616.134.9+616.133.33]-008.64-089
DOI: https://doi.org/10.17816/PAVLOVJ109601

Достижения и перспективы сосудистой хирургии в лечении вертебробазилярной недостаточности

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АННОТАЦИЯ

Вертебробазилярная недостаточность (ВБН) остается важной проблемой в современной медицине, поскольку примерно каждый четвертый инфаркт головного мозга возникает в вертебробазилярном бассейне. Эти инсульты сопровождаются тяжелыми последствиями и высоким риском повторных событий. В статье представлены сегодняшние концепции по хирургическому лечению поражений подключичной (ПкА) и позвоночной (ПзА) артерий, ответственных за развитие ВБН. В открытом хирургическом лечении симптомного поражения ПкА, в первую очередь окклюзионного, превалируют экстраторакальные вмешательства в виде сонно-подключичного шунтирования и сонно-подключичной транспозиции. По данным нашего анализа, результаты сонно-подключичной транспозиции оказываются более предпочтительны. При эндоваскулярном вмешательстве на ПкА применяется баллонная ангиопластика с возможным стентированием. При проведении анализа мы не обнаружили различий в проходимости в отдалённом периоде между ангиопластикой и стентированием, хотя и степень технического успеха была выше в группе стентирования. При наличии стеноза ПкА в мире отдаётся предпочтение эндоваскулярным методикам. На сегодняшний день нет четких данных, позволяющих выбрать между открытым и эндоваскулярным вмешательствами для лечения окклюзии ПкА, хотя возможный технический неуспех эндоваскулярной реваскуляризации и более высокая проходимость в отдаленном периоде позволяют отдавать предпочтение открытой хирургии. В отношении симптомного стеноза ПзА на сегодняшний день не существует доказательств преимущества стентирования над консервативной терапией. Так, хирургическое вмешательство скорее должно применяться при неэффективности медикаментозного лечения. Это же положение относится и к открытым реконструкциям ПзА, за исключением случаев с противопоказанием к стентированию ПзА, например, при её извитости.

Ключевые слова: *вертебробазилярная недостаточность; сонно-подключичное шунтирование; сонно-подключичная транспозиция; стентирование подключичной артерии; реваскуляризация позвоночной артерии*

Для цитирования:
Кондараки А.В., Чупин А.В., Алекян Б.Г., Кульбак В.А. Достижения и перспективы сосудистой хирургии в лечении вертебробазилярной недостаточности // Российский медико-биологический вестник имени академика И.П. Павлова. 2022. Т. 30, № 4. С. 563–574. DOI: https://doi.org/10.17816/PAVLOVJ109601

Рукопись получена: 03.08.2022 **Рукопись одобрена:** 01.12.2022 **Опубликована:** 31.12.2022

ЭКО•ВЕКТОР

DOI: https://doi.org/10.17816/PAVLOVJ109601

Achievements and Prospects for Vascular Surgery in Treatment of Vertebrobasilar Insufficiency

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ABSTRACT

Vertebrobasilar insufficiency (VBI) remains an important problem in the modern medicine since approximately every fourth cerebral infarction occurs in the posterior circulation of the brain. These strokes are accompanied by severe consequences and a high risk of repeated events. The article presents the current concepts for surgical treatment of lesions of the subclavian (ScA) and vertebral (VA) arteries responsible for the development of VBI. In the open surgical treatment of symptomatic lesion of the ScA, primarily of occlusion one, extrathoracic interventions prevail in the form of carotid-subclavian bypass and carotid-subclavian transposition. According to our analysis, the results of carotid-subclavian transposition prove to be more preferable. In the endovascular intervention on the ScA, balloon angioplasty is used with possible stenting. In the analysis, we found no differences in the long-term patency between angioplasty and stenting, although the extent of technical success was higher in the group of stenting. In case of stenosis of the ScA, the world medicine gives priority to endovascular methods. To date, there are no sharply defined criteria permitting to choose between the open and endovascular interventions for treatment of the ScA occlusion, although a probable technical failure of endovascular revascularization and higher long-term patency give priority to open surgery. As for symptomatic stenosis of VA, to date there is no evidence of the advantage of stenting over conservative therapy. Thus, surgical intervention should rather be used in case the drug treatment is ineffective. The same can be said about the open reconstruction of the VA, except for the cases of contraindications for stenting of the VA, for example, its tortuosity.

Keywords: *Vertebrobasilar insufficiency; carotid-subclavian bypass; carotid-subclavian transposition; subclavian artery stenting; vertebral artery revascularization*

For citation:
Kondaraki AV, Chupin AV, Alekyan BG, Kul'bak VA. Achievements and Prospects for Vascular Surgery in Treatment of Vertebrobasilar Insufficiency. *I.P. Pavlov Russian Medical Biological Herald.* 2022;30(4):563–574. DOI: https://doi.org/10.17816/PAVLOVJ109601

Received: 03.08.2022 **Accepted:** 01.12.2022 **Published:** 31.12.2022

ECO•VECTOR

LIST OF ABBREVIATIONS

CSB — carotid–subclavian bypass
CST — carotid–subclavian transposition
PC — posterior circulation
RCT — randomized clinical trial
ScA — subclavian artery
TLA — transluminal angioplasty
VA — vertebral artery
VBI — vertebrobasilar insufficiency

INTRODUCTION

Vertebrobasilar insufficiency (VBI) is a complex of ischemic events occurring in the posterior portion of the brain as a result of circulatory disorders in the arteries of the posterior circulation (PC).

Ischemic events are understood as transient ischemic attacks in the form of dizziness, balance problems, vision disorders, drop-attacks and ischemic stroke [1].

Today, stroke holds leading positions in the world structure of morbidity and mortality, being the second most common cause of death and the third cause of disability. In Russia alone there occur more than 400 thousand strokes annually which means the loss of 6 million years of productive life due to disability and premature death [2]. About 25%–30% of strokes occur in the PC, but they are given less attention in the literature compared to strokes in the carotid system [3, 4]. In the meanwhile, acute ischemic events in the PC are not inferior to carotid acute ischemic events in terms of mortality and disability. With that, according to some modern studies, in case of vertebrobasilar stroke the risk of early repeated stroke is higher [5, 6].

Approximately, in 25% of all cases VBI is the result of a trial fibrillation. About a quarter of all cerebral infarctions In the PC are lacunars. The main causes remain to be lesions of the vertebral artery (VA) (mostly of orifices), subclavian artery (ScA), and also of the brachiocephalic trunk [7]. Most often this steno-occlusive lesion is of atherosclerotic origin, but pathological tortuosity and inflammatory diseases of the arteries can also lead to VBI.

Until now, there still remains uncertainty in selection of treatment tactics in patients with symptomatic stenoses of the VA. Scarce randomized clinical trials (RCT) could not identify the advantages of the endovascular methods of treatment of these patients over the optimal drug treatment [8–11]. And no RCTs devoted to the open surgical methods of treatment of symptomatic stenoses of VA, were conducted.

The situation with symptomatic lesions of the first segment of the ScA is somewhat different. The majority of researches give preference to active surgical tactics [7, 12, 13], however, the choice of the method of surgical treatment remains the subject of active discussions.

In this article, we performed a comprehensive review of the modern achievements in surgery of VBI.

Surgical Treatment of Atherosclerotic Lesion of First Segment of Subclavian Artery

At present, experts on vascular surgery have come to a consensus about the priority of conservative methods of treatment over surgical methods in patients with asymptomatic stenoses of the first segment of the ScA. However, the consensus of the highly reputed surgeons is characterized by a low level of evidence and is not supported by studies indicating the reasonability of the wait-and-see surgical tactics in asymptomatic patients [14–16]. In our opinion, the current state of the problem dictates the need for further studies.

On the contrary, in patients with symptomatic stenoses of the first segment of the ScA, of an undeniable advantage are methods of surgical revascularization. However, some authors [17, 18] note scarcity of the data on the natural course and conservative treatment in such patients.

Thus, M. Schillinger, et al. [19] gave the only in the world literature evaluation of the effectiveness of the conservative treatment and balloon angioplasty in managing symptoms of hemodynamically significant stenosis of the ScA. Although in all operated patients no symptoms were noted immediately after the discharge, in the long-term follow-up period there was a tendency to commensuration of the share of asymptomatic patients in both groups. However, with lesion more than 2 cm in diameter and the existence of symptoms of VBI, persistent symptoms were observed in the conservative treatment group. The authors conclude that indications for intervention in stenotic lesions of the ScA include both severe symptoms, such as critical upper limb ischemia, repeated fainting, drop attacks, and extended lesions due to limited collateralization. The authors also

DOI: https://doi.org/10.17816/PAVLOVJ109601

take into account patients with concomitant occlusion of the internal carotid artery, and also patients with planned mammary-coronary bypass surgery or those who underwent it with the development of coronary subclavian steal syndrome, who require revascularization regardless of symptoms.

N. Epperla, et al. [20] compared cardiovascular events and mortality between the antiplatelet therapy and surgical treatment in addition to antiplatelet therapy. The groups did not differ in gender, age and the number of concomitant diseases. Based on the results of follow-up, on average within 8.45 years, the frequency of cardiovascular events and death was significantly higher in the group of conservative treatment despite the fact that these patients more frequently received double antiplatelet treatment.

Other studies evaluating the results of surgical intervention on the ScA, present the data that evidence a high level of symptom-free survival after surgery, which permits, although limitedly, to judge about the effectiveness of the procedure [21, 22]. Eventually, *three generations of European clinical guidelines of cardiology and vascular surgery societies unequivocally recommend active surgical tactics for symptomatic lesions of the ScA* [14, 16, 23]. With that, there remains some uncertainty in choosing the method of surgical treatment.

An achievement in the treatment of VBI was the widespread use of extrathoracic extra-anatomic open interventions, such as carotid-subclavian transposition (CST) and carotid subclavian bypass (CSB), as well as minimally invasive endovascular treatment: transluminal angioplasty (TLA) and TLA with stenting.

With that, since the development of open revascularization methods (CST, CSB) for symptomatic lesions of ScA, the discussion of the preferable technique is still ongoing. Thus, the statement about the greater technical complexity of operative access in CST, which predisposes to more frequent local complications, is an argument for limiting the use of CST. As for CSB, there is a judgment about physiological inferiority of the blood flow, which predisposes to thrombosis of the reconstruction. This discussion was reflected in the world professional literature: below we present the data of three large studies on this issue.

C. S. Cina, et al. [24] conducted a systematic review of 19 studies published from 1966 to 2000, which were devoted to CST and CSB using a synthetic prosthesis or autovein as a shunt (Table 1). In seven works, these techniques were compared directly. All studies were retrospective. In the early and long-term periods, patency and symptom-free survival were significantly higher in the CST group. The use of a venous conduit was associated with lower patency compared to a synthetic prosthesis, which was attributed by the authors to insufficient diameter, predisposition to tortuosity and bending.

Table 1. Consolidated Results of Comparative Studies of Open Interventions on Subclavian Artery

	Carotid-Subclavian Transposition	**Carotid-Subclavian Bypass**	**p**
Systematic Review C. S. Cinà, et al., 2002 [24]			
Number of patients, n	511	516	–
Patency, %	99	84	< 0.0001
Symptom-free survival, %	99	88	< 0.0001
Analysis of Registrar of A.L. Madenci, et al., 2013 (group of isolated revascularization) [25]			
Number of patients, n	87	702	–
Cerebrovascular events[1], %	4.6	3.1	0.52
Mortality[1], %	2.9	3.5	0.73
Combination of cerebrovascular events and mortality[1], %	5.1	6.9	0.45
Comparative Study of A.N. Kazantsev, et al., 2021 [26]			
Number of patients, n	87	95	–
Lymphorrhea in hospital period, %	1.1	9.5	0.03
Thrombosis of reconstruction[2], %	0	5.3	0.08
Cerebral and cardiovascular mortality[2], %	2.3	6.3	0.33
Non-fatal cerebrovascular events[2], %	8	8.4	0.85
Combination of cerebrovascular events and cardiovascular mortality[2], %	5.1	6.9	0.41

Notes: [1] — in 30th day period; [2] — in long-term period

A suggestion was also made about a hemodynamic advantage of CST over CSB because of the backward and turbulent blood flow from the shunt in the latter case. Moreover, a blind segment of the subclavian artery proximal to the anastomosis creates prerequisites for thrombosis of this segment and, consequently, of the vertebral artery. The frequency of perioperative complications, such as damage to nerves, hematoma, lymphorrhea, was similar, but infection of the reconstruction was seen only in the group of CSB. The authors came to the conclusion about CST being a surgery of choice in occlusive damage of the first segment of the subclavian artery.

Subsequently, the question of comparing the security of these open operations was considered. A. L. Madenci, et al. [25] analyzed the multicenter database of the American College of Surgeons, selecting adult patients who underwent planned CST or CSB (Table 1). The primary endpoint was determined as a combination of a cerebrovascular event and death within 30 days after surgery. Indications for the operation were occlusive-stenotic lesion of the ScA and expansion of the zone for endoprosthetics of the thoracic aorta, which was performed in 10% of patients. In the group of isolated revascularization of ScA, the patients who underwent CST, were younger and healthier in physical status than the patients who underwent CSB; despite this, there was no difference in cerebrovascular events, death or their combination, as well as in the number of postoperative complications. However, age, smoking, functional status, and increased white blood cell count were associated with the development of the primary endpoint.

Perioperative drug therapy and clinical data, as well as patency, could not be evaluated, which, probably, did not influence the result at all. Using the national data base, the authors managed to acquire a large amount of case reports (n = 789) in a short period of time (2005–2010), which permitted to obtain better understanding of them, although such interventions are rare in each separate center.

Recent data on the comparison of these operations were obtained by domestic researchers. A. N. Kazantsev, et al. [26] compared the results of CSB and CST in patients with occlusion of the first segment of the ScA (Table 1). The study was retrospective; the groups were comparable in the initial demographic and clinical parameters. In the hospital period, only complications of the surgical access were noted, the frequency of lymphorrhea alone was higher in the CSB group. To note, different accesses were used: in CSB — subclavian access, in CST — the access perpendicular to the clavicle along the outer edge of the sternocleidomastoid muscle, which could cause local complications. There was a tendency to decrease in patency and to cardiovascular mortality (death from stroke and myocardial infarction) in the CSB group compared with the CST group in the follow-up up to 2 years; however, in the follow-up more than 5 years, no difference was obtained. The authors also point out that thrombosis of reconstructions in the long-term period occurred only in the CSB group. The authors conclude that *CSB is a less preferred technique for revascularization of the ScA in case of its occlusion*.

Thus, *for open revascularization of ScA, a promising method for treatment of VBI is use of a specific operation of carotid-subclavian transposition in case of ScA occlusion* (Table 1).

As for endovascular methods, (TLA or TLA with stenting of ScA), their number is steadily growing [27], but it is still not completely clear which of these methods is more preferable; though TLA with stenting is usually recommended in case of ScA occlusion, ScA dissection and in significant residual stenosis after balloon angioplasty [28].

In the already mentioned study by M. Schillinger, et al. it is shown that surgical intervention on the ScA in the volume of TLA is more effective for relief of symptoms in a short period of time in comparison with conservative therapy [19].

As for the choice of TLA or TLA with stenting, S. Chatterjee, et al. [29] performed a systematic review and meta-analysis comparing these methods (Table 2). The analysis included 8 retrospective comparative studies and 544 patients. The authors evaluated patency in 1 year and found that it was higher in the group of angioplasty with stenting. S. Chatterjee, et al. believe that implantation of the stent in revascularization of ScA is preferable to angioplasty of ScA, however, these results may be a consequence of the primary technical failure, which was probably more characteristic of angioplasty and was included by the authors in the evaluation of patency [29].

Later, A. T. Ahmed, et al. [30] also published the results of a similar meta-analysis of 35 studies (n = 1726) in which these techniques were used (Table 2). The *non-comparable* and *retrospective character* of the studies included in the work, of course, increased the likelihood of distortions, which were explained by the authors in detail. As a result, the degree of technical success was higher in the stenting group, but there was no difference in primary patency both within 2 years and after 2 years. The frequency of symptom resolution and repeated interventions was similar, as was the 30-day stroke rate. The number of complications did not differ. The authors do not make an unambiguous conclusion from their study, however, in our opinion, as it follows from the results of the publication, *stent implantation is required only after the technical failure of angioplasty*.

A systematic review and meta-analysis of RCTs which compares TLA with TLA with stenting, was performed by W. Iared, et al. [31] under the sponsorship of the Cochrane Library. Such studies were not found in

Table 2. Results of Comparison of Endovascular Methods on Subclavian Artery

	Transluminal Angioplasty	Transluminal Angioplasty with Stenting	p
Meta-Analysis by S. Chatterjee, et al., 2013 [29]			
Number of patients, n	307	237	–
Adverse events in 1 year, n	54	22	0.004
Systematic Review by A. T. Ahmed, et al., 2016 [30]			
Number of patients, n	374	1352	–
Technical success, %	86.9	92.8	0.007
Primary patency within 2 years, %	89.9	88.7	0.794
Primary patency for more than 2 years, %	79.6	76.9	0.729
Frequency of resolution of symptoms, %	73.0	82.2	0.327
Stroke, %	2	2	0.742

Note: adverse events — restenosis, thrombosis and technical failure

systematic search. The authors insist on the statement that *to obtain unambiguous undistorted data on this matter, RCTs must be necessarily performed, and we share their position*.

Regarding the type of stents for ScA, it should be noted that the majority of researchers recommend using *balloon-expandable* stents, rather than *self-expandable* [32]. The advantage of the former is the exact location during the implantation due to the greater radial force, which prevents migration of the stent into the aorta and orifices of the VA and the internal thoracic artery, which, in turn, is fraught with occlusion or embolization of the latter [33]. However, for extended lesions it is proposed to use a self-expandable stent [34], and in some cases, researchers prefer the latter because of *the need for greater flexibility rather than the radial force in the first segment of the ScA* [28]. Yet, according to the study by Y. Soga, et al. [35], there were no differences in primary patency between the types of stents. The same paper describes the possibility of using intravascular ultrasound, which was more often used in occlusion of the ScA and was associated with greater primary patency. In addition, the authors consider the possibility of using a coated stent, especially in surgery on occlusion, to prevent rupture of the artery and displacement of the stent.

Thus, the prospect of endovascular treatment of this pathology belongs to TLA with possible stenting (in case of residual stenosis or severe damage) (Table 2), when both balloon-expandable and self-expandable stents can be used. To enhance the safety of the intervention, intravascular imaging methods will be widely used, such as intravascular ultrasound.

The choice of endovascular or open treatment methods is based both on the anatomic peculiarities, such as the extension of the lesion, the degree of stenosis, involvement of the VA in the lesion, and on the personal preferences of a surgeon. In many works [36, 37], surgeons are more often inclined to the open intervention in occlusion of the VA, although other studies [38, 39] demonstrate a successful experience in the endovascular treatment of such lesion.

The only prospective non-randomized study comparing endovascular and open interventions in lesion of ScA, was conducted by K. Linni, et al. [28]. The authors compared CST (n = 34) and TLA with stenting with a self-expanding nitinol stent (n = 40) in symptomatic lesion of the ScA (Table 3). The patients were similar in demographic, clinical and anatomical parameters. Primary technical failure in the stenting group was observed in 12 cases (30%), only in case of occlusion of the ScA. In total, 13 of 25 occlusions were recanalized in the study, so, the degree of success in ScA occlusion was 52%. All the patients received single-component antiplatelet therapy with acetylsalicylic acid, with early stent thrombosis in 5% of cases. There were only local complications, with no difference between the groups. In the five-year follow-up period, there were no significant differences in patency. The authors consider *endovascular treatment for a stenotic lesion, and open methods for an occlusive lesion*.

G. C. Galyfos, et al. [13] in a systematic review, compared both types of interventions (Table 3). The review included 7 studies and 760 interventions. Of them, CST was performed only in 16% of the open interventions, and only 17% of endovascular interventions were performed in occlusion of the ScA. No separate data on the ScA occlusion were presented. *Primary patency in 1, 3 and 5 years was higher in the open intervention group, while symptom-free survival and overall five-year*

Table 3. Results of Comparison of Open and Endovascular Interventions

	Open Interventions	Endovascular Interventions	p
Prospective Study by K. Linni, et al., 2008 [28]			
Количество пациентов, n	34	40	–
Окклюзия подключичной артерии, %	63	74	0.33
Первичный технический неуспех, %	30	0	0.002
Пятилетняя проходимость, %	100	95	0.14
Meta-Analysis by G. C. Galyfos, et al., 2019 [13]			
Number of patients, n	463	297	–
Occlusion of subclavian artery, %	76	21	0.0001
One-year primary patency, %	95	89	0.0003
Three-year primary patency, %	91	83	< 0.0001
Five-year primary patency, %	87	75	0.0004
Five-year survival, %	90	86	> 0.05
Five-year survival without symptoms, %	96	77	> 0.05

survival did not differ between the groups. According to the authors, this contradiction can be resolved on condition that restenoses and reocclusions were diagnosed and treated, that is, the use of secondary interventions or the development of collateral circulation, before appearance of symptoms. G. C. Galyfos, et al. emphasize the scarcity of the data for the analysis of primary-assisted or secondary patency. Finally, studies do not present the results of surgical interventions separately for stenoses and occlusions of ScA, which impedes assessment of outcomes with different degrees of lesion, although ScA occlusions were more commonly treated with open interventions.

Thus, not only the above presented studies (Table 3), but also current Clinical recommendations [14] *do not give preference to any particular method of surgical treatment*. There are no data on assessment of the influence of a certain kind of intervention on the patency of the VA, and, consequently, on the risk of neurologic complications.

Surgical Treatment of Atherosclerotic Lesion of Orifice of Vertebral Artery

Concerning a significant, but asymptomatic tA lesion, there are data on the low risk of stroke [40], in which case, according to the community of vascular surgeons, only *conservative therapy* is required [16].

An achievement to date is the use of powerful drug therapy for symptomatic stenoses of the VA, including antiplatelet (double, hypolipidemic and antihypertensive) therapy. In addition to conservative therapy, both open and endovascular surgical interventions have been developed and are being used. However, determination of indications for surgical treatment in such patients presents certain difficulties [16].

Thus, H. S. Markus, et al. [41] conducted a combined analysis of the data of three RCTs comparing the drug and endovascular treatment of patients with the first manifestation of symptomatic stenosis of the VA. The results of the analysis showed no difference in the outcomes between stenting and conservative therapy. This refers both to intracranial and extracranial lesions of the VA. To understand if there is a benefit from the revascularization of the VA within 2 weeks after an ischemic event, outcomes of patients with symptoms that developed within 14 days after randomization, were studied. There were no differences in this subgroup either. To determine the effect of the intervention in patients with stenosis of the extracranial segment of the VA, the authors recommend large RCTs to be conducted.

To note, at present it is proposed *to use the surgical treatment for patients with the recurrence of symptoms despite the use of drug therapy* [16, 32]. However, no research has been conducted on this issue.

For stenting of VA, 2 types of stents can be used: *holometallic* and *drug-coated*. To compare the results of this intervention depending on the type of stent, V. H. Tang, et al. [42] performed a meta-analysis of retrospective studies on this issue. The authors found that the use of drug-coated stents reduces the risk of recurrence of symptoms and of restenosis.

Accordingly, a promising direction in the endovascular therapy of symptomatic stenoses of the VA will be a careful selection of patients for endovascular intervention leaving it for patients with symptoms that

persisted despite the drug therapy and the widespread use of drug-coated stents.

In the open surgery of the orifice of the VA, several kinds of surgeries are used: transposition of the VA into the common carotid artery, endarterectomy from the VA with reimplantation into the initial orifice, and trans-subclavian endarterectomy from the VA. With that, the choice of the method often depends on the surgeon, since the data on their comparison are limited.

A large experience in comparison of these methods of open surgery with each other and with the endovascular treatment of stenoses of the VA was shown by A. N. Vachev, et al. [43]. Patients with hemodynamically significant VA stenosis, the clinical picture of VBI and no clinical improvement for 6 months of the conservative therapy, were divided to groups of open (n = 129) and endovascular (n = 65) interventions. Transposition of the VA into the common carotid artery (n = 67), endarterectomy from the VA with reimplantation into the initial orifice (n = 34), trans-subclavian endarterectomy from the VA (n = 28) and stenting of the VA (n = 65) were performed. Open interventions were performed only in combination of VA stenosis with its tortuosity. Drug-coated stents were implanted in 14 cases. There was no difference in the frequency of stroke in the PC within the entire follow-up period. In the group of open surgeries, clinical improvement was lowest after trans-subclavian endarterectomy from the VA both in the early and long-term follow-up periods, in other comparisons there were no differences in clinical improvement. There was a significantly higher amount of restenoses within 3 years in the stenting group. The authors admit the operations of transposition of the VA into the common carotid artery and endarterectomy from the VA with reimplantation into the initial orifice to be the operations of choice in patients with lesion of the orifice of the VA. The limitation of this study is its retrospective character, as well as the lack of information about complications of surgical interventions.

CONCLUSION

The promising surgical treatment of the symptomatic lesion of the subclavian artery seems to be endovascular intervention in stenosis of the subclavian artery. In its occlusion the choice is in favor of the open surgery in the long life expectancy and contraindications for endovascular treatment, and also in case of extended lesion in the proximity to the orifice of the vertebral artery or stenotic lesion of the vertebral artery itself.

The prospect of open interventions for lesions of the orifice of the vertebral artery seems to be transposition of the vertebral artery into the common carotid artery and endarterectomy from the vertebral artery with reimplantation into the initial orifice for patients with symptomatic stenosis in combination with tortuosity in case the conservative therapy is ineffective.

ADDITIONAL INFORMATION

Funding. This article was not supported by any external sources of funding.
Conflict of interests. The authors declare no conflicts of interests.
Acknowledgment. The authors would like to thank N. I. Verdikhanov, D. V. Polyanstkiy for their help in review of the study.
Contribution of the authors: *A. V. Kondaraki* — research concept and design, data collection and anaysis, draft writing, final approval; *A. V. Chupin* — research concept and design, critical review, final approval; *B. G. Alekyan* — research concept and design, critical review, final approval; *V. A. Kul'bak* — data collection and analysis, critical review, final approval. All authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work.

Финансирование. Авторы заявляют об отсутствии внешнего финансирования при проведении исследования.
Конфликт интересов. Авторы заявляют об отсутствии конфликта интересов.
Благодарность. Авторы выражают признательность Н. И. Вердиханову, Д. В. Полянскому за конструктивную критику работы в процессе её написания.
Вклад авторов: *Кондараки А. В.* — концепция и дизайн исследования, сбор и обработка материала, написание текста, финальное одобрение; *Чупин А. В.* — концепция и дизайн исследования, редактирование, финальное одобрение; *Алекян Б. Г.* — концепция и дизайн исследования, редактирование, финальное одобрение; *Кульбак В. А.* — сбор и обработка материала, редактирование, финальное одобрение. Авторы подтверждают соответствие своего авторства международным критериям ICMJE (все авторы внесли существенный вклад в разработку концепции, подготовку статьи, прочли и одобрили финальную версию перед публикацией).

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