



Original article



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The importance and principles of endovascular technologies and "hybrid approaches" in the treatment of occlusive lesions of lower extremity arteries

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ABSTRACT. The clinician must first understand the natural history of obliterative atherosclerosis and chronic limb threatening ischemia before making a decision regarding therapeutic or surgical treatment options. Clearly, mild ischemia as evidenced by claudication does not place the patient at significant risk for limb loss. The analysis of the literature shows that at the present time hybrid and endovascular approaches are applied more often, being an alternative to traditional surgeries. Most researchers have proved that while performing 'hybrid' and endovascular surgeries there is a very low incidence of cardiovascular issues and infectious complications, and in most cases, it is possible to save the limb. However, the principle and importance of the effectiveness of a particular method or approach of treatment of multilevel obliterative atherosclerotic lesions of lower limb arteries depends on the degree of limb ischemia as well as on the anatomical level of the lesion where revascularization is performed. We have already published many articles regarding the concept, advantages, comparisons of hybrid approach in Russian Highly Attested Commission Journals. This review article analyses and summarizes the possibilities of "hybrid" and endovascular approaches in the treatment of patients with multilevel obliterative atherosclerotic lesions, stenosis and chronic limb threatening ischemia.

Keywords: atherosclerosis, chronic limb threatening ischemia, hybrid operations, endovascular approach, limb salvage

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Оригинальная статья

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Значение и принципы применения эндоваскулярных технологий и «гибридных подходов» в лечении окклюзионных поражений артерий нижних конечностей

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РЕЗЮМЕ. Прежде чем принять решение о терапевтическом или хирургическом лечении, врач должен понять естественную историю облитерирующего атеросклероза и хронической угрожающей конечности ишемии. Очевидно, что легкая ишемия, проявляющаяся хромотой, не подвергает пациента значительному риску потери конечности. Анализ литературы показывает, что в настоящее время все чаще применяются гибридные и эндоваскулярные подходы, являющиеся альтернативой традиционным операциям. Большинство исследователей доказали, что при выполнении «гибридных» и эндоваскулярных операций очень низка частота сердечно-сосудистых проблем и инфекционных осложнений, а в большинстве случаев удается сохранить конечность. Однако принцип и значение эффективности того или иного метода либо подхода к лечению многоуровневых облитерирующих атеросклеротических поражений артерий нижних конечностей зависит от степени ишемии конечности, а также от анатомического уровня поражения, на котором выполняется реваскуляризация. Мы уже опубликовали множество статей о концепции, преимуществах, сравнительных характеристиках гибридного подхода в российских журналах высокой аттестации. В данной обзорной статье анализируются и обобщаются возможности «гибридного» и эндоваскулярного подходов в лечении пациентов с многоуровневыми облитерирующими атеросклеротическими поражениями, стенозами и хронической угрожающей ишемией конечности.

Ключевые слова: атеросклероз, хроническая угрожающая ишемия конечности, гибридные операции, эндоваскулярный подход, спасение конечности

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INTRODUCTION

In recent years, with increasing life expectancy, the number of patients with occlusive vascular diseases has increased significantly [1–4], among which atherosclerotic lesions occupy the major share and are registered in 14% of the population aged over 50 years [5–7].

To date, dissatisfaction with the results of treatment of patients with chronic limb threatening ischemia (CLTI) has led to the development and use of various methods of treatment of such group of patients [8, 9]. In particular, at the end of the XX century, gene therapy methods using stem cells, transposition of various tissues to the limb region [3, 4] were widely used, which, unfortunately, did not allow to fully achieve an adequate revascularization of the limb.

For a long time, bypass surgeries were the gold standard in the treatment of patients with lower limb arterial lesions [6, 7, 10–12]. At the same time, if bypass surgeries had a significant and lasting effect in proximal arterial lesions (category C and D according to TASC II classification), multilevel reconstructions with the use of several shunts were required in multistage arterial lesions [6–13]. As a rule, such operations were accompanied by the development of severe infectious complications in the postoperative period, both early and late. In the mid-90s of the last century, methods of endovascular treatment of patients with arterial lesions of various basins were actively introduced into practical angio-surgery. One of the first widely used methods was balloon angioplasty. However, its widespread use and hopes were replaced by a certain pessimism due to the low long-term efficacy of the method [14]. At the same time, the best results were achieved when angioplasty was supplemented with stenting [15].

At the same time, the multiple nature of vascular lesions, the severe condition of patients did not allow to perform in some cases only open or endovascular revascularization of the ischemic limb in isolation, which led to the emergence of a new trend in vascular surgery — hybrid operations, which are now widely spread in Russian Federation and whole world [16–21]. Currently, most specialists note that endovascular interventions are the “first line” of therapy in patients with CLTI [18–21]. The world’s first hybrid operation was performed in 1973 by Porter and Dotter, who performed angioplasty of the iliac arteries followed by femoral-popliteal bypass. From 2014-year hybrid operations are performed every often in St. Petersburg City Limb Salvage Center, City hospital No. 14 and many more hospitals and Limb Salvage Centers in the Russian Federation. “Hybrid intervention” is a combination of various methods used in different sub-specialties. In particular, with regard to cardiovascular surgery, hybrid operations are understood as a

conceptually consistent combination of open surgical reconstruction with endovascular techniques performed simultaneously [22–25, 39, 40, 44, 45, 60, 61]. At present, the number of surgical interventions with hybrid approach in the treatment of patients with limb ischemia is significantly increasing, which is also reflected in the number of publications devoted to various aspects of its application [22, 23]. Thus, P.S. Aho and M. Venermo in 2012 [8], demonstrated that in the vascular surgery department of Helsinki University Central Hospital, the number of hybrid procedures increased from 4 in 2004 to 73 in 2011.

However, the indications for hybrid surgeries remain controversial with no clear international guidelines. Based on the cooperation of two surgical centers in the Czech Republic and Sweden P. Balaz et al. in 2012 [24] believe that hybrid operations should be performed: (1) in patients with chronic limb threatening ischemia (2) acute limb ischemia and (3) in occlusions of previously applied shunts (Fig. 1). Hybrid (simultaneous open surgical and endovascular) procedures require an operating room equipped with advanced imaging capability, such as digital subtraction angiography. On the patient’s right side (R), open femoral endarterectomy with patch angioplasty is combined with retrograde placement of a balloon-expandable covered stent in the common iliac artery to treat severe combined common femoral artery and common iliac artery disease. On the patient’s left side (L), external iliac artery stenosis and long-segment occlusion of the superficial femoral artery are treated by placement of a self-expanding stent in the external iliac artery and a femoral-to-popliteal bypass graft [70].

The multistage lesions of the lower limb arteries are one of the indications for hybrid operations, as they are accompanied by shorter hospitalization duration, significantly lower number of postoperative complications and mortality rate, and similar results compared to open interventions [11, 16, 17, 21, 26, 39, 40–45, 59–61]. At the same time, high surgical risk is considered to be the main factor in the choice of indications. At the same time, as the authors rightly point out, the presence of critical/chronic ischemia, diabetes, renal failure can compromise the results of hybrid surgery. The high efficacy of hybrid technology was also demonstrated by the study of A.A. Kuchay, A.N. Lipin et al. in 2023 and 2024, Jin Hyun Joh et al. in 2014 [7, 21, 28, 40], in which the comparison of primary patency in patients with hybrid and open surgery was 100 and 90.9%, respectively. However, the study and comparison of the results of using hybrid surgery and open operative tactics, according to the published study by Peter Balaz et al. in 2013 [27], did not allow us to unequivocally judge the effectiveness of one or the other method, since in many respects the treatment results depend on both the degree of limb ischemia

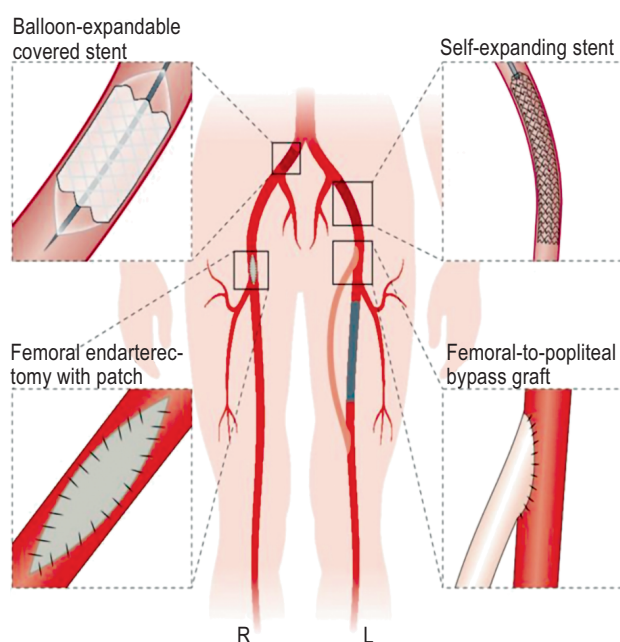


Fig. 1. Hybrid approaches for simultaneous, multilevel revascularization of advanced peripheral artery disease [70]

Рис. 1. Гибридные подходы для одновременной многоуровневой реваскуляризации прогрессирующего заболевания периферических артерий [70]

and the anatomical level of the lesion where endovascular recanalization was performed. In order to establish indications for a particular method of surgery, a combination of diagnostic invasive and non-invasive methods of investigation is currently used: duplex and triplex sonography, computed tomography (CT) angiography, magnetic resonance (MR) angiography. Nowadays magnetic resonance angiography (MRA) takes the main place in diagnostics of the level and degree of arterial channel lesions, the sensitivity and specificity of which reaches 99.5% and 98.8% respectively. At the same time, contrast angiography is the main method of investigation and confirmation of the operation result in almost all cases. However, computed tomography angiography (CTA) with 3D reconstruction allows to obtain the most complete information about the state of atherosclerotic lesion of the aorto-iliac segment, as well as to choose the diameter and length of the balloon, stent and catheter. The problem of performing one-stage combined operations is mainly of an organizational nature, as it requires a hybrid operating room, simultaneous presence of endovascular surgeon and a vascular surgeon in the operating room, or a vascular surgeon who is skilled in the technique of endovascular interventions. According to modern concepts, a hybrid operating theatre should be equipped with a high-quality angiographic system with high resolution and the ability to create high-quality images during

surgery. It should be noted that the hybrid approach in the treatment of patients with occlusive and stenotic lesions of the lower limb arteries should include cooperation of endovascular surgeons with angio-surgeons, as well as specially trained nursing staff.

HYBRID AND ENDOVASCULAR APPROACHES

The hybrid approach in critical or chronic ischemia surgery is highly controversial. It should be noted that there are different interpretations of hybrid surgery in the literature. Thus, D.P. Slovut in 2007 [32], published a "hybrid" approach in the treatment of patients with critical or chronic limb ischemia in whom it was impossible to use the patient's autovenous vein due to its insufficient length. Consequently, the author performed atherectomy with the Silverhawk device and femoral-popliteal bypass in 4 observations. However, this approach in the treatment of critical ischemia patients is debatable, especially under the terminology of "hybrid". For example, the hybrid approach is possible in patients with short arterial lesions [4]. In addition, in some cases it is necessary to perform angioplasty of arteries that are outflow pathways. Thus, M. Piazza et al in 2011 [35], A.A. Kuchay, A.N. Lipin et al. in 2019, 2021, 2022–2024 [7, 16, 17, 20, 21, 40, 44, 45, 59, 60, 69] showed that using a hybrid approach compared to open surgery significantly reduces the duration of the patient's stay in the intensive care unit, in addition, the immediate and long-term results of operations are comparable. I.G. Uchkin in 2013 [37], A.A. Kuchay et al [44] highlights a number of advantages of hybrid operations: a lower degree of invasiveness; reduction in the length of implants used; the ability to overcome prolonged lesions (Table 1, Fig. 2).

R.W. Chang et al. in 2008 [36] in their study convincingly showed that the hybrid approach in the treatment of patients with occlusive diseases of lower limb arteries can be an alternative to open surgery. Thus, based on the analysis of treatment results of 171 patients who underwent endarterectomy from the common femoral artery and stenting of the iliac artery, they demonstrated that 30-day postoperative mortality was 2.3% and five-year survival rate was 60%. At the same time five-year primary patency rate of the reconstructed vessels reached 60% and secondary patency 98%. A similar opinion was demonstrated by D.P. Slovut et al. in 2009 [31], who noted that hybrid approach in the treatment of patients with occlusive diseases of lower limb arteries allows not only to reduce the incidence of complications, but also to improve the results of treatment, besides, as the authors note, the technical success of the procedure is very high. Thus, according to M. Matsagkas et al. in 2011 [38], the



Table 1

Important clinical, angiographic, and treatment outcomes to be considered in trials and registries. Evaluating endovascular devices for peripheral arterial disease and critical limb threatening ischemia

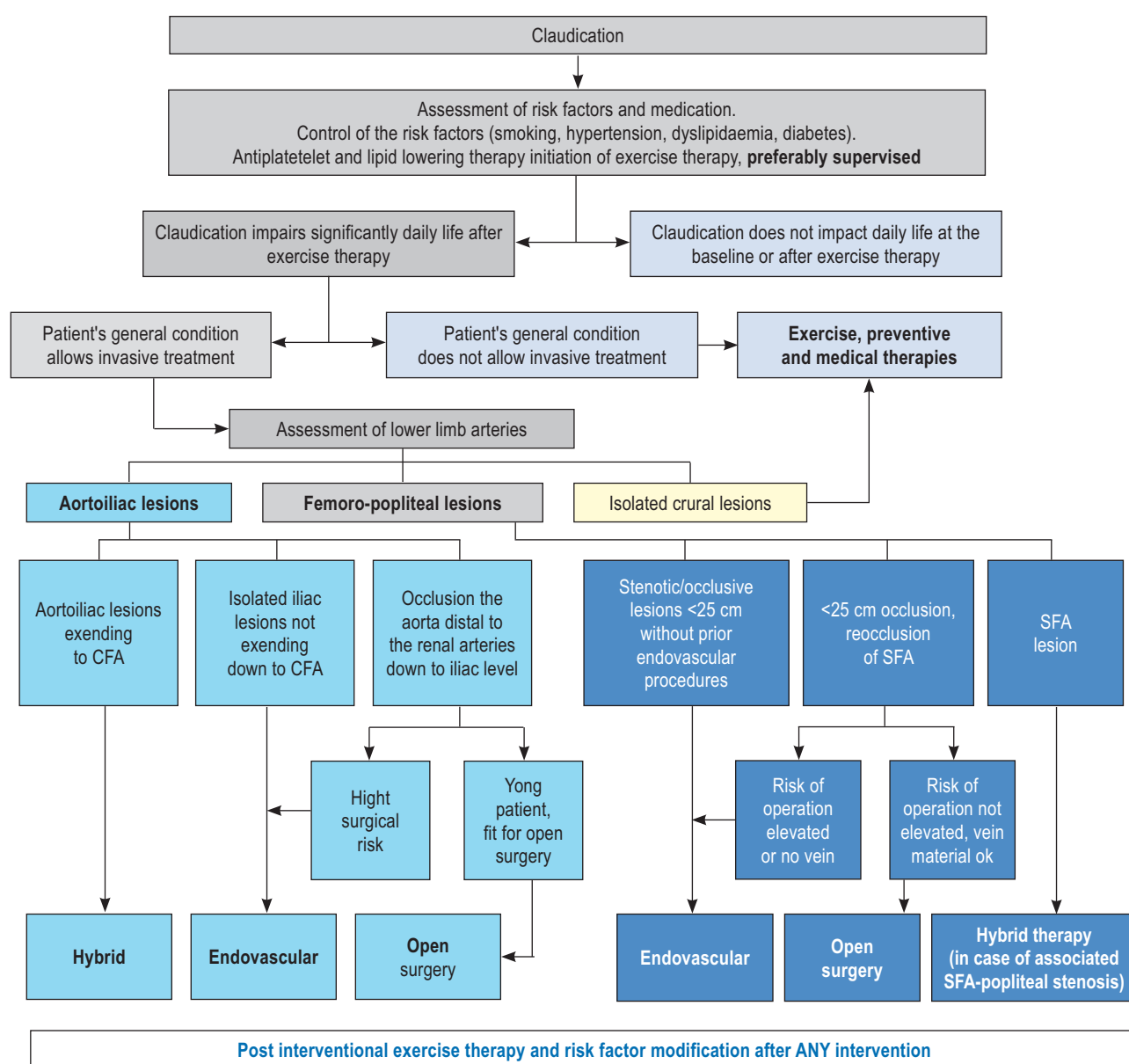
Таблица 1

Важные клинические, ангиографические и лечебные результаты, которые необходимо учитывать в исследованиях и реестрах.
Оценка эндоваскулярных устройств для лечения заболеваний периферических артерий и критической ишемии конечностей

Clinical characteristics	Angiographic characteristics	Outcomes
Demographics (age, sex, socioeconomic class)	Lesion location, length	Patency (primary, assisted primary, secondary)
Diabetes mellitus	Calcification	Clinically driven target lesion revascularization
Chronic kidney disease	Number of runoff	6-minute walk test
Rutherford class	Stenosis versus occlusion	Quality of life metrics
Ankle brachial index	De novo versus restenosis	Amputation free survival
Toe brachial index	–	Major adverse limb events
Comorbid coronary, cerebrovascular conditions	–	Time to wound healing
Wound location, size, and depth	–	Time to ambulation
Soft tissue/bone infection	–	Hospital length of stay
–	–	Readmission
–	–	Total medical expense

technical success of the procedure reached 98% in the authors' study, with primary and secondary patency at 24 months being 93.2% and 95.5%, respectively. However, factors such as the presence of diabetes mellitus and dyslipidemia may influence the decreased efficacy of treatment with the hybrid approach, as shown by G.A. Antoniou et al. in 2009 [30]. At the same time, V.I. Rusin et al. in 2014 [33], thanks to the use of hybrid technologies, preserved the limb in 85.7% of patients with critical ischemia during one year of follow-up. However, in a large single-center study published in 2014, M. Taurino et al. [34] stated that hybrid technologies are most effective in the treatment of patients with TASC II category C and D. According to the Russian guidelines for the management of patients with lower limb arterial diseases published in 2013, it is recommended to perform hybrid operations in multilevel lesions of lower limb arteries. It is believed that hybrid technologies can make a significant contribution to solving the problem of lower limb amputations, as by improving blood circulation, in some cases small amputations or necrectomy can be limited. At the same time, very compromising data of the hybrid approach are presented by Japanese authors M. Nakayama and F. Sakamoto in 2013 [29], whose study presented a group of 11 patients with occlusion of the superficial femoral artery, including the ostium, who underwent endovascular revascularization and endarterectomy from the ostium. In spite of the fact that all patients achieved improvement of the limb condition (pain reduction and wound healing), 9 of them died during the follow-up pe-

riod of 23.9 ± 14.7 months. At the same time, as the authors note, this was due to the initially severe condition of the patients. The work of V.V. Franz et al. in 2011 [41], who applied a hybrid technique — femoral-popliteal bypass with stenting of the deep femoral artery with titanium nickelide TH-10 construction, can be considered as very original research in the study of hybrid revascularization. The technique applied by the authors improved the blood supply to the limb by 31% in terms of clinical parameters compared to the control group. Up to the present time in the literature concerning the problem of surgical treatment of patients with lower limb ischemia there is no unambiguous answer concerning the first-priority choice of the method of limb revascularization. This is primarily determined by the type of lower limb arterial channel lesion, the level of occlusion or stenosis, the presence of severe comorbid status, surgeon's experience and technical equipment of clinics. Open revascularization of the limb even in high-risk patients is of great importance. This is primarily due to well-developed techniques and indications for various types of surgeries, as well as the results of their application, especially femoral-popliteal [42], aorto-femoral and femoral-tibial bypass [16, 17, 20, 21, 40, 43, 44], as well as revascularization using complex non-standard methods of surgery, including lumbar sympathectomy, spinal cord stimulation and gene therapy [66]. However, there are factors that account for the ambiguity of results and are independent of the severity of ischemia and anatomic localization. Another aspect is that one of the debated issues



CFA = common femoral artery; SFA = superficial femoral artery.

^a Related to atherosclerotic lower extremity artery disease (LEAD).

Fig. 2. Management of patients with intermittent claudication [68]

Рис. 2. Ведение пациентов с перемежающейся хромотой [68]

in open surgery is the choice of graft for limb revascularization. Despite the indisputable advantages of autovenous grafting, alternative shunts are still being searched for. The main disadvantage of open surgeries, according to the majority of studies, is their high traumatic nature and duration, possibility of wound and prosthesis infection, thrombosis of vascular prostheses in the distant period, development of restenosis, false aneurysms of anastomoses, etc. In many respects, these disadvantages of open operations led to the search and development of endovascular technologies [46], which

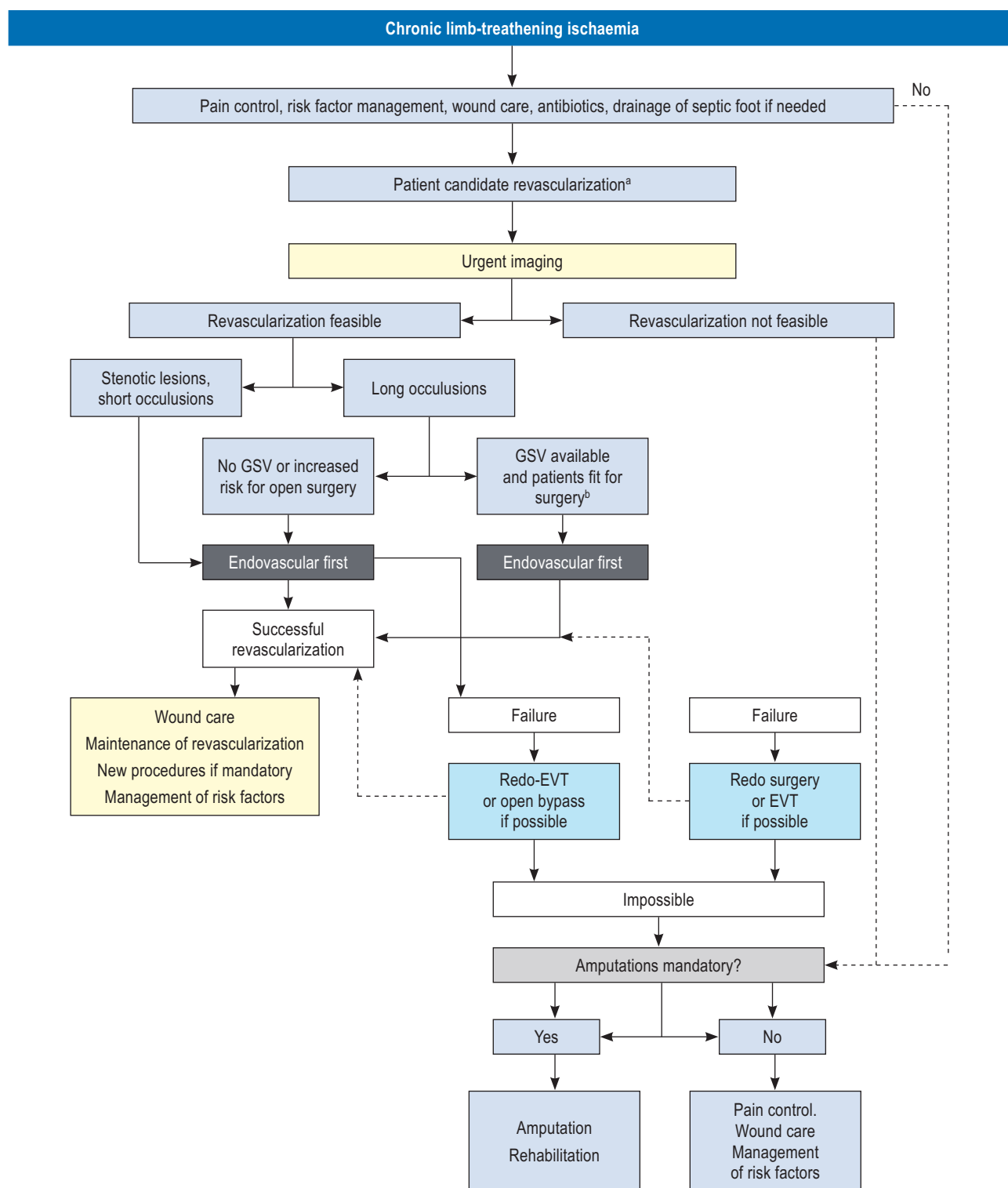
are also not without disadvantages and are accompanied by the development of such complications as stent restenosis [49, 67]. Despite the wide introduction of endovascular technologies and quite a significant number of publications comparing advantages and disadvantages of both endovascular and open interventions, the question of which technology is more effective is still open, even in spite of rather stable recommendations on the choice of revascularization method published in the TASC II consensus document in 2007. In spite of the fact that this document can be considered outdated to a



greater extent, despite the fact that it is practically fundamental for the choice of the method of limb revascularization, it still requires revision in the light of the development and achievement of new results of endovascular interventions in chronic limb ischemia. In this regard, on the pages of the European Journal of Vascular Surgery the president of the European Society of Vascular and Endovascular Surgeons spoke about significant disagreements on the drafting of a new consensus document by the world's leading specialists and societies of vascular surgeons of the USA and Europe, which also does not make corrections in the definition of both promising directions in the development of vascular surgery of critical limb ischemia and in the choice of the method of its treatment [48]. The increase in the frequency of endovascular interventions for peripheral arterial diseases was convincingly demonstrated by D.L. Cull et al. in 2010 [47]. Thus, according to their data, the frequency of endovascular revascularization of the lower limbs increased by 33% from 1995 to 2005, which is also indicated by other authors. The most studied aspect of treatment of patients with limb ischemia is the comparison of angioplasty and stenting results, when comparing which significantly better results were obtained using the stenting technique. However, this method is also not without disadvantages, which is associated with the development of stent reclosures or restenosis in the medium and long term. In addition, ambiguous results are obtained when performing angioplasty and stenting of outflow arteries, in particular, the arteries of the lower leg, especially in the presence of atypical anatomy and diabetes mellitus. At the same time, as A.A. Kuchay, A.N. Lipin et al in 2019 and D.V. Ovcharenko et al. in 2009 [45, 64] note, subintimal angioplasty is a valuable tool in the arsenal of an endovascular surgeon, as it allows to restore patency of extended chronic occlusions with minimal costs. N. Fernandez et al. in 2010 [65], A.A. Kuchay, A.N. Lipin et al in 2019, 2024 [44, 45] also demonstrated that after endovascular interventions on the lower leg arteries there is a high frequency of repeated re-interventional operations. As noted by N.U. Saqib in 2013 [56], endovascular interventions on the lower leg arteries in some cases are the only possible treatment method to save the limb from amputation. A number of authors have shown that endovascular interventions for critical ischemia of the lower limbs in patients with diabetic foot syndrome are effective and justified, allowing to perform economical resection interventions on the foot and to stop the phenomena of critical ischemia [55]. The number of works on this issue increases every year. In a meta-analysis published by G.A. Antoniou et al. in 2013 [50] comparing the results of endovascular versus open surgeries in occlusive stenotic lesions of the femoral-popliteal arterial segment, it was shown that the choice in favor of endovascular interven-

tions should be preferred in patients with severe comorbid status, as endovascular surgeries are less traumatic, which is also indicated by a number of other authors. Thus, to date, the choice of treatment technology in the lesion of the popliteal artery with involvement of the femoral artery or tibial arteries is debatable. As noted by M.B. Malas et al. in 2014 [54], bypass surgeries for lesions of the femoral-popliteal segment are performed in patients with more severe and multilevel lesions of atherosclerosis, which largely determines in some cases worse results of conventional surgical treatment in comparison with endovascular revascularization of the limb. T. Kudo et al. in 2006 [51] when comparing the results of treatment of patients with critical ischemia concluded that in recent years arterial angioplasty has been used more often than open revascularization, besides, the authors made a very controversial conclusion about the expediency of primary endovascular interventions compared to open operations. At the same time, the latter are assigned such indications for application as impossibility of endovascular revascularization or high probability of absence of clinically significant results. It should be noted that the results of endovascular interventions are still ambiguous. Thus, D.T. Baril et al. in 2010 [57] noted that the use of endovascular technologies in TASC II type C lesions require further study of the long-term results of treatment. According to one of the large studies BASIL (Bypass versus Angioplasty in Severe Ischemia of the Leg), which compared the results of endovascular treatment methods and bypass surgeries, summarized by M.S. Conte in 2010 [53], it is shown that, to date, the results of surgeries with the use of autovenous surgeries are superior to endovascular surgeries. It is now recognized that endovascular techniques are most effective when applied to stenoses or occlusions of the aorto-iliac segment [52, 58]. However, according to the systematic review by V. Jongkind et al. in 2010 [58], primary arterial patency after endovascular interventions is inferior to open surgical revascularization, although secondary patency almost reaches the same level as after open surgery.

At the same time, according to R. Pulli et al. in 2011 [63], the rate of reinterventions after endovascular surgeries for iliac arterial segment lesions varies from 2.5 to 12.5% within 2 to 60 months and depends on the severity of the condition, type of arterial lesion and its level. In turn, B.L. Chen in 2011 [62] believes that angioplasty of the iliac arteries can be the first line of choice for surgical treatment of such patients. In recent years, in endovascular treatment of patients with critical ischemia or intermittent claudication, drug-eluting or cutting-coated balloons, new generation stents and stent grafts: biodegradable, drug-eluting stents and others have been increasingly used, which allows



EVT = endovascular therapy; GSV = great saphenous vein.

^a In bedridden, demented and/or frail patients, primary amputation should be considered.

^b In the absence of contra-indication for surgery and in the presence of adequate target for anastomosis/runoff.

Fig. 3. Management of patients with chronic limb threatening ischemia [68]

Рис. 3. Ведение пациентов с хронической ишемией, угрожающей потерей конечности [68]



to significantly improve the results of treatment of this group of patients (Fig. 3).

CONCLUSION

Hybrid technique in obliterative atherosclerosis in lower limb arteries having multilevel lesions is most effective than open and endovascular techniques. It has shorter duration of surgical intervention with very low blood loss, short time in intensive care unit, very low complications rate. Hybrid interventions make it possible in all cases to eliminate ischemia symptoms and save the patients limb, while reducing complication rate and lethality, which is especially important in patients with high surgical risk due to severe concomitant pathology. In conclusion, it should be noted that the final conclusions about the feasibility and efficacy of a particular method of revascularization can be made only on the basis of the principles of evidence-based medicine after several randomized trials.

ADDITIONAL INFORMATION

Authors' contribution. 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.

Competing interests. The authors declare that they have no competing interests.

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REFERENCES

- Kuchay A.A., Lipin A.N., Gruzdev N.N., Borisov A.G., Kurach M. Lower extremity peripheral artery disease: contemporary epidemiology, management and future trends (a scientific statement). *Russian Biomedical Research*. 2023;8(4):54–64. (In Russian). <https://doi.org/10.56871/RBR.2023.32.30.007>.
- Kuchay A.A., Lipin A.N., Padaria Sh.F. et al. Chronic limb threatening ischemia — epidemiology, pathogenesis, diagnosis and treatment strategies. *Russian Biomedical Research*. 2024; 9(3):53–61. (In Russian). <https://doi.org/10.56871/RBR.2024.95.99.007>.
- Gavrilenko A.V., Van S., Al-Yusef N.N. Modern possibilities to predict surgical outcomes in patients with chronic lower limb ischemia. *Kardiologiya i Serdechno-Sosudistaya Khirurgiya*. 2017;10(5):52–57. (In Russian). <https://doi.org/10.17116/kardio201710552-57>.
- Blecha M.J. Critical limb ischemia. *Surg Clin North Am*. 2013;93(4):789–812. <https://doi.org/10.1016/j.suc.2013.04.006>.
- Glushkov N.I., Shlomin V.V., Ivanov M.A., Puzdryak P.D., Artyomova A.S., Bondarenko P.B. Comparative evaluation of various methods of revascularization for multifocal peripheral artery disease. *Kardiologiya i Serdechno-Sosudistaya Khirurgiya*. 2018;11(2):24–30. (In Russian). <https://doi.org/10.17116/kardio201811224-30>.
- Kuchay A.A., Lipin A.N. Revascularization of patients with multilevel artery lesions of the lower limbs. *Angiology and Vascular Surgery. Journal of Academician A.V. Pokrovsky*. 2023;29(S2):176–177. (In Russian).
- Kuchay A.A., Lipin A.N. et al. Evaluation of effectiveness of the application of hybrid operative interventions in the treatment of patients with multi-story artery lesions of the lower limbs in critical limb ischemia. *Angiology and Vascular Surgery. Journal of Academician A.V. Pokrovsky*. 2023;29(S2):177–179. (In Russian).
- Aho P.S., Venermo M. Hybrid procedures as a novel technique in the treatment of critical limb ischemia. *Scand J Surg*. 2012;101(2): 107–113. <https://doi.org/10.1177/145749691210100206>.
- Thukkani A.K., Kinlay S. Endovascular intervention for peripheral artery disease. *Circ Res*. 2015;116(9):1599–1613. <https://doi.org/10.1161/CIRCRESAHA.116.303503>.
- Mustapha J.A., Diaz-Sandoval L.J. Balloon angioplasty in tibioperoneal interventions for patients with critical limb ischemia. *Tech Vasc Interv Radiol*. 2014;17(3):183–196. <https://doi.org/10.1053/j.tvir.2014.08.007>.
- Borisov A.G., Atmadzas K.A., Gruzdev N.N., Kuchay A.A. et al. Alternative conduit from the contralateral of lower limb in infrainguinal reconstructions: assessment of risk factors for complications. *International Journal of Interventional Cardioangiography*. 2024;(S1-1):98. (In Russian).
- Kazakov Yu.I., Lukin I.B., Kazakov A.Yu., Efimov S.Yu., Velikov P.G. Choosing the method of reconstruction for lower-limb critical ischemia. *Angiology and Vascular Surgery*. 2015;21(2):152–158. (In Russian).
- Kuchay A.A., Lipin A.N., Gruzdev N.N. et al. Comparison of clinical outcome of bypass surgery versus below the knee angioplasty and stenting in infrapopliteal lesions that results in ulcer or toe gangrene. *Russian Biomedical Research*. 2024;9(2):50–56. (In Russian). <https://doi.org/10.56871/RBR.2024.50.12.006>.
- Naoum J.J., Arbid E.J. Endovascular techniques in limb salvage: infrapopliteal angioplasty. *Methodist Debaque Cardiovasc J*. 2013;9(2):103–107. <https://doi.org/10.14797/mdcj-9-2-103>.
- Mc Phee J.T., Nguyen L.L., Ho K.J., Ozaki C.K., Conte M.S., Belkin M. Risk prediction of 30-day readmission after infrainguinal



- bypass for critical limb ischemia. *J Vasc Surg.* 2013;57(6):1481–1488. <https://doi.org/10.1016/j.jvs.2012.11.074>.
16. Kuchay A.A., Lipin A.N. et al. The hybrid surgery concepts for atherosclerotic lesions of lower limb arteries. *Atherosclerosis and Dyslipidemias.* 2023;53(3):37–43. (In Russian). <https://doi.org/10.34687/2219-8202.JAD.2023.03.0005>.
 17. Kuchay A.A., Lipin A.N. Hybrid interventions on distal sections of the main arteries in extended chronic occlusions of the superficial femoral artery in patients with critical limb ischemia. *Atherosclerosis and Dyslipidemias.* 2024;55(2):33–40. (In Russian). <https://doi.org/10.34687/2219-8202.JAD.2024.02.0004>.
 18. Clair D., Shah S., Weber J. Current state of diagnosis and management of critical limb ischemia. *J Curr Cardiol Rep.* 2012;14(2):160–170. <https://doi.org/10.1007/s11886-012-0251-4>.
 19. Singh K.P., Sharma A.M. Critical limb ischemia: current approach and future directions. *J Cardiovasc Trans Res.* 2014;7(4):437–445. <https://doi.org/10.1007/s12265-014-9562-8>.
 20. Kuchay A.A., Lipin A.N. et al. Conception of “distal hybrid” for extended occlusions of the superficial femoral artery with severe lesions of outflow in critical limb ischemia. *Angiology and Vascular Surgery. Journal of Academician A.V. Pokrovsky.* 2022;28(S1):157–161. (In Russian).
 21. Kuchay A.A., Lipin A.N. et al. Modern concepts and principles of treatment for extended occlusions of the superficial femoral artery with severe lesions of the tibial arteries in critical limb ischemia. *Angiology and Vascular Surgery. Journal of Academician A.V. Pokrovsky.* 2023;29(S2):179–180. (In Russian).
 22. Baroi L.G., Verbist J., Peeters P., Popa R.F. Clinical and epidemiological assessment concerning hybrid revascularization techniques in the treatment of multilevel arterial occlusive disease. *Rev Med Chir Soc Med Nat Iasi.* 2014;118(3):764–771.
 23. Patel S.D., Donati T., Zayed H. Hybrid revascularization of complex multilevel disease: a paradigm shifts in critical limb ischemia treatment. *J Cardiovasc Surg (Torino).* 2014;55(5):613–623.
 24. Balaz P., Rokosny S., Bafnec J., Björck M. The role of hybrid procedures in the management of peripheral vascular disease. *Scand J Surg.* 2012;101(4):232–237. <https://doi.org/10.1177/145749691210100402>.
 25. Kuchay A.A., Lipin A. N., Antropov A.V. Treatment of multilevel lesions of arteries in lower extremities in cases of CLTI. *Medical Alliance.* 2022;10(S3):187–189. (In Russian). EDN: IWSMIP.
 26. Zhou M., Huang D., Liu C., Liu Z., Zhang M., Qiao T., Liu C.J. Comparison of hybrid procedure and open surgical revascularization for multilevel infrainguinal arterial occlusive disease. *Clin Interv Aging.* 2014;9:1595–1603. <https://doi.org/10.2147/CIA.S66860>.
 27. Balaz P., Rokosny S., Wohlfahrt P., Adamec M., Janousek L., Björck M. Early and late outcomes of hybrid endovascular and open repair procedures in patients with peripheral arterial disease. *Vasa.* 2013;42(4):292–300. <https://doi.org/10.1024/0301-1526/a000290>.
 28. Joh J.H., Joo S.H., Park H.C. Simultaneous hybrid revascularization for symptomatic lower extremity arterial occlusive disease. *Exp Ther Med.* 2014;7(4):804–810. <https://doi.org/10.3892/etm.2014.1513>.
 29. Nakayama M., Sakamoto F. Proximal direct endarterectomy combined with simultaneous distal endovascular therapy for chronic full-length occlusion of the superficial femoral artery in elderly patients. *Asian J Surg.* 2013;36(3):104–110. <https://doi.org/10.1016/j.asjsur.2012.11.006>.
 30. Antoniou G.A., Sfyroeras G.S., Karathanos C., Achouhan H., Koutsias S., Vretzakis G., Giannoukas A.D. Hybrid endovascular and open treatment of severe multilevel lower extremity arterial disease. *Eur J Vasc Endovasc Surg.* 2009;38(5):616–622. <https://doi.org/10.1016/j.ejvs.2009.06.016>.
 31. Slovut D.P., Sullivan T.M. Combined endovascular and open revascularization. *Ann Vasc Surg.* 2009;23(3):414–424. <https://doi.org/10.1016/j.avsg.2008.12.001>.
 32. Slovut D.P., Demaioribus C.A. Hybrid revascularization using Silverhawk atherectomy and infrapopliteal bypass for limb salvage. *Ann Vasc Surg.* 2007;21(6):796–800. <https://doi.org/10.1016/j.avsg.2007.07.008>.
 33. Rusin V.I., Popovich Yu.M., Korsak V.V., Rusin V.V. The place of hybrid surgery in treatment of critical lower limb ischemia. *Surgery News.* 2014;22(1):244–251.
 34. Taurino M., Persiani F., Fantozzi C., Ficarelli R., Rizzo L., Stella N. Trans-Atlantic Inter-Society Consensus II C and D iliac lesions can be treated by endovascular and hybrid approach: A Single-Center Experience. *Vasc Endovasc Surg.* 2014;48(2):123–128. <https://doi.org/10.1177/1538574413512381>.
 35. Piazza M., Ricotta J.J., Bower T.C., Kalra M., Duncan A.A., Cha S. et al. Iliac artery stenting combined with open femoral endarterectomy is as effective as open surgical reconstruction for severe iliac and common femoral occlusive disease. *J Vasc Surg.* 2011;54(2):402–411. <https://doi.org/10.1016/j.jvs.2011.01.027>.
 36. Chang R.W., Coodney P.P., Baek J.H., Nolan B.W., Rzucidlo E.M., Powell R.J. Long-term results of combined common femoral endarterectomy and iliac stenting/stent grafting for occlusive disease. *J Vasc Surg.* 2008;48(2):362–367. <https://doi.org/10.1016/j.jvs.2008.03.042>.
 37. Uchkin I.G., Shugushev Z.H., Talov N.A., Bagdasaryan A.G., Gonsales A.K., Khmyrova A.V. Experience with hybrid techniques of surgical treatment of patients with lower limb critical ischemia. *Angiology and Vascular Surgery.* 2013;18(2):48–57. (In Russian).
 38. Matsagkas M., Kouvelos G., Arnaoutoglou E., Papa N., Labropoulos N., Tassiopoulos A. Hybrid procedures for patients with critical limb ischemia and severe common femoral artery atherosclerosis. *Ann Vasc Surg.* 2011;25(8):1063–1069. <https://doi.org/10.1016/j.avsg.2011.07.010>.
 39. Kuchay A.A., Lipin A.N. et al. Distal hybrids for long total occlusion of superficial femoral artery with severely compromised runoff. *Journal of Vascular and Endovascular Therapy.* 2019;4(S):52–53. (In Russian).
 40. Kuchay A.A., Lipin A.N. A comparative retrospective analysis of the results of hybrid interventions and femoral-tibial bypass in extended multi-level infrainguinal arterial segment lesions in pa-



- tients with chronic critical limb ischemia. *Pediatrician (St. Petersburg)*. 2023;14(6):25–35. (In Russian). <https://doi.org/10.17816/PED626430>.
41. Frants V.V., Ivchenko O.A., Ivchenko A.O. Advantages of hybrid surgery using elastic stents of nikelid-titanium TH-10 in vascular surgery. *Bulletin of Siberian Medicine*. 2011;10(1):122–6. (In Russian).
42. Kalmykov E.L., Suchkov I.A., Nematzoda O.N. On the problem of lumbar sympathectomy. *Angiology and Vascular Surgery*. 2017;23(4):181–185. (In Russian).
43. Sazhinov A.P., Lukinskiy A.V., Chupin A.V. Ways to improve patency of the femoral-popliteal-crural bypass grafts. *Angiology and Vascular Surgery*. 2014;20(1):141–145. (In Russian).
44. Kuchay A.A., Lipin A.N., Kurianov P.S. Advantages of the hybrid revascularization technique in the treatment of extended occlusions of the superficial femoral artery and multilevel lesions of the lower extremity arteries. *Regional Hemodynamics and Microcirculation*. 2024;23(2):60–66. (In Russian). <https://doi.org/10.24884/1682-6655-2024-23-2-60-66>.
45. Kuchay A.A., Lipin A.N. et al. Hybrid approach in treatment of extended occlusions of arteries of the lower limbs in CLI. *Angiology and Vascular Surgery. Journal of Academician A.V. Pokrovsky*. 2019;25(S2):260–264. (In Russian).
46. Ghoneim B., Elwan H., Eldaly W., Khairy H., Taha A., Gad A. Management of critical lower limb ischemia in endovascular era: experience from 511 patients. *Int J Angiol*. 2014;23(3):197–206. <https://doi.org/10.1055/s-0034-1382825>.
47. Cull D.L., Langan E.M., Gray B.H., Jihson B., Taylor S.M. Open versus endovascular intervention for critical limb ischemia: A population-based study. *J Am Coll Surg*. 2010;210(5):555–563. <https://doi.org/10.1016/j.jamcollsurg.2009.12.019>.
48. Gonçalves F.B., Verhagen H.J.M. Invited Comment on: "Benefit of revascularization to critical limb ischemia patients evaluated by a patient-oriented Scoring System". *Eur J Vasc Endovasc Surg*. 2012;43(5):548. <https://doi.org/10.1016/j.ejvs.2012.01.005>.
49. Mehta M., Paty P.S.K., Roddy S.P., Kreienberg P.B., Sternbach Y., Taggart J.B. et al. Standardized angioplasty and stenting techniques for sfa-popliteal TASC C and D lesions improve outcomes: A prospective evaluation. *J Vasc Surg*. 2010;52(Issue 3):802. <https://doi.org/10.1016/j.jvs.2010.06.024>.
50. Antoniou G.A., Chalmers N., Georgiadis G.S., Lazarides M.K., Antoniou S.A., Serracino-Inglott F., Smyth J.V., Murray D. A meta-analysis of endovascular versus surgical reconstruction of femoropopliteal arterial disease. *J Vasc Surg*. 2013;57(1):242–253. <https://doi.org/10.1016/j.jvs.2012.07.038>.
51. Kudo T., Chandra F.A., Kwun W.H., Haas B.T., Ahn S.S. Changing pattern of surgical revascularization for critical limb ischemia over 12 years: Endovascular vs open bypass surgery. *J Vasc Surg*. 2006;44(2):304–313. <https://doi.org/10.1016/j.jvs.2006.03.040>.
52. Jongkind V., Akkersdijk G.J., Yeung K.K., Wisselink W. A systematic review of endovascular treatment of extensive aortoiliac occlusive disease. *J Vasc Surg*. 2010;52(5):1376–1383. <https://doi.org/10.1016/j.jvs.2010.04.080>.
53. Conte M.S. Bypass versus angioplasty in severe ischemia of the leg (BASIL) and the (hoped for) dawn of evidence-based treatment for advanced limb ischemia. *J Vasc Surg*. 2010;51(5 Suppl):69S–75S. <https://doi.org/10.1016/j.jvs.2010.02.001>.
54. Malas M.B., Enwerem N., Qazi U., Brown B., Schneider E.B., Reifsnnyder T. et al. Comparison of surgical bypass with angioplasty and stenting of superficial femoral artery disease. *J Vasc Surg*. 2014;59(1):129–135. <https://doi.org/10.1016/j.jvs.2013.05.100>.
55. Korhonen M., Halmesmäki K., Lepäntalo M., Venermo M. Predictors of failure of endovascular revascularization for critical limb ischemia. *Scand J Surg*. 2012;101(3):170–176. <https://doi.org/10.1177/145749691210100306>.
56. Saqib N.U., Domenick N., Cho J.S., Marone L., Leers S., Makaroun M.S., Chaer R.A. Predictors and outcomes of restenosis following tibial artery endovascular interventions for critical limb ischemia. *J Vasc Surg*. 2013;57(3):692–699. <https://doi.org/10.1016/j.jvs.2012.08.115>.
57. Baril D.T., Chaer R.A., Rhee R.Y., Makaroun M.S., Marone L.K. Endovascular interventions for TASC II D femoropopliteal lesions. *J Vasc Surg*. 2010;51(6):1406–1412. <https://doi.org/10.1016/j.jvs.2010.01.062>.
58. Burke C.R., Hanke P.K., Hernandez R., Rectenwald J.E., Krishnamurthy V., Englesbe M.J. et al. A contemporary comparison of aortofemoral bypass and aortoiliac stenting in the treatment of aortoiliac occlusive disease. *Ann Vasc Surg*. 2010;24(1):4–13. <https://doi.org/10.1016/j.avsg.2009.09.005>.
59. Kuchay A.A., Lipin A.N. et al. Treatment of multi-level arterial lesions of lower limb arteries in CLI. *Angiology and Vascular Surgery. Journal of Academician A.V. Pokrovsky*. 2021;27(S2):410–412. (In Russian).
60. Kuchay A.A., Lipin A.N. et al. Hybrid approach to extended occlusions of SFA in CLI. *Angiology and Vascular Surgery. Journal of Academician A.V. Pokrovsky*. 2022;28(S1):161–163. (In Russian).
61. Kuchay A.A., Lipin A.N., Gruzdev N.N. et al. Critical limb threatening ischemia and its management. *Russian Biomedical Research*. 2024;9(1):34–47. (In Russian). <https://doi.org/10.56871/RBR.2024.68.81.005>.
62. Chen B.L., Holt H.R., Day J.D., Stout C.L., Stokes G.K., Paneton J.M. Subintimal angioplasty of chronic total occlusion in iliac arteries: a safe and durable option. *J Vasc Surg*. 2011;53(2):367–373. <https://doi.org/10.1016/j.jvs.2010.08.073>.
63. Pulli R., Dorigo W., Fargion A., Innocenti A.A., Pratesi G., Marek J. et al. Early and long-term comparison of endovascular treatment of iliac artery occlusions and stenosis. *J Vasc Surg*. 2011;53(1):92–98. <https://doi.org/10.1016/j.jvs.2010.08.034>.
64. Ovcharenko D.V., Kaputin M.Yu. Technical issues of subintimal angioplasty of crural arteries. *International Journal of Interventional Cardiology*. 2009;(17):36–40.
65. Fernandez N., McEnaney R., Marone L.K., Rhee R.Y., Leers S., Makaroun M., Chaer R.A. Predictors of failure and success of tibial interventions for critical limb ischemia. *J Vasc Surg*. 2010;52(4):834–842. <https://doi.org/10.1016/j.jvs.2010.04.070>.



66. Gavrilenko A.V., Voronov D.A. Genetic engineering technologies of stimulating angiogenesis as an innovation trend in angiology and vascular surgery. *Angiology and Vascular Surgery*. 2015;21(2):7–14.
67. Kuchay A.A., Lipin A.N., Padaria Sh.F. et al. Arterial restenosis: past, current status and future directions. *J Chronic Dis Prev Care*. 2024;1(1):1–8.
68. Aboyans V., Ricco J.-B., Bartelink M.-L.E.L. et al. Editor's Choice — 2017 ESC Guidelines on the Diagnosis and Treatment of Peripheral Arterial Diseases, in collaboration with the European Society for Vascular Surgery (ESVS). *Eur J Vasc Endovasc Surg*. 2018;55(3):305–368. <https://doi.org/10.1016/j.ejvs.2017.07.018>.
69. Kuchay A.A., Lipin A.N. Kuchay A., Lipin A. Modern concept and revascularization of extended occlusion of the superficial femoral artery accompanied by multilevel occlusions of the lower extremities in chronic limb threatening ischemia. *Journal Modern Science: Actual Problems of Theory and Practice. Series "Natural and Technical Sciences"*. 2025;10:259–263. (In Russian). <https://doi.org/10.37882/2223-2966.2025.10.23>.
70. Hiramoto J.S., Teraa M., de Borst G.J., Conte M.S. Interventions for lower extremity peripheral artery disease. *Nat Rev Cardiol*. 2018;15(6):332–350. <https://doi.org/10.1038/s41569-018-0005-0>.
71. Ангиология и сосудистая хирургия. Журнал имени академика А.В. Покровского. 2023;29(C2):176–177.
72. Кучай А.А., Липин А.Н. и др. Оценка эффективности применения гибридных оперативных вмешательств при лечении больных с многоэтажным поражением артерий нижних конечностей при критической ишемии нижних конечностей. *Ангиология и сосудистая хирургия. Журнал имени академика А.В. Покровского*. 2023;29(C2):177–179.
73. Aho P.S., Venermo M. Hybrid procedures as a novel technique in the treatment of critical limb ischemia. *Scand J Surg*. 2012;101(2):107–113. <https://doi.org/10.1177/145749691210100206>.
74. Thukkani A.K., Kinlay S. Endovascular intervention for peripheral artery disease. *Circ Res*. 2015;116(9):1599–1613. <https://doi.org/10.1161/CIRCRESAHA.116.303503>.
75. Mustapha J.A., Diaz-Sandoval L.J. Balloon angioplasty in tibioperoneal interventions for patients with critical limb ischemia. *Tech Vasc Interv Radiol*. 2014;17(3):183–196. <https://doi.org/10.1053/j.tvir.2014.08.007>.
76. Борисов А.Г., Атнадзас К.А., Груздев Н.Н., Кучай А.А. и др. Альтернативный кондуит из контралатеральной нижней конечности при инфраингвинальных реконструкциях: оценка факторов риска осложнений. *Международный журнал интервенционной кардиоангиологии*. 2024;(S1-1):98.
77. Казаков Ю.И., Лукин И.Б., Казаков А.Ю., Ефимов С.Ю., Великов П.Г. Выбор метода реконструкции при критической ишемии нижних конечностей. *Ангиология и сосудистая хирургия*. 2015;21(2):152–158.
78. Кучай А.А., Липин А.Н., Груздев Н.Н. и др. Сравнение клинических результатов аортокоронарного шунтирования с ангиопластикой и стентированием сосудов ниже колена при подколенных поражениях, приводящих к язве или гангрене пальцев стопы. *Российские биомедицинские исследования*. 2024;9(2):50–56. <https://doi.org/10.56871/RBR.2024.50.12.006>.
79. Naoum J.J., Arbid E.J. Endovascular techniques in limb salvage: infrapopliteal angioplasty. *Methodist DeBakey Cardiovasc J*. 2013;9(2):103–107. <https://doi.org/10.14797/mdcj-9-2-103>.
80. Mc Phee J.T., Nguyen L.L., Ho K.J., Ozaki C.K., Conte M.S., Belkin M. Risk prediction of 30-day readmission after infrainguinal bypass for critical limb ischemia. *J Vasc Surg*. 2013;57(6):1481–1488. <https://doi.org/10.1016/j.jvs.2012.11.074>.
81. Кучай А.А., Липин А.Н. и др. Концепции гибридной хирургии атеросклеротических поражений артерий нижних конечностей. *Атеросклероз и дислипидемии*. 2023;53(3):37–43. <https://doi.org/10.34687/2219-8202.JAD.2023.03.0005>.
82. Кучай А.А., Липин А.Н. Гибридные вмешательства на дистальных отделах магистральных артерий при протяженных хронических окклюзиях поверхностной бедренной артерии у больных с критической ишемией нижних конечностей. *Атеросклероз и дислипидемии*. 2024;55(2):33–40. <https://doi.org/10.34687/2219-8202.JAD.2024.02.0004>.
83. Clair D., Shah S., Weber J. Current state of diagnosis and management of critical limb ischemia. *J Curr Cardiol Rep*. 2012;14(2):160–170. <https://doi.org/10.1007/s11886-012-0251-4>.

ЛИТЕРАТУРА

1. Кучай А.А., Липин А.Н., Груздев Н.Н., Борисов А.Г., Ширин В.А., Курач М. Заболевание периферических артерий нижних конечностей: современная эпидемиология, руководство и перспективные направления (научное сочинение). *Российские биомедицинские исследования*. 2024;8(4):54–64. <https://doi.org/10.56871/RBR.2023.32.30.007>.
2. Кучай А.А., Липин А.Н., Падария Ш.Ф. и др. Хроническая угрожающая ишемия конечности — эпидемиология, патогенез, диагностика и тактика лечения. *Российские биомедицинские исследования*. 2024;9(3):53–61. <https://doi.org/10.56871/RBR.2024.95.99.007>.
3. Гавриленко А.В., Ван С., Аль-Юсеф Н.Н. Современные возможности в прогнозировании результатов хирургического лечения больных с хронической ишемией нижних конечностей. *Кардиология и сердечно-сосудистая хирургия*. 2017;10(5):52–57. <https://doi.org/10.17116/kardio201710552-57>.
4. Blecha M.J. Critical limb ischemia. *Surg Clin North Am*. 2013;93(4):789–812. <https://doi.org/10.1016/j.suc.2013.04.006>.
5. Глушков Н.И., Шломин В.В., Иванов М.А., Пуздряк П.Д., Артёмова А.С., Бондаренко П.Б. Сравнительная оценка различных методов реваскуляризации при мультифокальном поражении периферических артерий. *Кардиология и сердечно-сосудистая хирургия*. 2018;11(2):24–30. <https://doi.org/10.17116/kardio201811224-30>.
6. Кучай А.А., Липин А.Н. и др. Реваскуляризация больных с многоуровневым поражением артерий нижних конечностей.



19. Singh K.P., Sharma A.M. Critical limb ischemia: current approach and future directions. *J Cardiovasc Trans Res.* 2014;7(4):437–445. <https://doi.org/10.1007/s12265-014-9562-8>.
20. Кучай А.А., Липин А.Н. и др. Концепция «дистального гибрида» при протяжённых окклюзиях поверхностной бедренной артерии с тяжёлым нарушением оттока при критической ишемии конечности. *Ангиология и сосудистая хирургия. Журнал академика А.В. Покровского.* 2022;28(С1):157–161.
21. Кучай А.А., Липин А.Н. и др. Современные представления и принципы лечения протяжённых окклюзий поверхностной бедренной артерии с тяжёлым поражением большеберцовых артерий при критической ишемии конечности. *Ангиология и сосудистая хирургия. Журнал академика А.В. Покровского.* 2023;29(С2):179–180.
22. Baroi L.G., Verbiest J., Peeters P., Popa R.F. Clinical and epidemiological assessment concerning hybrid revascularization techniques in the treatment of multilevel arterial occlusive disease. *Rev Med Chir Soc Med Nat Iasi.* 2014;118(3):764–771.
23. Patel S.D., Donati T., Zayed H. Hybrid revascularization of complex multilevel disease: a paradigm shifts in critical limb ischemia treatment. *J Cardiovasc Surg (Torino).* 2014;55(5):613–623.
24. Balaz P., Rokosny S., Bafnec J., Björck M. The role of hybrid procedures in the management of peripheral vascular disease. *Scand J Surg.* 2012;101(4):232–237. <https://doi.org/10.1177/145749691210100402>.
25. Кучай А.А., Липин А.Н., Антропов А.В. Лечение многоуровневых поражений артерий нижних конечностей при ХИНК. *Медицинский Альянс.* 2022;10(С3):187–189. EDN: IWSMIP.
26. Zhou M., Huang D., Liu C., Liu Z., Zhang M., Qiao T., Liu C.J. Comparison of hybrid procedure and open surgical revascularization for multilevel infrainguinal arterial occlusive disease. *Clin Interv Aging.* 2014;9:1595–1603. <https://doi.org/10.2147/CIA.S66860>.
27. Balaz P., Rokosny S., Wohlfahrt P., Adamec M., Janousek L., Björck M. Early and late outcomes of hybrid endovascular and open repair procedures in patients with peripheral arterial disease. *Vasa.* 2013;42(4):292–300. <https://doi.org/10.1024/0301-1526/a000290>.
28. Joh J.H., Joo S.H., Park H.C. Simultaneous hybrid revascularization for symptomatic lower extremity arterial occlusive disease. *Exp Ther Med.* 2014;7(4):804–810. <https://doi.org/10.3892/etm.2014.1513>.
29. Nakayama M., Sakamoto F. Proximal direct endarterectomy combined with simultaneous distal endovascular therapy for chronic full-length occlusion of the superficial femoral artery in elderly patients. *Asian J Surg.* 2013;36(3):104–110. <https://doi.org/10.1016/j.asjsur.2012.11.006>.
30. Antoniou G.A., Sfyroeras G.S., Karathanos C., Achouhan H., Koutsias S., Vretzakis G., Giannoukas A.D. Hybrid endovascular and open treatment of severe multilevel lower extremity arterial disease. *Eur J Vasc Endovasc Surg.* 2009;38(5):616–622. <https://doi.org/10.1016/j.ejvs.2009.06.016>.
31. Slovut D.P., Sullivan T.M. Combined endovascular and open revascularization. *Ann Vasc Surg.* 2009;23(3):414–424. <https://doi.org/10.1016/j.avsg.2008.12.001>.
32. Slovut D.P., Demaioribus C.A. Hybrid revascularization using Silverhawk atherectomy and infrapopliteal bypass for limb salvage. *Ann Vasc Surg.* 2007;21(6):796–800. <https://doi.org/10.1016/j.avsg.2007.07.008>.
33. Rusin V.I., Popovich Yu.M., Korsak V.V., Rusin V.V. The place of hybrid surgery in treatment of critical lower limb ischemia. *Surgery News.* 2014;22(1):244–251.
34. Taurino M., Persiani F., Fantozzi C., Ficarelli R., Rizzo L., Stella N. Trans-Atlantic Inter-Society Consensus II C and D iliac lesions can be treated by endovascular and hybrid approach: A Single-Center Experience. *Vasc Endovasc Surg.* 2014;48(2):123–128. <https://doi.org/10.1177/1538574413512381>.
35. Piazza M., Ricotta J.J., Bower T.C., Kalra M., Duncan A.A., Cha S. et al. Iliac artery stenting combined with open femoral endarterectomy is as effective as open surgical reconstruction for severe iliac and common femoral occlusive disease. *J Vasc Surg.* 2011;54(2):402–411. <https://doi.org/10.1016/j.jvs.2011.01.027>.
36. Chang R.W., Coodney P.P., Baek J.H., Nolan B.W., Rzuclidlo E.M., Powell R.J. Long-term results of combined common femoral endarterectomy and iliac stenting/stent grafting for occlusive disease. *J Vasc Surg.* 2008;48(2):362–367. <https://doi.org/10.1016/j.jvs.2008.03.042>.
37. Учкин И.Г., Шугушев З.Х., Талов Н.А., Багдасарян А.Г., Гонсалес А.К., Хмырова А.В. Опыт применения гибридных методик хирургического лечения больных с критической ишемией нижних конечностей. *Ангиология и сосудистая хирургия.* 2013;18(2):48–57.
38. Matsagkas M., Kouvelos G., Arnaoutoglou E., Papa N., Labropoulos N., Tassiopoulos A. Hybrid procedures for patients with critical limb ischemia and severe common femoral artery atherosclerosis. *Ann Vasc Surg.* 2011;25(8):1063–1069. <https://doi.org/10.1016/j.avsg.2011.07.010>.
39. Кучай А.А., Липин А.Н. и др. Дистальные гибриды для тотальной окклюзии протяженной поверхностной бедренной артерии с выраженным нарушением оттока. *Журнал сосудистой и эндоваскулярной терапии.* 2019;4(С):52–53.
40. Кучай А.А., Липин А.Н. Сравнительный ретроспективный анализ результатов гибридных вмешательств и бедренно-тибиального шунтирования при протяженных многоуровневых поражениях инфраингвинального артериального сегмента у больных с хронической критической ишемией нижних конечностей. *Педиатр (Санкт-Петербург).* 2023;14(6):25–35. <https://doi.org/10.17816/PED626430>.
41. Франц В.В., Ивченко О.А., Ивченко А.О. Преимущества гибридной хирургии с использованием эластичных стентов из никелида титана ТН-10 в сосудистой хирургии. *Вестник сибирской медицины.* 2011;10(1):122–126.
42. Калмыков Е.Л., Сучков И.А., Нематзода О.Н. К вопросу о поясничной симпатэктоми. *Ангиология и сосудистая хирургия.* 2017;23(4):181–185.



43. Сажин А.П., Лукин А.В., Чупин А.В. Способы улучшения проходимости бедренно-подколенно-берцовых шунтов. *Ангиология и сосудистая хирургия*. 2014;20(1):141–5.
44. Кучай А.А., Липин А.Н., Курьянов П.С. Преимущества метода гибридной реваскуляризации при лечении протяженных окклюзий поверхностной бедренной артерии и многоуровневых поражений артерий нижних конечностей. *Региональная кровообращение и микроциркуляция*. 2024;23(2):60–66. <https://doi.org/10.24884/1682-6655-2024-23-2-60-66>.
45. Кучай А.А., Липин А.Н. и др. Гибридный подход в лечении протяженных окклюзий артерий нижних конечностей при КИНК. *Ангиология и сосудистая хирургия. Журнал академика А.В. Покровского*. 2019;25(S2):260–264.
46. Ghoneim B., Elwan H., Eldaly W., Khairy H., Taha A., Gad A. Management of critical lower limb ischemia in endovascular era: experience from 511 patients. *Int J Angiol*. 2014;23(3):197–206. <https://doi.org/10.1055/s-0034-1382825>.
47. Cull D.L., Langan E.M., Gray B.H., Johnson B., Taylor S.M. Open versus endovascular intervention for critical limb ischemia: A population-based study. *J Am Coll Surg*. 2010;210(5):555–563. <https://doi.org/10.1016/j.jamcollsurg.2009.12.019>.
48. Gonçalves F.B., Verhagen H.J.M. Invited Comment on: "Benefit of revascularization to critical limb ischemia patients evaluated by a patient-oriented Scoring System". *Eur J Vasc Endovasc Surg*. 2012;43(5):548. <https://doi.org/10.1016/j.ejvs.2012.01.005>.
49. Mehta M., Paty P.S.K., Roddy S.P., Kreienberg P.B., Sternbach Y., Taggart J.B. et al. Standardized angioplasty and stenting techniques for sfa-popliteal TASC C and D lesions improve outcomes: A prospective evaluation. *J Vasc Surg*. 2010;52(Issue 3):802. <https://doi.org/10.1016/j.jvs.2010.06.024>.
50. Antoniou G.A., Chalmers N., Georgiadis G.S., Lazarides M.K., Antoniou S.A., Serracino-Inglott F., Smyth J.V., Murray D. A meta-analysis of endovascular versus surgical reconstruction of femoropopliteal arterial disease. *J Vasc Surg*. 2013;57(1):242–253. <https://doi.org/10.1016/j.jvs.2012.07.038>.
51. Kudo T., Chandra F.A., Kwun W.H., Haas B.T., Ahn S.S. Changing pattern of surgical revascularization for critical limb ischemia over 12 years: Endovascular vs open bypass surgery. *J Vasc Surg*. 2006;44(2):304–313. <https://doi.org/10.1016/j.jvs.2006.03.040>.
52. Jongkind V., Akkersdijk G.J., Yeung K.K., Wisselink W. A systematic review of endovascular treatment of extensive aortoiliac occlusive disease. *J Vasc Surg*. 2010;52(5):1376–1383. <https://doi.org/10.1016/j.jvs.2010.04.080>.
53. Conte M.S. Bypass versus angioplasty in severe ischemia of the leg (BASIL) and the (hoped for) dawn of evidence-based treatment for advanced limb ischemia. *J Vasc Surg*. 2010;51(5 Suppl):69S–75S. <https://doi.org/10.1016/j.jvs.2010.02.001>.
54. Malas M.B., Enwerem N., Qazi U., Brown B., Schneider E.B., Reifsnnyder T. et al. Comparison of surgical bypass with angioplasty and stenting of superficial femoral artery disease. *J Vasc Surg*. 2014;59(1):129–135. <https://doi.org/10.1016/j.jvs.2013.05.100>.
55. Korhonen M., Halmesmäki K., Lepäntalo M., Venermo M. Predictors of failure of endovascular revascularization for critical limb ischemia. *Scand J Surg*. 2012;101(3):170–176. <https://doi.org/10.1177/145749691210100306>.
56. Saqib N.U., Domenick N., Cho J.S., Marone L., Leers S., Makaroun M.S., Chaer R.A. Predictors and outcomes of restenosis following tibial artery endovascular interventions for critical limb ischemia. *J Vasc Surg*. 2013;57(3):692–699. <https://doi.org/10.1016/j.jvs.2012.08.115>.
57. Baril D.T., Chaer R.A., Rhee R.Y., Makaroun M.S., Marone L.K. Endovascular interventions for TASC II D femoropopliteal lesions. *J Vasc Surg*. 2010;51(6):1406–1412. <https://doi.org/10.1016/j.jvs.2010.01.062>.
58. Burke C.R., Hanke P.K., Hernandez R., Rectenwald J.E., Krishnamurthy V., Englesbe M.J. et al. A contemporary comparison of aortofemoral bypass and aortoiliac stenting in the treatment of aortoiliac occlusive disease. *Ann Vasc Surg*. 2010;24(1):4–13. <https://doi.org/10.1016/j.avsg.2009.09.005>.
59. Кучай А.А., Липин А.Н. и др. Лечение многоуровневых поражений артерий нижних конечностей при КИНК. *Ангиология и сосудистая хирургия. Журнал академика А.В. Покровского*. 2021;27(CS):410–412.
60. Кучай А.А., Липин А.Н. и др. Гибридный подход к протяженным окклюзиям ПБА при КИНК. *Ангиология и сосудистая хирургия. Журнал академика А. В. Покровского*. 2022; 28(S1): 161–163.
61. Кучай А.А., Липин А.Н., Груздев Н.Н. и др. Критическая ишемия конечности и ее лечение. *Российские биомедицинские исследования*. 2024;9(1):34–47. <https://doi.org/10.56871/RBR.2024.68.81.005>.
62. Chen B.L., Holt H.R., Day J.D., Stout C.L., Stokes G.K., Panneton J.M. Subintimal angioplasty of chronic total occlusion in iliac arteries: a safe and durable option. *J Vasc Surg*. 2011;53(2):367–373. <https://doi.org/10.1016/j.jvs.2010.08.073>.
63. Pulli R., Dorigo W., Fargion A., Innocenti A.A., Pratesi G., Marek J. et al. Early and long-term comparison of endovascular treatment of iliac artery occlusions and stenosis. *J Vasc Surg*. 2011;53(1):92–98. <https://doi.org/10.1016/j.jvs.2010.08.034>.
64. Ovcharenko DV, Kaputin MYu. Technical issues of subintimal angioplasty of crural arteries. *International Journal of Interventional Cardio angiology*. 2009;(17):36–40.
65. Fernandez N., McEnaney R., Marone L.K., Rhee R.Y., Leers S., Makaroun M., Chaer R.A. Predictors of failure and success of tibial interventions for critical limb ischemia. *J Vasc Surg*. 2010;52(4):834–842. <https://doi.org/10.1016/j.jvs.2010.04.070>.
66. Гавриленко А.В., Воронов Д.А. Генно-инженерные технологии стимуляции ангиогенеза как инновационное направление в ангиологии и сосудистой хирургии. *Ангиология и сосудистая хирургия*. 2015;21(2):7–14.
67. Kuchay A.A., Lipin A.N., Padaria Sh.F. et al. Arterial restenosis: past, current status and future directions. *J Chronic Dis Prev Care*. 2024;1(1):1–8.
68. Aboyans V., Ricco J.-B., Bartelink M.-L.E.L. et al. Editor's Choice — 2017 ESC Guidelines on the Diagnosis and Treatment of Peripheral Arterial Diseases, in collaboration with the European Society for Vascular Surgery (ESVS). *Eur J Vasc*



Endovasc Surg. 2018;55(3):305–368. <https://doi.org/10.1016/j.ejvs.2017.07.018>.

69. Кучай А.А., Липин А.Н. Современная концепция и реваскуляризация протяженной окклюзии поверхностной бедренной артерии на фоне многоуровневых окклюзий нижних конечностей при хронической ишемии, угрожающей потерей конечности. *Современная наука: актуальные проблемы*

теории и практики. Серия «Естественные и технические науки». 2025;(10):259–263. <https://doi.org/10.37882/2223-2966.2025.10.23>.

70. Hiramoto J.S., Teraa M., de Borst G.J., Conte M.S. Interventions for lower extremity peripheral artery disease. *Nat Rev Cardiol.* 2018;15(6):332–350. <https://doi.org/10.1038/s41569-018-0005-0>.

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