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Современные методики подготовки аутовены к проведению шунтирующих операций (несистематический обзор)

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АННОТАЦИЯ

Актуальность. Использование аутовенозного кондуита при выполнении шунтирующих операций в сосудистой и кардиохирургии занимает ведущее место. В связи с высоким риском повторных вмешательств, а также ограниченным количеством качественных венозных ресурсов возникает необходимость как можно более длительного поддержания функционирования аутовенозного шунта.

Цель. Изучить динамику выводов современных исследований по забору, сохранению и оценке качества аутовенозного трансплантата в периоперационном периоде.

Проходимость шунтов после открытого и эндоскопического способа (ЭС) забора имеет сопоставимые результаты. Неудовлетворительные результаты отдаленной проходимости аутовены при ЭС могут быть связаны с длительным периодом обучения эндоскопической методике. ЭС способствует быстрому заживлению послеоперационных ран на ноге, уменьшению болевого синдрома. Методика открытого забора *no touch*, применение низкого давления при расправлении аутовенозного трансплантата и перевязке притоков являются факторами, снижающими риск послеоперационной гиперплазии интимы, что способствует поддержанию длительного функционирования шунта и приводит к снижению количества повторных вмешательств. Для выделения аутовенозного трансплантата при шунтирующих операциях на нижних конечностях предпочтительным является способ открытого забора аутовены — бридж методика. Сохранение аутовенозного трансплантата до шунтирования в цельной аутокрови предположительно также снижает риск повреждения аутотрансплантата, но необходимо проведение рандомизированных исследований с большим количеством наблюдений. Применение контроля качества трансплантата до и после наложения анастомоза и пуска кровотока способствует улучшению непосредственных и отдаленных результатов шунтирования, выполняется с помощью ультразвуковой визуализации и измерения транзитного времени кровотока, ангиографического исследования, введения индоцианинового зеленого, тепловизионного исследования.

Заключение. В данном обзоре проведен современный многокомпонентный анализ роли механических, температурных, средовых и органических факторов, участвующих в формировании свойств аутовенозного кондуита, направленных на поддержание его максимальной проходимости в виде артериального шунта, а также способов контроля интраоперационного контроля проходимости.

Ключевые слова: *эндоскопический забор аутовены; no touch; бридж методика; гидравлическое расправление; сохранение трансплантата; бедренно-подколенное шунтирование; аортокоронарное шунтирование*

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Modern Methods of Preparing Autologous Vein for Bypass Surgery (Non-Systematic Review)

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ABSTRACT

INTRODUCTION: The use of an autologous vein conduit in bypass operations is the leading trend in vascular and cardiac surgery. In the context of a high risk of repeated interventions and of limited availability of high-quality venous resources, it is important that the autovenous conduit remain functional as long as possible.

AIM: To study the dynamics of conclusions from the modern research works on harvesting, preservation and quality assessment of autovein grafts in the postoperative period.

The graft patency after open and endoscopic harvesting is comparable. Unsatisfactory results in terms of the long-term patency of an endoscopically harvested autovein may be associated with a long period of training in endoscopic techniques. They facilitate fast healing of postoperative wounds on the leg and reduce pain syndrome. The *no touch* open harvest technique, the use of low pressure when distending an autovenous graft, and ligation of the tributaries are factors that reduce the risk of postoperative hyperplasia of intima, thus contributing to a long-term functioning of the shunt and reducing the number of reinterventions. The preferable method of harvesting an autovenous graft for bypass surgeries in the lower limbs is an open bridging method. Keeping the autovenous graft in the whole autologous blood before the bypass surgery is also believed to reduce the risk of autograft injury, but randomized studies with a greater number of observations are required. Control of the graft quality before and after application of anastomosis and initiation of blood flow helps to improve the immediate and long-term bypass patency, and is performed using ultrasound imaging, measurement of blood flow transit time, angiographic examination, introduction of indocyanine green, and thermal imaging.

CONCLUSION: This review presents a modern multicomponent analysis of the role of mechanical, thermal, environmental and organic factors in the formation of the properties of an autovein conduit, essential for maintaining its maximal patency as of an arterial bypass, and the methods of intraoperative patency control.

Keywords: *endoscopic vein harvesting; no touch technique; bridging technique; hydraulic distension; graft preservation; femoropopliteal bypass; coronary artery bypass grafting*

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ECO•VECTOR

LIST OF ABBREVIATIONS

AVG — autovenous graft
AHWB — autologous heparinized whole blood
CABG — coronary artery bypass grafting
CI — confidence interval
LL — lower limb
CI — continuous incision
HR — hazards ratio
OR — odds ratio
SI — skip incision
NS — normal saline
ES — endoscopic method

INTRODUCTION

The use of autovenous graft (AVG) in bypass operations is the leading tendency in vascular and cardiac surgery [1, 2]. In view of a high risk of repeated interventions and the limited high-quality vein resources, there is a *need to maintain maximally long functioning of the autovenous bypass*, which is especially important in coronary artery bypass grafting (CABG) operations. An additional feature of autovenous bypass operations in the lower limbs (LL) is the need for a *significant length of the AVG*. In the absence of the great saphenous vein, S. R. Komshian, et al. recommend to use a single-segment *v. cephalika* with a 5-year patency and limb preservation rates of 55% and 72%, respectively, with these parameters remaining higher than those of comparable synthetic prostheses [3, 4].

The use of saphenous veins for aortocoronary bypass leads to significant hyperplasia of intima as early as within several weeks, which predisposes to thrombosis and progression of atherosclerosis. These are the two main causes for impairment of the venous graft patency [5]. On average, the patency of one graft is ≈95% at 1 month, ≈ 85% at 1 years, ≈ 70% at 5 years and ≈ 60% at 10 years [5, 6]. The thing is that saphenous veins do not develop significant hyperplasia in the venous environment compared to the environment created after transplantation of the autovein into the arterial bloodstream. It is assumed that f*actors associated with isolating and preparing the saphenous vein, as well as the differences between the venous and arterial environments, facilitate progression of the disease*. There is evidence that mechanical trauma associated with traditional methods of graft preparation, can significantly injure the vessel and potentially reduce the graft patency. The mechanical factors of the arterial bloodstream influence the autovenous graft remodeling. Elevated pressure may lead to media thickening, but its role in the intimal hyperplasia is less clear. Changes in the blood flow including increased shear stress on the vessel wall, can reduce intimal hyperplasia, while the disturbed blood flow will probably increase it. Non-mechanical stimuli such as the effect of oxygenation of the arterial blood, may also play a significant, although not widely recognized role in the initiation of intimal hyperplasia [5]. According to V. V. Bazylev, et al., the analysis of the cumulative risks for progression of atherosclerosis in the bypass arteries at later periods (with the mean follow-up 53.4 ± 26.5 months) showed the lower frequency of proximal stenosis of the bypassed coronary artery with autoarterial grafts compared to AVG ($p \leq 0.001$) [7]. Therefore, the modern research on this problem focuses on studying the issues of atraumatic conduit harvest, maximally sparing storage and processing of AVG, and assessment of AVG quality in the postoperative period.

The **aim** of this study to dynamics of the conclusions of modern studies primarily based on the analysis of the results of randomized studies and systematic reviews on harvesting, preservation and assessment of the quality of autovenous grafts in the perioperative period.

An analysis of PubMed, Google Academy, eLibrary databases showed the existence of a significant number of articles on the topic, in particular, searching the PubMed database for the query '*vein graft harvesting*' gave 3,576 articles.

We have analyzed 24 sources over the last 12 years, of them 4 randomized clinical trials, 5 systematic reviews and meta-analyses, 3 meta-analyses. The analysis of materials showed a greater number of observations concerning comparison of various AVG harvest methods, while conclusions of the studies on the preservation of the graft and assessment of its quality immediately in the postoperative period, were based on small samples (Table 1). The main studied factor affecting the risk of significant complications, was the patency of the autovenous graft.

Autovenous Graft Harvesting

According to available sources, there exist open methods of autovein harvesting where it can be isolated through long continuous incisions (CI). In cardiac surgery, this method is divided to: CON (conventional) group, where the vein is skeletonized, dilated and placed in

Table 1. Summary Characteristics of Analyzed Literature Sources

No.	Authors, type of research, year of publication, source number in the list of references	Number of observations, n	Comparison criteria
1	Linni K., et al. randomized study, 2015 [3]	64	Comparison of vein of arm or contralateral great saphenous vein for bypass in LL
2	Bazylev V. V., et al. prospective non-randomized study, 2017 [7]	292	Risk of progression of atherosclerosis of coronary arteries bypassed using autovein or internal mammary artery in the long-term period
3	Ferdinand F. D., et al. systematic review and meta-analysis, 2017 [9]	281459	Open harvesting of saphenous vein and radial artery compared to ES harvesting in CABG
4	Zenati M. A., et al. randomized study, 2019 [10]	1150	Comparison of open and ES methods of AVG harvesting in CABG
5	Li G., et al. systematic review and meta-analysis, 2019 [11]	27911	Comparison of open and ES methods of AVG harvesting in CABG
6	Kodia K., et al. systematic review and meta-analysis, 2018 [12]	18131	Comparison of open and ES methods of AVG harvesting in CABG
7	Khan S. Z., et al. retrospective nonrandomized study, 2016 [13]	153	Comparison of open and ES methods of AVG harvesting for bypass in LL
8	Kronick M., et al. single-center nonrandomized study, 2019 [14]	113	Comparison of open and ES methods of AVG harvesting for bypass in LL
9	Zingaro C., et al. single-center randomized study, 2012 [15]	60	Comparison of ES method of AVG harvesting with carbon dioxide insufflation
10	Chernyavskiy A., et al. single-center randomized study, 2015 [16]	228	Comparison of open and ES methods of AVG harvesting in CABG without taking into account bypass patency
11	Wartman S. M., et al. single-center nonrandomized study, 2013 [17]	76	Comparison of open and ES methods of AVG harvesting for bypass in LL
12	Biroš E., et al. single-center retrospective study, 2016 [18]	16	Study of ES method of AVG harvesting for bypass in LL
13	Eid R. E., et al. single-center nonrandomized study, 2014 [19]	88	Comparison of open and ES methods of AVG harvesting for bypass in LL
14	Deb S., et al. multicenter randomized study, 2019 [20]	250	Comparison of open and *no touch* methods of AVG harvesting in CABG
15	Guo Q., et al. systematic review and meta-analysis, 2021 [22]	12 956	Comparison of different methods of harvesting and preservation of AVG for bypass in LL
16	Mirza A. K., et al. single-center retrospective study, 2018 [23]	505	Comparison of open and ES methods of AVG harvesting for bypass in LL
17	Elshafay A., et al. systematic review and meta-analysis, 2018 [25]	1479	Comparison of *no touch* and other AVG harvest methods in CABG
18	Angelini G. D., et al. single-center randomized study, 2021 [26]	96	Comparison of *no touch* and open harvest method in CABG with increased and decreased pressure
19	Kazachkov E. L., et al. single-center retrospective study, 2016 [27]	30	Comparison of the original and open methods of AVG harvest in CABG
20	Antonopoulos A. S., et al. meta-analysis, 2019 [28]	1492	Study of clinical, anatomic and surgical factors associated with risk of early AVG occlusion (within 12 months after surgery)
21	Winkler B., et al. meta-analysis, 2016 [29]	478	Comparison of different methods of AVG preservation in CABG
22	Wilbring M., et al. single-center retrospective study, 2013 [30]	36	Study of methods of AVG preservation in autologous blood and normal saline in CABG
23	Chen S. W., et al. single-center retrospective study, 2019 [31]	21	Study of AVG preservation conditions
24	Pimentel M. D., et al. single-center retrospective study, 2022 [32]	12	Assessment of influence of various preservation solutions and different intraluminal tension pressure on endothelium of autovein segments in CABG
25	Caliskan E., et al. meta-analysis, 2019 [33]	4450	Comparison of various methods of AVG harvesting and preservation in CABG

Notes: AVG — autovenous graft; CABG — coronary artery bypass grafting; LL — lower limb; ES — endoscopic method saline solution; group I (intermediate), where the vein is skeletonized, with use of local application of papaverine instead of dilation, after which the vessel is stored in heparinized blood. The next open method is the bridging method performed through skip incisions (SI). There should be separately mentioned an endoscopic method performed through small punctures. The above methods permit collection of, as a rule, a skeletonized autovein. An alternative to them is a *no touch* (NT) technique, where the vein is taken together with the surrounding tissue and not subjected to dilation [8].

ES harvest became common in cardiac surgery, especially in the United States. There are some enthusiasts in vascular surgery who use this method, although it has not become widespread probably due to the cost of the equipment, problems with a long training period and a high risk of injury to the vein segments when a long conduit is needed [8]. Based on a systematic review of the results from 76 studies (23 randomized controlled studies and 53 nonrandomized controlled studies) involving 281,459 patients, consensus statements and recommendations were analyzed comparing the risks and benefits of ES versus open conduit harvesting in patients undergoing CABG. The panel recommends (Class I, Level B) the use of ES harvest of the great saphenous vein and radial artery as the standard of treatment of patients requiring such grafts for coronary revascularization. Thus, a combined analysis of four studies (n = 2,389) providing follow-up data for more than 1 year showed the probability for graft stenosis or occlusion to be slightly higher in patients with ES harvest compared with open harvest methods (odds ratio (OR) 1.58; 95% confidence interval (CI) 0.92–2.71; p = 0.10) [9].

At the same time, there are contradictory data regarding ES harvest of autovein. On the one hand, ES procedure seems to reduce wound-related complications, improves patient satisfaction, decreases postoperative pain, length of hospital stay, and use of wound care resources. On the other hand, an observational study of 1,471 patients who underwent CABG using autovein, comparing ES and open techniques from the ROOBY study, showed no significant differences between the groups in terms of mortality or serious perioperative complications, including reoperation, cardiac arrest, stroke, or renal dysfunction requiring dialysis. Of interest is the observation of a subgroup of 894 patients with angiographic control, which showed that the patency of the ES-harvested autovein compared with SI was 74.5% and 85.2%, respectively (p < 0.0001) (adjusted relative risk (HR) 0.83; 95% CI 0.77–0.89) [10]. A large meta-analysis (22 studies, 27,911 patients) also confirmed that ES method is associated with more cases of graft injuries (weighted mean difference 0.73; 95% CI 0.18–1.28; p = 0.009), lower than average graft patency (OR 0.80; 95% CI 0.70–0.91; p = 0.0005), and reduced long-term graft patency (OR 0.15; 95% CI 0.04–0.61; p = 0.008) compared with SI [11]. These findings are consistent with the results of another large systematic review including 11 studies and 18,131 patients [12].

To note, surgeon's experience in the ES autovein harvest method plays a major role in the probability for development of complications [13, 14]. Another negative aspect of ES method can be elevated carbon dioxide level in the blood, cases of micro- and macroembolism due to use of carbon dioxide to expand the space in harvesting [15]. In a Russian study including 228 operated patients, the vein harvest time was shorter with ES method than with open method: 31.8 ± 6.2 min. and 40.3 ± 15.8 min., respectively (p < 0.01). There were fewer complications in the group of ES harvest (11.5% and 4.4%; p = 0.001). Upon that, luminoscintigraphic data in the group of ES method did not demonstrate any significant disturbances in lymph outflow after surgery. Electron microscopy of vein fragments did not reveal considerable injury to the venous wall in either group [16].

ES and open techniques for infrainguinal arterial bypass grafting provide similar harvesting time, complication rates, and early graft patency, while hemodialysis has a negative effect on patency after both techniques of autovein harvesting (p > 0.05). ES harvesting is associated with less amount of perioperative narcotic analgesics, suggesting potential benefit of ES treatment [13, 17, 18]. Results of another study concerning surgeries for critical ischemia demonstrate lower primary patency with the ES autovein harvesting. Primary graft patency was 43.2% in the ES harvest group and 69.4% in the SI group (p < 0.007) at 3 years. In addition, a significantly higher re-intervention rate was found in the ES harvest cohort, as well as a higher rate of vein graft stenosis. Nevertheless, the ES method was associated with a 20% reduction in wound-related complication rates. Thus, ES autovein harvesting should be used selectively in patients with a high risk of wound complications [19, 20]. Besides, there are studies on successful ES harvesting of the small saphenous vein for CABG [21].

It should be noted that there is a small number of works devoted to the harvest and preservation of AVG in bypass operations on the lower limb arteries. The Systematic Review and Meta-Analysis of Saphenous Vein Harvesting and Grafting for Lower Extremity Arterial Bypass (2021) based on 37 studies over the past 30 years, compared short- and long-term results of various methods of autovenous conduit harvesting in patients who underwent bypass grafting of LL arteries [22]. The patients with harvesting through CI, skip incisions and by ES method for bypass with reversed autovein, were compared. Six of the included studies presented the data on CI versus ES method. The meta-analysis showed that CI had a higher result of primary patency (HR 1.63; 95% CI 1.44–1.84; $p < 0.001$), but with a higher rate of wound-related complications (HR 1.35; 95% CI 1.03–1.77; $p = 0.03$) and a longer hospital stay ($p < 0.001$). Four works studied the data on extraction using SI versus ES harvest method. The autovein harvest using SI method significantly increased the primary patency compared with ES harvesting (HR 1.67; 95% CI 1.46–1.92; $p < 0.001$) without increase in the frequency of wound complications (HR 1.55; 95% CI 0.91–2.66; $p = 0.11$) or prolongation of hospital stay ($p = 0.73$) [14].

Only three studies presented the data on harvesting with CI versus SI. Two works analyzed primary patency, and three – wound complications. These studies did not reveal any significant difference in patency between harvesting with CI and SI (HR 0.93; 95% CI 0.83–1.04; $p = 0.20$) [23].

In the mid-1990s a new AVG harvesting method emerged, a contact-free *no touch* technique [24]. The advantage of this method is that it prevents the graft spasm and therefore does not require hydrocompression. Currently, there are many ongoing and completed studies on the techniques of preparing a graft from *no touch* veins, which showed excellent patency comparable with that of the left internal mammary artery. A meta-analysis [25] of 1,479 surgeries conducted in 2018 showed that with the contactless method of autovein harvesting, its patency was significantly higher compared to that with the conventional or combined harvesting. The graft hyperplasia in the *no touch* group was considerably lower compared to the open harvest group ($p = 0.011$) 20% and 78% respectively. Besides, *no touch* technique was associated with slowdown of progression of atherosclerosis in the bypass graft after transplantation (14.5% vs. 50% with the open harvest technique over 18 months).

During preparation for open harvesting, autovein hydrocompression is performed to counteract the spasm caused by the removal of surrounding tissues. Autovein hydrocompression can be performed either mechanically, by perfusion under pressure, or pharmacologically [10]. It has been established that autovein distension was associated with increased expression of several inflammatory biomarkers, such as platelet and endothelial cell adhesion molecule, vascular cell adhesion molecule, and intercellular adhesion molecule, which play a role in the induction of inflammation and can lead to graft rejection. Therefore, preventing the autovein hydrocompression is one of the important aspects of the *no touch* technique [25, 26]. According to one single-center randomized study, traditional saphenous vein graft preparation with distension under low pressure and vein harvesting using the *no touch* technique permitted to preserve the graft wall thickness after 12 months and to eliminate intimal hyperplasia [26].

The great saphenous vein was isolated according to the technology developed in Chelyabinsk, with the preservation of 0.5 cm of perivascular tissues on both sides using a Harmonic Ultracision harmonic ultrasonic scalpel (Ethicon, USA). This method, in the opinion of the authors, permitted to modify the *no touch* technique for the better [27].

Another review analyzed works on investigation of the incidence of early occlusion of autovenous bypass graft in CABG surgery. In the meta-analysis of summary data (48 studies, 41,530 autoveins), the incidence of early occlusion of the autovenous bypass was assessed as 11%. The developed model for early detection of autovenous bypass graft occlusion included clinical, anatomical and operational characteristics. Based on this model, a simplified system including 12 parameters was constructed to assess the risk of early impairment of primary patency of autovenous bypass graft (SAFINOUS assessment) with good effectiveness (c-index = 0.700; 95% CI, 0.684–0.716) [28] (Table 2).

Preservation of Autovenous Transplant

Of no less importance is the problem of storage of the autovenous conduit from the moment of harvesting until start of blood flow. Currently it remains least studied due to low quality of the available works.

Solutions for venous grafts preservation after harvesting until implantation, despite their presumptive influence, are often ignored when assessing the AVG patency results. There is no doubt that the endothelium plays a key role in the long-term patency of venous grafts, but the effect of various solution for autovein storage on the endothelium remains unclear.

The review by B. Winkler, et al. includes 20 works devoted to this issue [29]. Which of the currently available preservation methods are preferable, harmless, dangerous or ineffective? The main attention is paid to normal saline (NS) and autologous heparinized whole blood (AHWB). At the moment, there are no randomized clinical trials concerning NS and available AHWB. The review compares all the previous studies that can provide a certain level of evidence on this topic. Normal saline was found to have a negative impact on all the endothelial layers, and, consequently, may reduce the graft patency [29].

A study by M. Wilbring, et al. (2013) shows that NS *should no longer be recommended as a graft storage medium*. The study used human vein segments stored in NS or AHWB for 30 min. at room temperature. Analysis was performed using a Mulvaney myograph. After preconstriction with norepinephrine, concentration-relaxation curves were assessed with solutions containing bradykinin and sodium nitroprusside in a

Table 2. Frequency of Using Various Methods of Harvesting and Preserving Autovenous Graft. Results of Graft Patency after their Use (long-term results – more than 12 month)

Authors, type of research, year of publication, source number in the list of references	n	CI	SI	ES	No touch	AHWB	NS	p
Ferdinand F. D., et al., 2017 [9]	281459	1369		1532				*1*
Zenati M. A. et al., 2019 [10]	1150	574		576				*0.47*
Li G., et al., 2019 [11]	27911	14554		13357				*< 0.01*
Kodia K., et al., 2018 [12]	18131	10873		7258				*< 0.01*
Khan S. Z., et al., 2016 [13]	153	83		88				*0.785*
Kronick M., et al., 2019 [14]	113	64		49				*0.18*
Wartman S. M., et al., 2013 [17]	76	41		35				*0.8*
Eid. R. E., et al., 2014 [19]	88	49		39				*0.07*
Deb S., et al., 2019 [20]		123			127			*0.15*
Guo Q., et al., 2021 [22]	12 956	5729		1526				*< 0.001*
Mirza A. K., et al., 2018 [23]	505	194		86				*0.006*
Elshafay A., et al., 2018 [25]	1479	577 633			233 347	577 633		*0.009* *0.001*
Angelini G. D., et al., 2021 [26]	96	45			51			*0.22*
Wilbring M., et al., 2013 [30]	36					18	18	*< 0.05*
Chen S.W., et al., 2019 [31]	21					7	7	*< 0.001*
Pimentel M. D., et al., 2022 [32]	12					6	6	*< 0.01*

Notes: AHWB — autologous heparinized whole blood; CI — continuous incisions; SI — skip incisions; NS — normal saline; ES — endoscopic method

study of vasorelaxation, which, as known, depends on endothelial cells and smooth muscle cells. After incubation time, receptor-dependent and non-receptor-dependent maximum of developed vessel wall tension decreased in the NS group ($p = 0.05$), and the charge energy was significantly ($p = 0.046$) better preserved in the AHWB group [30]. Associated factors such as the pressure in hydraulic distension of the AVG may outweigh the initial storage advantage of the AHWB and may also increase the detrimental effects of warm NS when stored in it.

There is no consensus on the superiority of the AHWB for storing vein grafts. This creates opportunities for alternative variants such as one of the specially developed storage solutions, e. g., TiProtec™ or Somaluthion™. Whether these preservation solutions are superior or beneficial remains a subject for further research [29].

The aim of a group of Chinese authors was to study the microenvironment of human saphenous vein graft stored in NS or AHWB. The study included 21 patients who underwent CABG, and a total of 162 collected saphenous vein grafts. NS and AHWB were used to investigate the effect of the microenvironment. Hypoxia, oxidative stress, and vascular apoptosis were analyzed by Western blotting, and endothelial integrity was assessed in immunohistochemistry. Analysis of the results showed that the PaO_2 level was lower in AHWB than in NS (median 100.5 mm Hg vs. 185.8 mm Hg; $p = 0.004$). This hypoxic condition resulted in the production of higher amounts of factor-1 (median 60.1% vs. 15.1%; $p = 0.008$) and endothelial nitric oxide synthase (median 52.6% vs. 25%; $p = 0.046$) during 30 min of storage. The authors concluded that AHWB creates an environment that is superior to NS for storing the saphenous vein graft before CABG [31]. In the study by M. D. Pimentel, et al. (2022) autoveins kept in NS, according to electron microscopy, showed significantly greater endothelial damage compared to both the control group and the groups with storage in AHWB ($p < 0.001$) [32] (Table 2).

Assessment of Autovenous Graft Quality

The intraoperative control for the presence of damage and for patency of the autovenous conduit before and after the start of blood flow by functional and anatomical assessment of shunts and anastomoses is important to reduce the incidence of acute bypass thrombosis.

In the past decade, intraoperative measurement of transit flow has become the most frequently used functional approach [33], which may lead to major bypass graft revision in 2-4% of patients who underwent CABG. The pulsatility index obtained from the formula of flow measurement in the functioning bypass, is a good indicator of the blood flow pattern and the quality of anastomosis, which is useful for predicting outcomes [34]. The ideal pulsatility index in a well-functioning bypass should be between 1 and 3 (between 3 and 5 is also acceptable), with the mean flow through the graft 15 ml/min–20 ml/min. There is always a risk of graft revision in case of a low flow or a high pulsatility index. According to the 2018 European Guidelines on Myocardial Revascularization, the routine intraoperative graft blood flow measurement should be taken into account (class IIb recommendation, A evidence level) [33]. Angiographic examination to determine the bypass graft patency in the postoperative period is one of methods of choice [35].

Other recommended methods for identifying low-flow grafts that may be revised intraoperatively include additional epicardial ultrasound or thermal imaging [34, 36, 37]. In addition, a number of authors also use indocyanine green to visualize arteries in CABG. The results of this study revealed moderate correlations between the graft patency and luminance intensity and mean acceleration value. However, it can be definitely concluded that a decrease in the luminance intensity ratio indicates stenosis or thrombosis of the bypass graft, which justify CABG revision [38, 39]. Some authors propose changes in the bypass graft be monitored by control of markers of embryonic arteriovenous differentiation of endothelial cells that determine the destiny of arteries and veins. Ephrin-B2 is specifically expressed in the arterial endothelium, while Eph-B4 is expressed in the venous endothelium. Arterialization of the autovein is characterized by the loss of the venous marker Eph-B4 without the acquisition of arterial Ephrin-B2, which is accompanied by negative morphological remodeling of the vein wall, consisting in the wall thickening. Eph-B4 in the venous endothelium interacts with a number of molecules, such as eNOS, caveolin, and others, regulating the adaptation process [40].

CONCLUSION

As follows from the presented material, bypass graft patency is comparable after the use of the open and endoscopic harvest techniques. Endoscopic harvest of autovein may be associated with a poor long-term patency of the autovein graft due to its damage in the harvest procedure. Endoscopic harvest also contributes to faster healing of postoperative leg wounds and to reducing pain syndrome.

The open *no touch* harvest method, use of low pressure when distending an autovenous graft and ligating the tributaries are factors that reduce the risk of postoperative intimal hyperplasia, which helps maintain a long-term functioning of the bypass and reduces the number of repeated interventions.

The preferable method of harvesting an autovenous graft in bypass surgeries in the lower limbs is an open bridging technique.

Storage of the autovenous graft before the surgery in the autologous whole blood presumably reduces the risk of the graft damage, but randomized trials with a greater number of observations are needed.

The use of the graft quality control before and after application of anastomosis and initiation of the blood flow is aimed at identifying technical defects of the autovenous graft, and, according to a number of authors, helps improve the immediate and long-term outcomes of bypass surgery, but also requires randomized trials with a larger number of observations and comparison of various methods of both coronary artery bypass grafting and bypass surgeries in the lower limbs.

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