### **ORIGINAL ARTICLE**

# SURGICAL TREATMENT IMMEDIATE RESULTS OF LOWER LIMBS CHRONIC CRITICAL ISCHEMIA IN SIMMULTANEOUS DIRECT AND INDIRECT REVASCULARIZATION

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# Mykhailo M. Lopit, Vasily I. Rusin, Patricia O. Boldizhar, Fedir V. Gorlenko, Olexander M. Kochmar

HIGHER STATE EDUCATIONAL ESTABLISHMENT OF UKRAINE "UZHHOROD NATIONAL UNIVERSITY", UZHHOROD, UKRAINE

#### ABSTRACT

**The aim:** To assess the immediate results of autovenous femoral-tibial shunting in combination with rotary osteotrepanation of the tibia by studying changes in the transcutaneous pt02 tension in the tibia and foot tissues depending on the revascularization of the tibial arteries.

Materials and methods: We analyzed the treatment of 69 patients with obliterating atherosclerosis of the vessels of the lower extremities. According to the degree of ischemia of the lower extremities, the patients were distributed as follows: III A degree of ischemia - 20 (29%), III B - 28 (40.6%), IV - 21 (30.4%) patients.

All patients had atherosclerotic lesions of the popliteal-tibial segment of the great arteries with preserved central blood flow in the aorto-iliac segment.

**Results:** Occlusion of the anterior tibial artery was recorded significantly more often than the peroneal artery (72% and 42%, respectively, p = 0.05), but with the same frequency compared to the posterior tibial artery (68%, p = 0.61).

The lesion of two or three arteries of the lower leg was recorded more often than occlusion of one (n = 51; 73.9% and n = 18; 26.1%). Occlusive-stenotic lesion of the popliteal artery was observed in 54 (78.2%) patients.

The highest incidence of lesions of the tibial arteries was observed in the basin of the anterior tibial artery in 28 (40.6%) patients. Combined lesions of the anterior tibial artery and posterior tibial artery were diagnosed in 19 (27.5%) patients. Limited lesions of the posterior tibial artery were found in 15 (21.7%) patients. The combination of lesions of the posterior tibial artery and personal artery was diagnosed in 7 (10.2%) patients.

Conclusions: 1. The patency of the femoral-tibial autovenous shunt during the year was 71%. High limb amputation was performed in 29% of patients.

2. According to CT data, the localization of trophic changes on the foot during critical ischemia of the lower extremities corresponds to the affected segment of the arterial angiosome, which supplies the corresponding area with blood.

3. After femoral-tibial autovenous bypass grafting, the highest levels of transcutaneous oxygen tension were observed in the basin of the posterior tibial artery and peroneal artery, and the lowest indicators of transcutaneous oxygen tension were observed in the basin of the anterior tibial artery.

4. During femoral-tibial autovenous shunting operations in combination with rotary osteotrepanation, the transcutaneous oxygen tension indices increased threefold in the angiosomal basin of the posterior tibial artery and peroneal artery, and twofold in the angiosomes of the dorsum of the foot and sole.

KEY WORDS: chronic ischemia of the lower extremities, distal autovenous femoral-tibial shunting, transcutaneous oxygen tension, angiosomal theory

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### INTRODUCTION

Treatment of occlusive diseases of the arteries of the lower extremities is one of the urgent and difficult tasks of surgery. Reconstructive surgery is associated with a high risk, and in 25-40% of patients it is impossible to perform the intervention due to the prevalence of the occlusive process [1-4]. In the absence of an adequate distal vascular supply, the development of purulent-necrotic processes in the affected limb and the presence of contraindications to reconstructive surgery, conservative therapy or amputation remain the only treatment techniques [1-4]. For these patients in complex treatment, it is possible to perform indirect methods of revascularization rotary osteotrepanation of the tibia (ROT) - as an alternative to the amputation of the lower limb [2-5]. Theoretically, for the onset of a full-fledged effect after ROT surgery, months are required, during which collateral circulation will gradually develop. Rotary osteotrapation of the tibia increases possibilities of limb salvage or performance of more favorable resection operations on the foot in patients with IV grade limb ischemia [2,3,6].

However, some authors note the effect of revascularization osteotrepanations almost immediately after surgery, which is manifest s both clinically and by an increase of the transdermal pO2 [2-5]. Rotary osteotrepanation of the tibia can be performed alone or in combination with reconstructive interventions or sympathectomy. The positive effect after combined treatment is more significant and longtermed in patients with distal forms of obliterating atherosclerosis [4, 5, 7]. Considering the above, we used a combination of direct and indirect techniques of treatment in patients with distal forms of atherosclerosis to improve the state of the limb microvasculature in order to decrease the number of postoperative thrombosis and amputations. The combination of direct and indirect revascularization technics provides an improvement in the state of the inflow and outflow pathways, a decrease in the thrombosis incidence in the postoperative period and an increase of the limb salvage rate [7,8,9].

### THE AIM

To assess the immediate results of autovenous femoral-tibial shunting in combination with rotary osteotrepanation of the tibia by studying changes in the transcutaneous ptO2 tension in the tibia and foot tissues depending on the revascularization of the tibial arteries.

### **MATERIALS AND METHODS**

We analyzed the treatment of 69 patients with obliterating atherosclerosis of the lower extremities vessels. The patients were hospitalized at the Department of Vascular Surgery of the Transcarpathian Regional Clinical Hospital n.a. Andrey Novak from 2015 to 2020yy. According to the degree of ischemia of the lower extremities, the patients were distributed follows groups: III A degree - 20 (29%), III B - 28 (40.6%), IV degree - 21 (30.4%) patients.

In the demographic structure men dominated - 64 (92.7%) patients. The average age of women ( $66.1 \pm 5.4$ ) was almost five years higher than the average age of men (60.9 + 8.6).

All patients had atherosclerotic lesions of the popliteal-tibial segment of the magistral arteries with preserved central blood flow in the aorto-iliac segment.

Trophic changes in the skin of the foot were observed in 30.4% of patients. Limited by a few toes necrotic changes prevailed - 42.9%, most often I and IV toes were affected. Concerning concomitant diseases, the following pathologies were diagnosed: ischemic heart disease - 45 (65.2%) cases, arterial hypertension - 51 (74%), chronic cerebrovascular insufficiencies II - III degree - 23 (33.3%) cases, diabetes mellitus 25 (36.2%), erosive and ulcerative-erosive lesions of the gastrointestinal tract - 37 (53.6%), chronic obstructive pulmonary diseases - 19 (27.5%).

The diagnostic program included ultrasound examination (US) - Doppler sonography, multispiral computed tomography with contrast enhancement, determination of the regional perfusion index based on the measurement of transcutaneous oxygen tension (TcPO2) in the basin of the anterior tibial artery, posterior tibial artery, peroneal artery and arteries of the foot in the postoperative period after three months.

For the statistical analysis of the mean values of the TcPO2 index in patients before and after operative interventions, a t-test paired two-sample for means was used. For the TcPO2 index changes we used the percentage

ratio of the regional tissue perfusion index before and after surgery in relation to the norm. Microsoft Excel 2019 was used to analyze the data.

Depending on the type of surgical treatment, the patients were divided into two groups:

I group - 34 patients who underwent distal autovenous femoral-tibial bypass grafting in combination with rotary osteotrapation of the tibia.

II group - 35 patients who underwent distal autovenous femoral-tibial bypass grafting.

## RESULTS

Contrast-enhanced multispiral computed tomography and ultrasound examination analysis allowed us to identify the following types of distal arterial lesions:

- occlusive-stenotic lesions of the popliteal artery , patent arteries of the lower extremity;
- occlusive stenotic lesion of the popliteal artery, occlusion of 1-2 arteries of the lower extremity;
- diffuse lesion of the popliteal-tibial segment with patency and / or with the absence of patency of the one tibial artery;

Occlusion of anterior tibial artery was recorded significantly more often than peroneal artery (72% and 42%, respectively, p = 0.05), but with the same frequency as compared with posterior tibial artery (68%, p = 0.61). The involvement of the foot arteries in the process was found in 21 (30.4%) patients.

The occlusion of two or three arteries of the lower leg was recorded more often than occlusion of one (n = 51; 73.9% and n = 18; 26.1%). Occlusive-stenotic lesion of the popliteal artery was observed in 54 (78.2%) patients.

The highest incidence of lower leg artery lesions was observed in the anterior tibial artery basin in 28 (40.6%) patients. Combined lesions of anterior tibial artery and posterior tibial artery were diagnosed in 19 (27.5%) patients. Limited posterior tibial artery lesions were found in 15 (21.7%) patients. The combination of posterior tibial artery and peroneal artery lesions was diagnosed in 7 (10.2%) patients.

Necrobiotic changes in the foot were most often observed on the dorsum of the foot distal parts and toes - 11 (52.4%) patients. Nine (42.9%) patients had necrosis on the plantar surface of the foot in the projection of the 2-5 metatarsal bones. In one patient (4.8%) trophic changes took place in the heel area.

The indices of the ankle pressure index ranged from 0.24 to 0.4 and directly proportionally depended on the level and extent of atherosclerotic alteration, ranged from 0.42  $\pm$ 0.15, in III B degree - 0.38  $\pm$  0, 12 and in IV degree - 0.24  $\pm$ 0.12.

A total of 69 operations were performed using direct revascularization (table I).

As can be seen from the table, posterior tibial artery (34.8%), anterior tibial artery (26.1%), peroneal artery (21.7%) and tibioperoneal trunk (17.4%) were used most often for tibial bypass grafting.

Antonia	Distal anastomosis		
Artery	«end to end»	« end to side »	
Anterior tibial artery	17	1	
Posterior tibial artery	20	4	
Peroneal artery	15	-	
Tibioperoneal trunk	8	4	
Tatal	60	9	
Total –	6	9	

**Table I.** Distribution of patients according to the localization and technique of the distal anastomosis

In this case, the advantage in the formation of the distal anastomosis was given to the "end-to-side" technique (87%).

The immediate results of direct revascularization and ROT were assessed within three months on the basis of changes in clinical symptoms, which were identified during examination before surgery, as well as the presence or absence of postoperative complications. The permeability of the reconstruction zone with direct methods of revascularization in the first three months was 69.6%. Reoperations were performed in 21 (30.4%) patients due to shunt thrombosis. In 20 patients from this group amputations were at the lower third level of the thigh, and only in one cause there was technical possibility to restore the blood flow.

Thrombosis after anterior tibial artery shunting occurred in 14 (18.8%) patients, and after posterior tibial artery shunting - in 8 (11.6%) patients.

We did not observe thrombosis of the autovenous shunt in cause of using tibioperoneal trunk and peroneal artery as a tibia shunt artery.

Despite of a rather high percentage of unsatisfactory results of the direct methods of revascularization, the oxygen tension in the angiosomes of the leg and foot increased (table II).

According to the above data, a statistically significant difference was revealed in the regional perfusion index after surgery between the first and second groups in the angiosomal region of the posterior tibial artery and the peroneal artery (p <0.05). When comparing other indicators, no statistically significant difference was found. Statistically significant differences were found in the groups (p <0.05)

Table II. Index of regiona	l perfusion of the le	g and foot angiosome	es after autovenous femo	oral-tibial shunting
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	Surgery techniques				
Angiosoma	Distal autovenous femoral-tibial shunting		Distal autovenous femoral-tibial shunting + ROT		
	Before surgery	After surgery	Before surgery	After surgery	
Anterior tibial artery	0,51±0,04	0,72±0,18	0,5±0,05	0,73±0,21	
Posterior tibial artery	0,63±0,03	1,8±0,07	0,62±0,01	1,9±0,06	
Peroneal artery	0,41±0,03	1,1±0,19	0,41±0,03	1,2±0,15	
Dorsum foot	0,39±0,04	0,62±0.23	0,4±0,02	0,58±0.18	
Plantar foot	0,4±0,04	0,83±0.23	0,41±0,03	0,85±0.26	
t-test	p<0,05(p=0,037)		p<0,05(p=0,046)		



**Fig. 1.** Percentage ratio of tissue perfusion index relative to normal before and after surgery for distal autovenous femoral-tibial bypass grafting.



**Fig. 2.** Percentage ratio of tissue perfusion index relative to normal before and after surgery in cause of distal autovenous femoral-tibial bypass grafting in combination with ROT.

while comparing the indicators before and after surgery using the Student's t-test

At the same time, a stable increase in oxygen tension was observed in the angiosomes of the posterior tibial artery and / or peroneal artery in the case of the femoral-posterior tibial artery and bypass grafting of the femoral-tibioperoneal trunk; consistently low transcutaneous oxygen tension values were observed on the dorsum of the foot. In tibial arteries, the lowest regional perfusion index was observed in the anterior tibial artery basin below revascularization, despite of its usage as a receiving artery. (Fig. 1).

With the use of distal autovenous femoral-tibial bypass grafting, the indices of the regional tissue perfusion index in the angiosomes of the posterior tibial artery and peroneal artery increased almost threefold, and in the angiosomal basin of the dorsum of the foot and sole they doubled. The similar situation, even with better indicators was observed in patients who underwent distal autovenous femoral-tibial bypass grafting in combination with ROT. The indices in the angiosomes of the posterior tibial artery, peroneal artery increased threefold, the indices of regional perfusion in the angiosomes of the dorsum of the foot and sole doubled. (Fig. 2.).

### DISCUSSION

In recent years, due to the development of new technologies, the frequency of the lower extremities revascularization has increased significantly [9-14]. In cases where revascularization is not possible, the amputation percentage is 50% and increases over the next five years [7,10]. In the group of patients with successfully performed revascularization it ranges from 21.2 to 60% [1,2,3,7].

The main problem today is to find a way to stimulate the blood supply of the ischemic zone. One of the possible options is the restoration of blood flow in the maximum number of leg arteries; a number of other authors estimate that it is sufficient to restore blood flow only in anterior tibial artery and / or posterior tibial artery for a positive result; according to some data, only restoration of the vessel, which supplies blood to the affected area, can lead to a positive result of revascularization [1,3]. At the same time, when comparing the CT data, and the peculiarities of the trophic changes localization in the aspect of the angiosomal theory, most often trophic changes were found in the dorsal angiosome zone of the foot (52.4%), which comes from the anterior tibial artery. In 9 (42.9%) patients, trophic changes were found in the zone of the lateral plantar angiosome, which comes from the posterior tibial artery. In 4.8% of patients, necrosis was detected in the area of the medial-calcaneal angiosome, which comes from the posterior tibial artery at the border of the angiosome area from peroneal artery intermediate branch.

Angiosomal theory, despite a large amount of research, still raises many questions. This is primarily due to the lower extremities ischemia degree, as a treatment the treatment of foot ulcers in grade IV ischemia is a complex problem, that requires an integrated approach. A very important problem is the patients selection to the study groups for comparing the direct and indirect revascularization results. As a rule, indirect revascularization is performed only in cases of technical impossibility of direct revascularization, and this factor must be taken into account when evaluating the study results. Taking into account the fact that the "angiosomal artery" is most affected by the atherosclerotic process and the combined lesions of the foot arteries make up 30.4% of cases, only the skill of surgical revascularization can lead to the ischemia liquadation of the affected segment of the limb. After performing direct bypass surgery the peripheral blood flow and the volume of the microvasculature of the lower leg increase. In this case, performing indirect revascularization in addition will be more effective than usage this technique isolately for chronic critical ischemia treatment.

### CONCLUSIONS

- 1. The patency of the femoral-tibial autovenous shunt during the year was 71%. High limb amputation was performed in 29% of patients.
- 2. According to CT data, the localization of trophic changes on the foot during critical ischemia of the lower extremities corresponds to the affected segment of the arterial angiosome, which supplies the corresponding area with blood.

- 3. After femoral-tibial autovenous bypass grafting, the highest levels of transcutaneous oxygen tension were observed in the basin of the posterior tibial artery and peroneal artery, and the lowest indicators of transcutaneous oxygen tension were observed in the basin of the anterior tibial artery.
- 4. During femoral-tibial autovenous shunting operations in combination with rotary osteotrepanation, the transcutaneous oxygen tension indices increased threefold in the angiosomal basin of the posterior tibial artery and peroneal artery, and twofold in the angiosomes of the dorsum of the foot and sole.

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### ORCID and contributionship:

*Mykhailo M. Lopit: 0000-0002-6425-2990<sup>B,C,D</sup> Vasily I. Rusin: 0000-0001-5688-9951<sup>A,F</sup> Patricia O. Boldizhar: 0000-0002-6295-5692<sup>B,E,F</sup> Fedir V. Gorlenko: 0000-0002-0496-2069<sup>C</sup> Olexander M. Kochmar: 0000-0003-4040-7561<sup>C</sup>* 

### **Conflict of interest:**

The Authors declare no conflict of interest.

#### CORRESPONDING AUTHOR Mykhailo M. Lopit

Uzhhorod National University Str. Kapushanska 22, 88018 Uzhhorod, Ukraine tel: +380671188100 e-mail: lopitmykhailo@gmail.com

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A - Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis,
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