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Compensating crural anastomoses in chronic critical limb ischaemia

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Compensating crural anastomoses develop in patients with multi-level occlusion of the calf arteries in the course of atherosclerosis, arteriitis, diabetes, and in vascular malformations of the limbs. The peroneal artery is frequently the only patent calf vessel, especially in diabetic patients who have advanced tibial occlusive disease. The purpose of this study was to identify different types of compensating crural anastomoses in chronic critical limb ischaemia. Using combined anatomical-radiographic and statistical methods, 86 compensating crural anastomoses were studied in 59 specimens of lower limbs (amputated at the thigh) in the course of chronic critical ischaemia. Three types of compensating crural anastomosis and their components were identified. The most common type (55.8%) was the posterior tibioperoneal anastomosis. Less common (23.3%) was the intertibial anastomosis and least common (20.9%) the anterior tibioperoneal anastomosis. The posterior tibioperoneal anastomosis was concurrent with anterior tibioperoneal anastomosis in 26.3% of cases and with the intertibial anastomosis in 15.3% of cases. The great importance of the peroneal artery in the formation of natural crural collateral circulation should encourage vascular surgeons to consider peroneal bypasses.

Key words: collateral circulation, by-pass, occlusive disease

INTRODUCTION

The compensating crural anastomoses develop on the basis of arterial muscular branches in patients with multi-level occlusion of the calf arteries in the course of atherosclerosis, arteriitis and diabetes [2, 4, 13, 14]. They also develop, for corrective reasons, in vascular malformations of the limbs [17]. As a result of their development, a temporary improvement of circulation occurs below the knee, which alleviates resting pains in the calf or prolongs the distance in intermittent claudication [4], in addition, ischaemic ulceration heals [11]. This is clearly indicated by the increased ankle-brachial index [6] and Doppler examination of the calf arteries [8]. In the literature the studies reported focus only on the clinical aspect of collateral crural circulation, and not on the anatomical analysis of this phenomenon. The aims of this study were: 1. to identify different types of compensating crural anastomosis and 2. to study the concurrence of compensating anastomoses.

MATERIAL AND METHODS

A total of 59 specimens of lower limbs were studied. These had been amputated at the thigh in patients (39 men aged 41–82 years, 20 women aged 52–96 years) with chronic critical ischaemia in the course of atherosclerosis. Using the anatomical method, the popliteal artery and its branches were prepared as well as the tibial arteries in their terminal parts. The exposed arteries, proximally 3 arteries (i.e. the anterior tibial, posterior tibial and peroneal arteries) and distally 2 arteries (i.e. the tibial

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arteries) were injected (using a 0.5 mm needle) with 75% uropoline. Arteriograms of this vascular region were then obtained with Unipan 401 apparatus. After fixation with 10% formalin, the arteries were dissected using a stereoscope with Huygens ocular. The findings were statistically analysed with the use of a difference significance test ($p < 0.01$) with two mean values and two variations of independent variables.

RESULTS

In the material studied 86 compensating crural anastomoses were observed (64 in men, 22 in women). Statistical analysis did not show gender and syntopic differences ($p > 0.05$). The anastomoses were grouped into 3 types: 1. anterior tibioperoneal anastomosis, 2. posterior tibioperoneal anastomosis and 3. intertibial anastomosis (Table 1). Respective compensating anastomoses occurred individually (57.7%) or in concurrence (42.3%) (Table 2).

I. The anterior tibioperoneal anastomosis (Fig. 1, Tables 1, 2) (20.9%) developed on the basis of muscular branches of the anterior and posterior tibial, and soleus muscles. Individual occurrence was very rare (variant I = 3.4%). Most often it was concomitant with the posterior tibioperoneal anastomosis (variant IV = 23.6%). In variant IV, the configuration of the anastomoses resembled a reversed letter Y. This occurred at a strong peroneal artery which forked out into tibial arteries which were patent only in one-third of the calf. When the tibial arteries were occluded, also in one-third of their lower part, then the peroneal artery anastomosed through its perforating branch to the dorsal pedis artery or communicated through its muscular and calcaneal branches with the lateral plantar artery.

II. The posterior tibioperoneal anastomosis (Fig.1, Tables 1, 2) (55.8%) resulted from developed intramuscular circulation of the soleus muscle and profound flexor muscles (variant II = 39.0%). It was rarely concurrent with the anterior tibioperoneal anastomosis (variant IV = 23.6%) or with the intertibial anastomosis (variant V = 15.3%). It was best developed at the occluded tibial arteries, or above on occluded distal part of the peroneal artery.

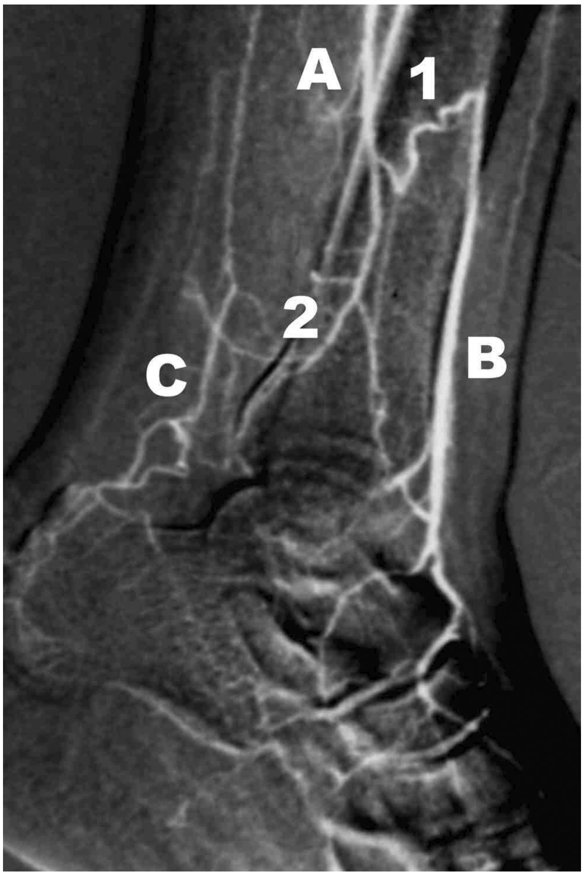

Figure 1. Arteriogram showing anterior (1) and posterior (2) tibioperoneal anastomoses: A — peroneal artery; B — anterior tibial artery; C — posterior tibial artery.

Table 1. Types of the compensating crural anastomoses

Type	Number				Total	
	Male		Female		Absolute	%
	Right	Left	Right	Left		
Anterior tibioperoneal anastomosis	7	6	3	2	18	20.9
Posterior tibioperoneal anastomosis	21	16	6	5	48	55.8
Intertibial anastomosis	6	8	2	4	20	23.3
Total	34	30	11	11	86	100.0

Table 2. Variants of the compensating crural anastomoses

Variant	Type	Representation	
		Absolute	%
I	1	2	3.4
II	2	23	39.0
III	3	9	15.3
IV	1+2	14	23.6
V	2+3	9	15.3
VI	1+2+3	2	3.4

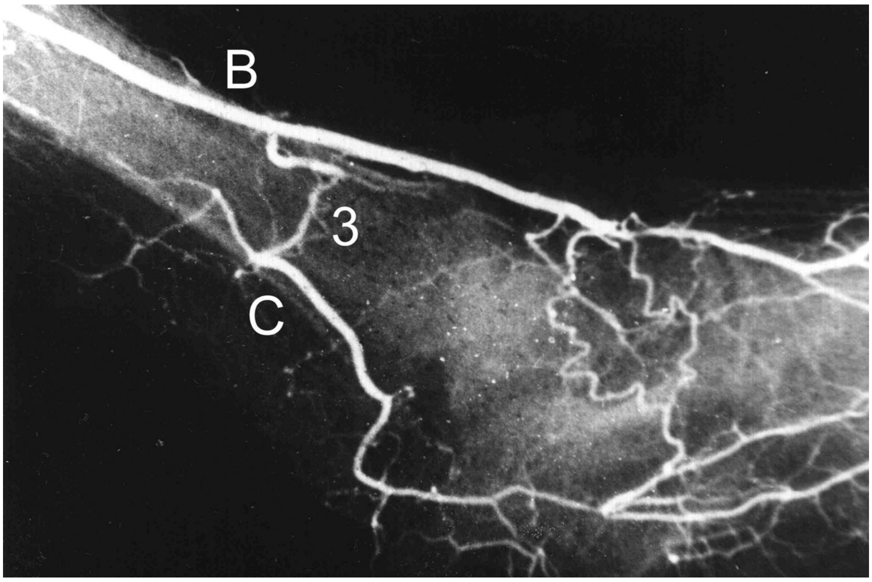

Figure 2. Arteriogram illustrating the intertibial (3) compensating anastomosis: B — anterior tibial artery; C — posterior tibial artery.

III. Intertibial anastomosis (Fig. 2, Tables 1, 2) was found to occur individually (variant III = 15.3%) as frequently as together with the posterior tibioperoneal anastomosis (variant V = 15.3%). It developed on the basis of muscular branches of the extensors and profound flexors. The anastomosis perforated the crural interosseous membrane. It was particularly strong at the occluded peroneal artery and unoccluded, yet with several multi-level narrowings, tibial arteries. In this case it was zigzag in shape. The blood supply to both tibial arteries came from the collateral circulation of the knee. Thus a collateral chain of anastomoses was formed, which supplied the blood from the thigh to the foot. The absence of compensating anastomoses was observed when the 3 calf arteries were not pathologically changed or when only one calf artery was patent. Concurrence of the anterior tibioperoneal anastomosis and intertibial anastomosis was not observed in the material studied.

DISCUSSION

Compensating crural anastomoses develop on the basis of muscular branches of 3 calf arteries [1]. In producing intermittent claudication in the calf without occlusion proximally to the popliteal artery, the sural arteries, the posterior tibial artery and the muscle nutritive arteries are very important [4]. The "corkscrew" appearance of the collateral circulation is significantly characteristic of Buerger's disease and represents dilated *vasa vasorum* of the occluded main artery. The corkscrew-shaped vessels were seen in 21.7% of limbs affected by *thromboangiitis obliterans*, but in only 3.2% of limbs affected by *arteriosclerosis obliterans* [13, 14]. These vessels extend from the arterial occlusion sites to the periphery of the feet and without opacification of the main pedal arteries indicate a poor prognosis. A specific kind of collateral in Buerger's disease was reported by Schindo et al. [11] in patients with diffuse arterial occlusion in the limbs except for a persistent sciatic artery and sural artery, which was the main collateral. Thus, reversed bifurcated saphenous vein bypass was performed from the sciatic artery to the sural artery and the posterior tibial artery. Angiographic and Doppler examinations [7], showed that in the occlusion of the anterior tibial artery the collateral circulation was ensured through the collaterals of the posterior tibial artery and the peroneal artery, whereas in the occlusion of the posterior tibial artery, the collateral circle was established through the great communicating arteries, through the arterial circle of the ankle and from the profound plantar artery. Finally, in the occlusion of the peroneal artery, collateral circulation was only represented by the collaterals of the ankle. Occlusions of the anterior tibial artery (the Windsor Index; IW = 35.48%), of the peroneal artery (IW = 44.71%) and of the posterior tibial artery (IW = 55.44%) showed progressively lower haemodynamic compromise.

Several vascular anomalies are corrected by nature through formation of compensating anastomoses. Saadeh et al. [10], using a combined radiographic-anatomical study, noted the anterior tibial artery as a branch of the posterior tibial artery at about its midpoint. It gave off an unusual lateral calcaneal vessel that coursed initially in the musculoperoneal canal. This collateral, in the light of my observations, forms a specific anterior tibioperoneal compensating anastomosis. Though Adachi [1] questions a total absence of the posterior tibial artery, Zwass and Abdelwahab [17] describes a rare developmental anomaly of the absent posterior tibial artery with a hypoplastic anterior tibial artery. In this case marked hypertrophy of the peroneal artery compensated for the absent arteries. The peroneal artery also gave collaterals to form the dorsal pedis and the plantar arteries. This anomaly clearly resembles my variant IV, in which a strong peroneal artery ramifies and passes to the dorsum and the sole of the foot.

The absence of compensating anastomoses in vascular anomalies may lead to malformations. This observation was reported by Hootnick et al. [5] who described congenital tibial aplasia with polydactyly and hypoplasia of the crural arteries. Neither of the anterior tibial and peroneal arteries could be identified below the ankle. The authors suggest that a diminished anterior tibial artery reduced the number of vessels available for collateral circulation and thus put the limb at risk of subsequent malformation. Arteriographic examinations made by Karmody et al. [6] in patients with an occluded popliteal artery indicate that among the 3 calf arteries, the peroneal artery was the least diseased in 40% and was the only available vessel in 37% of instances. Radiological examinations performed by Walden et al. [16] also reveal less intense pathological changes in the peroneal artery (16.5%) as compared with the anterior tibial artery (27.5%) and the posterior tibial artery (28.5%). Furthermore, intra-operative examinations performed by Wagner et al. [15] and Cullen et al. [3] confirmed the suitability of the peroneal artery as the best available vessel for distal insertion in 28-39% of cases. Since the peroneal artery is the least diseased infrapopliteal vessel, it is in 76.7% an organiser of compensating crural anastomoses. In my material it formed anterior tibioperoneal anastomoses in 20.9%, and posterior tibioperoneal anastomoses in 55.8% of cases. For this reason, the peroneal artery is used for distal extremity reconstruction. Among 152 femoro-peroneal bypasses in the Karmody et al. material [6], the cumulative limb salvage rate obtained at 3 years was 81%. The authors report that mean ankle/brachial indices, pre-operatively (0.27) and postoperatively (0.84), correlated with bypasses to the anterior tibial artery (0.25, 0.86) and to the posterior tibial artery (0.29, 0.92). The patency and limb salvage rates for the peroneal bypass are comparable to those for the anterior and posterior tibial arteries. Moreover, Plecha et al. [9] concluded that the peroneal artery should be selected for outflow when it is the single tibial run-off vessel and is preferable to a bypass to an inframalleolar arterial segment. The quality of the venous conduit and the technical skill of the surgeon are the two most important factors in the success of bypasses to the peroneal artery. Sidawy et al. [12] reported the following bypass patency rates at 3 years, depending on the recipient vessel: 63% — for the anterior tibial artery, 81% — for the posterior tibial artery, and 80% — for the peroneal artery. The differences were not statistically significant. However, they indicate that the peroneal artery is really an acceptable recipient vessel in the crural bypass. The peroneal artery appears the better preserved vessel on angiography but this appearance may be misleading because the more functional pulse-generated run-off studies show no significant difference in the patency or degree of preservation of the 3 calf arteries [8]. Angiography is also needed in diabetic patients with gangrene and palpable foot pulses. Andros et al. [2] indicate that the pulse at the ankle can be present even when the 3 calf trunks are occluded. This mechanism depends on a good blood supply from the popliteal artery through the compensating anastomoses of the crural collateral circulation to the recipient vessels of the foot. It should be noted, however, that in diabetic patients, the arteries in the collateral circulation become occluded sooner than in atherosclerosis, which considerably worsens the prognosis [13, 14].

CONCLUSION

In conclusion, I have identified 3 types of compensating crural anastomoses, determined their incidence and analysed 6 variants of concomitance. These results indicate the great importance of the peroneal artery in the formation of natural crural collateral circulation, which should encourage vascular surgeons to consider peroneal bypasses.

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