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An angiographic study of the anterior tibial artery in patients with aortoiliac occlusive disease

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The anterior tibial artery is of great clinical relevance to vascular infrapopliteal surgery. The sources (origins), length and luminal diameter of the anterior tibial artery in 46 men and 30 women with Lerich syndrome were studied by means of radiological and digital methods. The results obtained were described by two-way analysis of variance (Multi-group ANOVA) for unpaired data — the means for six subtypes with regard to sex and side of the body, using the STATISTICA 5.5 program. The anterior tibial artery occurred most frequently (92.11%) as a terminal branch of the popliteal artery in its normal (IA: 87.5 %, IB: 2.63%) and high (IIA 1: 1.32%, IIA 2: 0.66%) division. In the remainder (7.89%), the anterior tibial artery arose from both the anterior tibioperoneal trunks (IC: 1.97%, IIB: 5.92%). The statistical analysis of the sources of the anterior tibial artery did not show gender differences. Symmetry of the left and right popliteal patterns was observed in the two most frequent subtypes: IA ($r_1 = 0.80$) and IIB ($r_2 = 0.83$). The anterior tibial artery was the longest ($p = 0.02$ for men, $p = 0.04$ for women) in subtype IIA 2. The greatest diameter of the anterior tibial artery was characteristic for a trifurcation (IB) and the smallest for subtype IIA 2 ($p = 0.04$). Both the length ($p = 0.03$) and luminal diameter ($p = 0.04$) of the anterior tibial artery in men were significantly greater than in women in all the popliteal subtypes observed. Morphometric parameters of the right and left anterior tibial artery showed no statistically significant differences. The anterior tibial artery was the predominant vessel in a trifurcation (IB) and in the two subtypes with an anterior tibioperoneal trunk (IC, IIB). These results have implications in vascular grafting below the knee.

Key words: anterior tibial artery, angiographic study, digital analysis, symmetry of vascular patterns, length, luminal diameter, vascular grafting

INTRODUCTION

Knowledge of the typological and morphometric findings of the popliteal artery is important for the safe performance of infrapopliteal interventions such as bypass surgery, transluminal angioplasty, and subintimal angioplasty [1, 10, 19–22].

The anterior tibial artery is really an acceptable run-off vessel in femorotibial grafting [11, 20]. The luminal diameter of the anterior tibial artery is the most important determinant of the patency rate in anterior femorotibial bypass [17]. Some authors have shown an association between the absence of the

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anterior tibial artery and bony malformations of the lower limbs [7, 12] or campomelic syndrome [18].

No morphometric features of the anterior tibial artery have previously been reported in the radiological or anatomical literature. The present study was undertaken in order to construct a normal range for the morphometric features of the anterior tibial artery in the different subtypes of the popliteal artery division. In view of the data available in the literature the objectives for the present study were set to examine:

- the sources (origins) of the anterior tibial artery;
- the length and luminal diameter of the anterior tibial artery in the different subtypes of the popliteal artery division;
- the influence of sex and side of the body on the source of the anterior tibial artery and on the value of the features examined (length, luminal diameter);
- the symmetry of the popliteal artery division.

MATERIAL AND METHODS

The examinations were carried out on femoral preoperative arteriograms in non-diabetic patients with aortoiliac occlusive disease (Lerich syndrome). All the arteriograms that documented single level disease confined to the aortoiliac system and that included adequate views of the popliteal artery and its major branches were studied. Therefore, the arteriograms of 210 patients with Lerich syndrome that had any evidence of atherosclerosis in the popliteal artery or its branches were excluded as providing inadequate views. Exclusion of these individuals did not alter the results of the present study. Distal popliteal arterial variants and the dimensions of the crural arteries in patients with Lerich syndrome provide data that is representative of healthy patients [10, 21].

This study was based on bilateral arteriograms of 76 patients (46 men and 30 women) aged 39–84 years. The men mean age of the men was 61.3 ± ± 8.2 years, and that of the women's was 65.2 ± ± 7.9 years, while the mean age of the series as a whole was 63.2 ± 8.1 years. The effect of age on the luminal diameters of the popliteal artery and its branches is minimal [21, 22]. The configurations of the popliteal artery division were described according to the unified angiographic classification proposed by Lippert and Pabst [13] and Kim et al. [10]. In the normal type the popliteal artery divided below the knee joint, whereas in the high type it divided at or above the knee joint. The classification into high and low divisions of the popliteal was not influenced by the orientation of the image. Afterwards source pictures were recorded in 24 bit BMP using the Digital Image Analysis System Q 500 MC of Leica (Cambridge), which estimated the length (mm) and internal diameter (mm) of the anterior tibial artery [21, 22]. The luminal diameter of the anterior tibial artery was measured 5 mm below its origin. For each artery five measurements were taken for the luminal diameter and length and the results averaged. The measurements of the arteries seen on an arteriogram give the actual dimensions because of the right angle between the artery and the X-ray beam (the X-rays were taken approximately perpendicular to the artery). The results obtained were described by two-way analysis of variance (Multi-group ANOVA) for unpaired data — the means for six subtypes with regard to sex (male, female) and side of the body (left, right), using the STATISTICA 5.5 program. Symmetry of the popliteal configurations (r) was estimated using the Pearson test.

RESULTS

The incidence of bilaterality of the anterior tibial artery was observed on all examined arteriograms. In 1.98% of cases the anterior tibial artery was hypoplastic.

The sources of the anterior tibial artery were closely correlated with the branching of the popliteal artery without gender differences ($p \geq 0.05$). According to Lippert and Pabst [13] and Kim et al. [10] two general types of popliteal artery division, normal (I) and high (II), have been distinguished. The high type of popliteal artery was seen 12 times less frequently (7.89%:92.11%) than the normal one. The normal type of popliteal artery (92.11%) comprised the following three subtypes: IA, IB and IC (Fig. 1).

In subtype IA (87.5%) the anterior tibial artery and the short type of posterior tibioperoneal trunk were found. In subtype IB (2.63%) an arterial trifurcation was observed. The anterior tibial artery, peroneal artery and posterior tibial artery arose in close proximity. I have followed the criteria of Adachi and Hasebe [1], wherein a trifurcation is described only if the common trunk following the origin of the first branch is less or equal to 5 mm in length. In subtype IC (1.97%) the posterior tibial artery and the short type of anterior tibioperoneal trunk were described. The high division comprised the following three subtypes: IIA 1, IIA 2 and IIB (Fig. 2). In two subtypes, IIA 1 (1.32%) and IIA 2 (0.66%), the anterior tibial artery and the long type of posterior tibioperoneal trunk were found. In the first (IIA 1) the anterior tibial artery

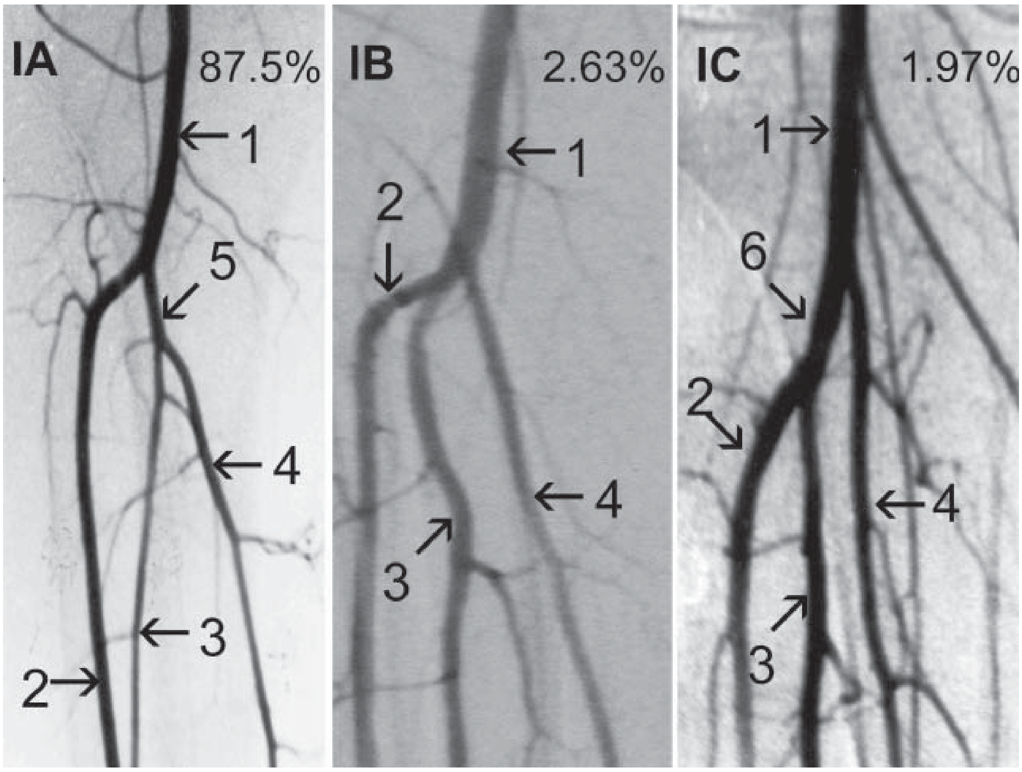

Figure 1. Normal subtypes (IA–C) of popliteal artery division: 1— popliteal artery, 2 — anterior tibial artery, 3 — peroneal artery, 4 — posterior tibial artery, 5 — posterior tibioperoneal trunk, 6 — anterior tibioperoneal trunk.

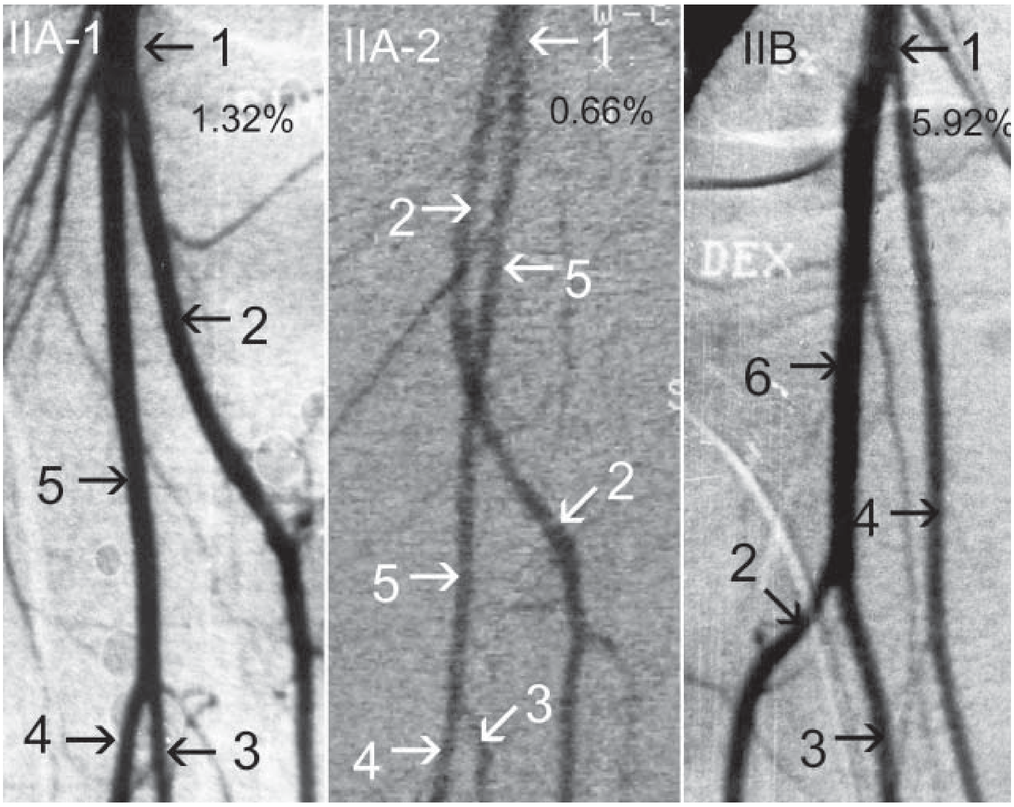

Figure 2. High subtypes (IIA 1, IIA 2, IIB) of popliteal artery division: 1 — popliteal artery, 2 — anterior tibial artery, 3 — peroneal artery, 4 — posterior tibial artery, 5 — posterior tibioperoneal trunk, 6 — anterior tibioperonal trunk.

had a straight course, whereas in the second (IIA 2) it coursed with a medial swing.

In subtype II B (5.92%) the long type of anterior tibioperoneal trunk and the posterior tibial artery were observed. In this pattern an anomalous origin of the posterior tibial artery proximal to the anterior tibial artery was noted. Subtype IIB is the correlative of subtype IC, differing in that the posterior tibial artery arises high. The anterior tibial artery occurred most frequently as a terminal branch of the popliteal artery in its normal (IA: 87.5%, IB: 2.63%) and high division (IIA 1: 1.32%, IIA 2: 0.66%). In the remainder the anterior tibial artery arose from both anterior tibioperoneal trunks (IC: 1.97%, IIB: 5.92%). There was no right — left predominance of the popliteal patterns. The symmetry of the left and right popliteal patterns was observed in the two most frequent subtypes: IA ($r_1 = 0.80$) and IIB ($r_2 = 0.83$).

Characterisation of the anterior tibial artery was completed by digital morphometry of the length and luminal diameter of the anterior tibial artery in all the observed subtypes of popliteal artery division with regard to sex and side of the body. The anterior tibial artery was longest ($p = 0.02$ for men, $p = 0.04$ for women) in two subtypes: IIA 1 and IIA 2 (Table 1). In the other subtypes no statistically significant differences were observed in the length. The greatest diameter of the anterior tibial artery was characteristic

Table 1. Length ($x \pm SD$) of the anterior tibial artery

Subtype	Side	Length [mm]	
		Men	Women
IA	Right	$351.2^{b,d} \pm 32.1$	$341.2^{c,e} \pm 18.1$
	Left	$345.9^{b,d} \pm 31.4$	$344.2^{c,d} \pm 21.2$
IB	Right	$349.2^{b,d} \pm 29.1$	$341.1^{c,e} \pm 27.3$
	Left	$349.8^{b,d} \pm 27.9$	$339.9^{c,e} \pm 27.4$
IC	Right	$348.3^{b,d} \pm 27.4$	$342.8^{c,e} \pm 21.9$
	Left	$347.2^{b,d} \pm 30.3$	$344.3^{c,e} \pm 26.3$
IIA 1	Right	$403.8^{a,d} \pm 22.1$	$389.2^{b,e} \pm 22.3$
	Left	$398.4^{a,d} \pm 30.1$	$387.9^{b,e} \pm 23.8$
IIA 2	Right	$419.3^{a,d} \pm 30.1$	$408.9^{a,e} \pm 31.2$
	Left	$415.2^{a,d} \pm 35.7$	$403.5^{a,e} \pm 21.9$
IIB	Right	$347.9^{b,d} \pm 30.5$	$339.8^{c,e} \pm 29.4$
	Left	$346.8^{b,d} \pm 31.3$	$338.9^{c,e} \pm 31.4$

The means for the length of the anterior tibial artery in the different subtypes, distinguished by the letters a, b (in men) and a, b, c (in women) in the columns, differ significantly ($p = 0.02$ for men, $p = 0.04$ for women). The means for the length of the anterior tibial artery in both sexes, distinguished by the letters d, e in the rows, differ significantly ($p = 0.03$).

Table 2. Diameter ($x \pm SD$) of the anterior tibial artery

Subtype	Side	Diameter [mm]	
		Men	Women
IA	Right	$3.5^{c,e} \pm 0.3$	$3.4^{c,f} \pm 0.3$
	Left	$3.5^{c,e} \pm 0.3$	$3.4^{c,f} \pm 0.3$
IB	Right	$4.5^{a,e} \pm 0.4$	$4.4^{a,f} \pm 0.4$
	Left	$4.5^{a,e} \pm 0.4$	$4.4^{a,f} \pm 0.4$
IC	Right	$4.1^{b,e} \pm 0.4$	$4.0^{b,f} \pm 0.4$
	Left	$4.1^{b,e} \pm 0.4$	$4.0^{b,f} \pm 0.3$
IIA 1	Right	$2.4^{d,e} \pm 0.2$	$2.3^{d,f} \pm 0.2$
	Left	$2.1^{d,e} \pm 0.2$	$2.0^{d,f} \pm 0.2$
IIA 2	Right	$2.2^{d,e} \pm 0.2$	$2.1^{d,f} \pm 0.2$
	Left	$2.2^{d,e} \pm 0.2$	$2.1^{d,f} \pm 0.2$
IIB	Right	$4.1^{b,e} \pm 0.4$	$4.0^{b,f} \pm 0.3$
	Left	$4.1^{b,e} \pm 0.4$	$4.0^{b,f} \pm 0.4$

The means for the diameter of the anterior tibial artery in the different subtypes, distinguished by the letters a, b, c, d (in men) and a, b, c, d (in women) in the columns, differ significantly ($p = 0.04$ for both sexes). The means for the diameters of the anterior tibial artery in both sexes, distinguished by the letters e, f in the rows, differ significantly ($p= 0.04$).

for a trifurcation (IB), and the smallest ($p = 0.04$) for subtype IIA 2 (Table 2). Intermediate values in diameter were found in three subtypes: IA, IC and IIB. Both the length ($p = 0.03$) and luminal diameter ($p = 0.04$) of the anterior tibial artery in men were significantly larger than those in women in all the popliteal subtypes observed. The statistical analysis of the morphometric parameters showed no differences between the right and left anterior tibial arteries. Of the three calf arteries, the anterior tibial artery was the predominant vessel in a trifurcation (IB) and in subtypes with the anterior tibioperoneal trunk (IC, IIB).

DISCUSSION

The lower extremity arteries arise from two sources: the primary limb bud artery (sciatic artery) and the femoral artery. By the 14 mm embryonic stage the femoral artery has grown into the thigh and joined the sciatic artery at the level of the adductor canal [4, 5, 26]. Variability in the crural arteries depends on both the regression of the sciatic artery and also on the persistence of its junction with the primary femoral artery in the popliteal region [21, 22]. The anterior tibial artery stems from the anterior germ of the middle part of sciatic artery. The high origin of the anterior germ implicates the genesis of two subtypes of the high division of the popliteal artery (IIA 1 and IIA 2).

Table 3. Incidence of appearance (%) of the subtypes of popliteal artery division according to different authors

Authors [references source]	Number of examined extremities	Methods	IA	IB	IC	IIA1	IIA2	IIB
Adachi, Hasebe [1]	770	Limb dissection	96	0.8	0.5	0.9	1	0.8
Keen [9]	280	Limb dissection	90.7	4.3	0.4	3.6	0.4	1.1
Lippert, Pabst [13]	100	Limb dissection	90	4	1	3	1	1
Trotter [23]	1168	Limb dissection	93.4	0.5	1.3	1.5	2.4	1.4
Bardsley, Staple [3]	235	Angiography	92.8	0.4	–	4.2	–	1.7
Kim et al. [10]	605	Angiography	92.6	2	1.2	3	0.7	0.8
Mauro et al. [15]	343	Angiography	88	4.1	1.2	2.3		0.9
Morris et al. [16]	246	Angiography	88.6	2.9	1.2	3.6	–	0.8
Voboril [25]	253	Angiography	81.8	5.5	–	1.6	0.4	2.4
Szpinda [this study]	152	Angiography	87.50	2.63	1.97	1.32	0.66	5.92

The low origin of the anterior germ of the middle part of the sciatic artery determines the other four subtypes: IA, IB, IC and IIB. Table 3 summarises the frequency of each subtype of arterial variant in my study and lists those reported by previously authors using angiography and limb dissection. Generally, my statistical findings agree with those of other angiographic [3, 10, 15, 16, 25] and anatomical [1, 9, 13, 23] studies. Subtype II B, however, was found more frequently (5.92%) in this study than in the work of other authors (0.8–2.4%). Kim et al. [10] described a single case of a new variant (subtype IIC < 0.2%) of popliteal artery division. The peroneal artery arose above the knee joint. A short common trunk for both tibial arteries therefore ensued.

In the material under examination there was no right — left predominance of the arterial pattern. A high degree of symmetry of bilateral variants was observed in two subtypes: IA ($r_1 = 0.80$) and IIB ($r_2 = 0.83$) of popliteal artery division. Similar results concerning symmetry of the popliteal variants were observed by Sanders and Alston [19] in three out of four patients (75%). It should be noted that in the present study no statistically significant gender differences were observed with respect to the different sources of the anterior tibial artery. It was confirmed that in two arterial patterns, IIA 1 and IIA 2, the length of the anterior tibial artery reaches its maximum value. In the remaining subtypes (IA, IB, IC and IIB) the length did not show statistically significant differences. The greatest diameter of the anterior tibial artery was found for a trifurcation (IB) and the smallest for subtype IIA 2. The anterior tibial artery showed intermediate values in diameter in three subtypes: IA, IC and IIB. My findings demonstrated that in men both the length and luminal diameter of the anterior tibial artery were significantly greater than in women. However, in my series the statistical analysis of the morphometric parameters did not show differences between the right and left anterior tibial arteries. These statistical findings correspond to the ultrasonographic observations of Macchi et al. [14]. The luminal diameters of the anterior tibial artery presented in this work were much greater than the mean diameters in the angiographic material of Heise et al. [6], namely 0.27 ± 0.02 mm for the anterior tibial artery. The differences between the data of Heise et al. [6] and my observations resulted from the fact that the subject of his examination was the luminal diameters of arteries with intensive pathological changes.

The luminal diameter of the anterior tibial artery is the most important determinant of the patency rate in anterior femorotibial graft. The luminal diameters closely correlated with the percentage of the three-year patency rate for bypass [11] and the cumulative limb salvage rate [8]. In the series of Sidawy et al. [20] the three-year patency rate for anterior femorotibial bypass equalled 63%. In 1.98% of cases in the material under examination a hypoplastic anterior artery was observed. At the ankle the dorsal pedis artery was replaced to the perforating branch of the peroneal artery. Similar anomalies were described unilaterally by Ali and Mohajir [2] and bilaterally by Tuncel et al. [24]. During foetal development anastomoses between the anterior tibial and peroneal arteries were formed [26]. The hypoplastic anterior tibial artery, by reducing the number of collateral blood supply routes, puts the limb at risk of teratogenic damage. Rodriguez [18] described the coexistence of campomelic syndrome with marked deficiency of the anterior tibial artery. Hootnick et al. [7] and Levinsohn et al. [12] also presented the absence of the anterior tibial artery in patients with severe bony malformations of the leg such as clubfoot, deficiency of the calf bone, tibial aplasia, metatarsal absence, ectrodactyly and diplopodia.

This study has demonstrated that popliteal arterial variants and the normative data for the anterior tibial artery are important for vascular surgery below the knee.

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