ORIGINAL ARTICLE

STUDY OF EXTERNAL DIAMETER OF CRURAL ARTERIES AND THEIR CLINICAL SIGNIFICANCE

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ABSTRACT: BACKGROUND: Popliteal artery, continuation of femoral artery situated in popliteal fossa, divides into anterior tibial artery (ATA) and posterior tibial artery (PTA) at the lower border of popliteus muscle. The external diameter of these arteries and the peroneal artery (PeA) may vary and are inversely proportional to one another. Variations in arterial supply to the leg and foot depends on, hypoplastic/aplastic conditions of these arteries, resulting in compensatory hypertrophy of other artery. **AIMS:** The aim of present study is to measure external diameter of crural arteries and correlate these results with the clinical significance. **MATERIALS & METHODS:** The study was done by dissection method on 100 lower limbs (50 right, 50 left) of embalmed human cadavers, at department of Anatomy, Kempegowda Institute of Medical Sciences, Bangalore and medical colleges in and around Bangalore. In each specimen the external diameter of crural arteries were measured with the help of sliding calipers and findings noted down. Data analyzed by applying statistical method. **RESULTS:** Diameter of ATA was greater than PeA and PTA in all the specimens studied. The crural arteries were classified on the basis of their diameters into strong, intermediate & small. The study showed crural arteries with intermediate diameter constituted the major group and 13 different patterns were noticed. **CONCLUSION:** The results of the present study indicate the compensatory mechanism exists with regards to hypoplastic/aplastic conditions of a vessel leading to increase in the diameter of the other artery. This results in variation in the arterial distribution to leg and foot with clinical significance.

KEY WORDS: Crural arteries; external diameter of artery; anterior tibial artery; posterior tibial artery; peroneal artery; popliteal artery.

INTRODUCTION: Popliteal artery continuation of femoral artery divides into anterior and posterior tibial arteries at the lower border of popliteus muscle. [1]

Anterior tibial artery or posterior tibial artery may be absent or reduced or increased in size. The size of peroneal artery is inversely related to the size of anterior tibial artery and posterior tibial artery. Variant arterial supply to foot can be suspected when the infrapopliteal vessels show a hypoplastic / aplastic anterior tibial artery or posterior tibial artery and compensatory hypertrophy of peroneal artery. The diameter of the ATA is the most important determinant of the patency rate in anterior femorotibial graft.

Knowledge of these variants is important to angiographers and vascular surgeons, and also may influence the success of femorodistal popliteal and tibial arterial reconstruction, and vascularised free fibular grafts. [2]

The objectives of present study is to measure 1) external diameter of anterior tibial artery, posterior tibial artery and peroneal artery 2) Relation of external diameter of peroneal artery with anterior tibial artery and / or posterior tibial artery and 3) discuss their clinical significance.

MATERIALS AND METHODS: The external diameter of crural arteries was studied in 100 lower limbs of embalmed human cadavers irrespective of their sex. (50 right and 50 left lower limb) The specimens were obtained from the Department of Anatomy, Kempegowda Institute of Medical Sciences, Bangalore and Medical Colleges in and around Bangalore.

The gross dissection was done by following the guidelines of Cunningham's manual. [2]The popliteal fossa was approached. The external diameter of the anterior tibial, posterior tibial and peroneal artery was measured using sliding calipers close to their origin. From a series of such measurements of terminal branches and peroneal artery an average percentage was obtained and SD was calculated. Results obtained were statistically analyzed by means of student's t test for independent variable (right and left side). The data obtained was recorded, analyzed and compared with that of the previous studies.

RESULTS:

Mean external diameter of crural arteries: The mean external diameter of ATA was greater on right side than left side ($p \leq 0.01$), and the mean diameter of PTA was greater on left side than right side ($p \leq 0.01$).But the mean diameter of PeA was almost equal on both sides. **(Table no.1)**

Relation of external diameter of PeA with ATA and /or PTA (Table 2): Diameter of ATA was greater than the corresponding PeA and PTA in all specimens studied (100%).In 90% of the cases studied, the diameter of PTA was more than corresponding PeA.

In 7% of cases (6 were of left side) the diameter of PTA and PeA were equal. Out of these, 5 cases had intermediate ATA (0.22-0.32cm) and 2 cases had small ATA (0.11-0.21cm).In 3% of cases (2 were of right side) the diameter of PeA was greater than PTA. Out of these, the ATA was intermediate (0.22-0.32cm) in 2 cases (2%) and 1 case showed ATA of small diameter (0.11-0.21cm).

Comparison of diameter of ATA, PTA, PeA: The crural arteries were classified as strong, intermediate and small after analyzing the data regarding their diameters. **(Table 3)**

Individual variability of diameter (%) of crural arteries (Table no. 4 & 5): Crural arteries showed individual variability with respect to diameter. In most of the cases, all 3 vessels were of intermediate diameter.

The association of crural arteries with respect to their different mean diameter studied. Out of the 25% of cases of strong ATA, in 9% it was associated with intermediate PTA and intermediate PeA. All the three vessels were strong in 6% of cases. 8% cases showed strong ATA and strong PTA with intermediate PeA. In another 2% cases, strong ATA was associated with strong PTA and small PeA.59% of cases studied had intermediate ATA. In 29% of cases all the crural arteries were of intermediate mean diameter. The intermediate ATA with strong PTA and intermediate PeA was observed in 14% cases. In 6% cases each intermediate ATA was accompanied by small PTA and PeA or strong PTA and PeA. The small PeA was associated with intermediate ATA and PTA in 3% of cases. Small ATA was seen in 16% of cases. All the three vessels were small in 10% cases. 5% cases showed small ATA with intermediate PTA and small PeA. An intermediate PTA is associated with intermediate ATA and strong PeA or with small ATA and intermediate PeA in 1 case each. (1%)It is seen that small ATA is either associated with small PTA and small PeA (10%) or intermediate PTA and small PeA (5%). But a small ATA was never associated with strong PTA or strong PeA. Similarly a strong ATA is usually never associated with small PTA and small PeA.

DISCUSSION:

External Diameter of ATA, PTA and PeA: In the present study external diameter of the anterior tibial artery, posterior tibial artery and peroneal artery are measured at the origin by using sliding calipers in all the 100 specimens.

The mean and SD were calculated. The data was analysed and compared with the previous studies and tabulated as below. (Table 6 & Table 7).

In the present study the diameters were smaller than those observed by Barut [5] and Szpinda [4], which may be attributed to racial or individual morphological differences. The mean diameters of ATA in Barut [5] and Szpinda [4] study were comparable. But the mean diameters of PTA and PeA noted by Barut [5] were greater than those observed in Szpinda [4] study.

Comparison of diameter of ATA, PTA, PeA: In the present study and study by Szpinda [4] the crural arteries were classified as strong, intermediate and small depending on their diameter.

In the study by Szpinda [4], same measurements (diameter range) were considered for the classification of all 3 vessels i.e. ATA, PTA and PeA as small, intermediate, and strong.

In the present study the different (diameter range) measurements were considered for classification of ATA, PTA and PeA as small, intermediate, and strong. (Table no. 3) From the above tables, it can be seen that the diameters considered for classification in both studies are different. Considering that the given values were standard for their population as both studies were done in different parts of the world, the results are compared in the following paragraphs.

It is seen that the results of both present study and the study by Szpinda [4] are comparable regarding variability of diameter (%) of ATA, PTA and PeA. The maximum number of samples belongs to intermediate group. In the present study 36% of PTA was of large diameters as compared to 17.23% in Szpinda [4] study.

In 16.45% of cases their diameter values were identical, as noted by Szpinda [4], but not reported in the present study. In the Szpinda study, strongest vessel was the anterior tibial artery (37.06%), rarely the posterior tibial artery (17.23%) and the least common (11.34%) was the peroneal artery. [4]Compared to this, in the present study strongest vessel was mainly the PTA (36%), rarely the anterior tibial artery (25%) and the least common was the peroneal artery (13%).On both the studies the smallest vessel was PeA.

* The association of crural arteries with respect to their different mean diameters was studied and 13 different patterns were found in the present study as compared to 24 different (variant) patterns reported by Szpinda. [4]

In the present study, in 29% cases, all the crural arteries were of intermediate mean diameter, similar results were noted by Szpinda (21.71%). [4]

In the present study, it was noted that all the three vessels were strong in 6% of cases and were small in 10% cases as noted in the present study. This was in contrast to the study by Szpinda [4] where no two extreme angiometric configurations were identified, neither three strong nor three weak crural arteries in the same specimen.

From the table no.5, it can be seen that in the present study an intermediate PTA is associated with intermediate ATA and strong PeA or with small ATA and intermediate PeA in 1 case each. (1%)

It is also seen that small ATA is either associated with small PTA and small PeA (10%) or intermediate PTA and small PeA (5%). But a small ATA was never associated with strong PTA or strong PeA.

Similarly in the study by Szpinda [4] there was no evidence for the coexistence of strong posterior tibial and strong peroneal arteries with an intermediate anterior tibial artery.

A strong ATA was not seen associated with small PTA and small PeA in the present study (Table no. 5), but was observed in 2.63% of cases in the study by Szpinda.

In the study by Szpinda, three variants were formed by a weak ATA and a strong PeA in association with strong, intermediate and weak posterior tibial arteries. Each had incidence of 0.66%. These variants were not observed in the present study. In all these cases the ATA was hypoplastic and terminated in the lower half of the shin. This artery was accompanied by a hyperplastic PeA, the perforating branch of which compensated for the dorsal pedis artery.

A further 4 variants, of identical frequency (0.66%), were found by Szpinda [4]:

1) A strong hyperplastic PeA, an intermediate ATA and a hypoplastic PTA
2) An intermediate PeA and weak tibial arteries.

These two variants were not found in the present study.

3) A weak PeA with intermediate PTA and small ATA
4) A weak PeA with weak PTA and intermediate ATA.

These variants were noted in the present study in 5% and 6% of cases respectively.

Hypoplastic or aplastic vessels: The size of peroneal is inversely related to size of anterior tibial artery and posterior tibial artery as it replaces them in their aplasia /absence. [6]

Kim had classified a special category III, which includes Hypoplastic or aplastic branching with altered distal supply. [2]

Other angiographic studies did not include incidence figures for subtypes of type III, which was found in the study by Kim[2], but either grouped them together or included only one of the three subtypes.

The pattern at the foot could be predicted by observing the area of the popliteal bifurcation because the hypoplastic or absent vessel was evident along with a concomitant increased caliber of the proximal peroneal artery. Caution must be used to differentiate this phenomenon from atherosclerotic occlusive disease of the ATA or PTA, with the hypertrophied peroneal collateralizing the distal ATA or PTA. The presence of gradual tapering of the hypoplastic artery, the lack of collateral reconstitution distally, and a straight, non-undulating appearance of the distal segment of the peroneal reaching the dorsalis pedis or distal PTA favor against atherosclerosis. In case of collateral reconstitution, there will be transitional tapering. [2]

*Hypoplastic PTA with hyperplastic PeA was seen in 2.3- 4% of cases [7, 2, 8, 9] and Hypoplastic ATA with hyperplastic PeA was seen in 1.6-6.9% of cases. [10, 11, 12] Both PTA and ATA being hypoplastic with hyperplastic PeA (peroneal arteria magna) was seen in 0.2% of cases.[2, 13] Similar cases were also reported by Lawrence. [14] Arteria magna is an absolute contraindication of free fibular flap harvest.

The continuation of distal peroneal artery to the ATA or PTA was considered as major variant in Jin's study and was seen in 8.47% cases, which is quiet higher incidence reported. Also he reported hypoplasia of ATA in 3.39% cases. [15]

An uncommon case of 42yr old male patient, who sustained a deep laceration on the anterolateral aspect of left leg paralleling the proximal fibula, has been reported. Arteriography showed a normal popliteal artery that trifurcated into a hypoplastic ATA, a PTA ending at ankle, and an enlarged peroneal artery. A 2.5cm pseudoaneurysm originated from the peroneal artery. Due to above mentioned anomalies a prompt diagnosis and treatment are important because delayed treatment leads to paralysis, infection and limb loss.

The patient's pulseless foot suggested anomalous popliteal artery branching (termination).

Therapeutic occlusion of the peroneal artery could have resulted in limb loss.

Therapeutic endovascular embolisation of traumatic peroneal or tibial artery pseudoaneurysm is a viable alternative to surgical ligation, but anomalous popliteal artery branching and tibial artery supply to the foot may represent a contraindication. [16]

Bilateral variation was observed in the fibular artery during dissection of a 52yr old male cadaver. On the right side type IIIB, and on left side Type IIIA branching pattern of popliteal artery were seen.

And it was noted that the variations in the arteries of the leg can be best explained by treating the fibular artery as the main artery and defining the tibial arteries as its branches. If one of the tibial arteries is lacking or very small, the fibular artery supplies that part of the foot.

It was noted by Lippert et al that, fibular artery is a major contributor to the blood supply of the foot in 12% of all cases. [17]

The use of fibular free flaps has become established as a reliable and popular method for reconstructing segmental mandibular defects. Moreover, to ensure lower extremity viability after flap harvest, it is necessary to determine the adequate perfusion to the donor extremities because vascular variations and peripheral arterial occlusive disease, after harvesting the peroneal vessels, can cause ischaemia in the lower leg or foot.

The arterial anatomical conditions that adversely affect the harvest of the fibula are as follows: significant atherosclerotic stenosis of the tibioperoneal trunk or peroneal artery, peroneal arteria magna (a condition in which only the peroneal artery supplies the foot), and the absence of the peroneal artery (which occurs congenitally or as an acquired defect) combined with a hypoplastic PTA. Fibular free flap transfer in these cases will result in ischaemia of the foot and eventual limb loss. Also the harvest of a peroneal artery supplying collateral circulation to the territory of a deficient tibial artery has the potential to cause foot ischaemia. Thus, leg with a continuation of the peroneal artery as ATA or PTA should not be selected for fibular free flap harvest to prevent a possible postoperative foot ischaemia. [15]

Assessment of peroneal artery patency plays a fundamental role in patients being evaluated for either fibular free-flap harvesting or lower extremity reconstruction with the goal of preserving two-vessel runoff to the foot. [14]

In the present study, hypoplastic ATA or PTA was not associated with hyperplastic PeA. The small ATA was always associated with either small or intermediate PeA, and the small PTA was associated with small PeA in all cases.

The small vessels with adequate circulation to the foot seen in the present study can be explained on the basis of; either the racial or morphological difference in the source (vessel) and demand (foot) which was compatible to each other. The author noted that each case with small ATA or small PTA was not associated with a strong PeA. So it can be deduced that an intermediate or small PeA along with small ATA or small PTA can supply sufficient blood supply in a healthy leg.

CONCLUSION: The mean diameter of ATA was greater on right side than left side ($p \leq 0.01$), and the mean diameter of PTA was greater on left side than right side ($p \leq 0.01$). But the mean diameter of PeA was almost equal on both sides.

Diameter of anterior tibial artery was greater than the corresponding peroneal and posterior tibial artery in all specimens studied (100%). In 90% of the cases studied the diameter of corresponding crural arteries were related as posterior tibial>peroneal. In 7% of cases the diameter of posterior tibial and peroneal was equal. Of these, 6 were seen in left limb. In 3% of cases the diameter of peroneal was greater than posterior tibial artery.

The crural arteries were classified as strong, intermediate and small after analyzing the data regarding their diameters. Crural arteries showed individual variability with respect to diameter. In most of the cases, all 3 vessels were of intermediate diameter. The strongest vessel was mainly the PTA (36%), rarely the anterior tibial artery (25%) and the least common was the peroneal artery (13%).

The association of crural arteries with respect to their different mean diameters was studied and 13 different patterns were found. In 29% of cases, all the crural arteries were of intermediate mean diameter. All the three vessels were strong in 6% of cases and were small in 10% cases. It is also seen that small ATA is either associated with small PTA and small PeA (10%) or intermediate PTA and small PeA (5%). But a small ATA was never associated with strong PTA or strong PeA. (Table 7).

Hypoplastic ATA or PTA was not associated with hyperplastic PeA. The small ATA was always associated with either small or intermediate PeA, and the small PTA was associated with small PeA in all cases.

It was concluded that, the small vessels with adequate circulation to the foot seen in the present study can be explained on the basis of; either the racial or morphological difference in the source (vessel) and demand (foot) which were compatible to each other. The author noted that each case with small ATA or small PTA was not associated with a strong PeA. So it can be deduced that an intermediate or small PeA along with small ATA or small PTA can supply sufficient blood supply in a healthy leg.

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TABLES:

Mean external diameter +/- SD at origin			
Sample studied	ATA	PTA	PeA
Both sides (n=100)	0.282cm +/- 0.072	0.189cm +/- 0.067	0.152 cm +/- 0.057
right side (n=50)	0.285cm +/- 0.076.	0.187cm +/- 0.071	0.151cm +/- 0.059
left side (n=50)	0.278cm +/- 0.071	0.193cm +/- 0.066	0.153cm +/- 0.056

Table 1: Mean external diameter +/- SD of crural arteries at the origin

Type of relation	No. of specimens	Percentage
ATA>PTA	100	100%
ATA>PeA	100	100%
PTA>PeA	90	90%
PTA=PeA	7	7%
PTA<PeA	3	3%

Table 2: Showing the relation of diameter of PeA with ATA and /or PTA

Artery	Small	Intermediate	Large
ATA	0.11-0.21	0.22-0.32	0.33-0.43
PTA	<0.11	0.11-0.21	0.22-0.32
PeA	<0.11	0.11-0.21	>0.22

Table 3: showing the classification of crural arteries based on their diameters

Artery	Large diameter	Intermediate diameter	Small diameter
ATA	25%	59%	16%
PTA	36%	48%	16%
PeA	13%	61%	26%

Table 4: Showing the individual variability of diameter (%) of crural arteries.

		Diameter of PTA		
	Diameter of PeA	strong	Intermediate	small
Strong ATA	strong	6%	0	0
	Intermediate	8%	9%	0
	small	2%	0	0
		Diameter of PTA		
	Diameter of PeA	strong	Intermediate	small
Intermediate ATA	strong	6%	1%	0
	Intermediate	14%	29%	0
	small	0	3%	6%
		Diameter of PTA		
	Diameter of PeA	strong	Intermediate	small
Small ATA	strong	0	0	0
	Intermediate	0	1%	0
	small	0	5%	10%

Table 5: Showing association of crural arteries with respect to their different mean diameter.

Author	ATA	PTA	PeA
Szpinda	0.35cm+/-0.032	0.306cm+/-0.038	0.268cm+/-0.027
Barut	0.35cm+/-0.10	0.41cm+/-0.07	0.30cm+/-0.07
Present study	0.285cm+/-0.076	0.187cm +/-0.070	0.151cm +/-0.059

Table 6: showing comparison of mean diameters +/- SD of ATA, PTA and PeA on right side found in earlier studies with that of the present study.

Author	ATA	PTA	PeA
Szpinda	0.344cm+/-0.0315	0.266cm+/-0.021	0.263cm+/-0.025
Barut	0.37cm+/-0.09	0.40cm+/-0.09	0.32cm+/-0.06
Present study	0.278cm+/-0.071	0.193cm +/-0.066	0.153cm +/-0.056

Table 7: showing comparison of mean diameters +/- SD of ATA, PTA and PeA on left side found in earlier studies with that of the present study.

Category	Diameter (cm)
Small	</=0.25
Intermediate	0.25-0.4
Strong	>/=0.4

Table 8: showing the classification of vessels based on their diameters in the Szpinda study

Author	Artery	Large diameter	Intermediate diameter	Small diameter
Szpinda [4]	ATA	37.06%	49.15%	14.37%
Present study		25%	59%	16%
Szpinda	PTA	17.23%	64.28%	19.67%
Present study		36%	48%	16%
Szpinda [4]	PeA	11.34%	65.03%	24.20%
Present study		13%	61%	26%

Table 9: showing comparison of variability of diameter (%) of ATA, PTA, PeA

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