

Blood vessels of the shin — anterior tibial artery — anatomy and embryology — own studies and review of the literature

IZABELA MRÓZ¹, STANISŁAS KIELCZEWSKI¹, DOMINIK PAWLICKI¹, WOJCIECH KURZYDŁO²,
PIOTR BACHUL¹, MONIKA KONARSKA¹, TOMASZ BEREZA¹, KLAUDIA WALOCHA¹,
LOURDES NIROJA KAYTHAMPILLAI¹, PAWEŁ DEPUKAT¹, ARTUR PASTERNAK¹,
TOMASZ BONCZAR¹, PRZEMYSŁAW CHMIELEWSKI¹, EWA MIZIA¹, JANUSZ SKRZAT¹,
MAŁGORZATA MAZUR¹, ŁUKASZ WARCHOŁ¹, KRZYSZTOF TOMASZEWSKI¹

¹Department of Anatomy, Jagiellonian University Medical College
ul. Kopernika 12, 31-034 Kraków, Poland

²Institute of Physiotherapy, Clinic of Rehabilitation, Jagiellonian University Medical College
ul. Kopernika 19, 31-501 Kraków, Poland

Corresponding author: Izabela Mróz, MD, Department of Anatomy, Jagiellonian University Medical College
ul. Kopernika 12, 31-034 Kraków, Polska; Phone/Fax: +48 12 422 95 11; E-mail: izabelamroz@poczta.onet.pl

Abstract: Injuries of the lower leg are rather frequent in every day orthopedic routine. Process of healing takes quite a long time and is commonly dependent on the proper vasculature. The study was carried out on 50 human lower legs obtained during autopsies. The anatomy of the vascular system of the leg was studied using classical anatomical dissection methods. Based also on literature we have reviewed the current knowledge on the vascularization of the lower leg and its embryological background.

Key words: anterior tibial artery, posterior tibial artery, fibular artery, dorsal pedal artery, anatomy, embryology.

Introduction

Main arteries, which supply the lower leg, are the ending branches of the popliteal artery — the anterior and the posterior tibial arteries.

Anterior tibial artery, is a weaker anterior branch, which arises from the subdivision of the popliteal artery. It begins immediately below the popliteus muscle and the vicinity

of the tendinous arch of soleus muscle. It ends opposite the inferior extensor retinaculum of the crus, where it continues as the dorsal pedal artery. Following the projection of the anterior tibial artery onto the skeleton its lower end is positioned opposite the gap of the talocrural joint. In the beginning the anterior tibial artery runs obliquely downward and forward, slightly lateral. It traverses the superior opening of the interosseous membrane of the crus, leaving the posterior compartment of the shin and enters the anterior chamber. Next it runs vertically downward adhering to the anterior surface of the membrane. It descends next to the fibula, and then becomes distant, and reaches tibia. During its course anterior tibial artery runs relatively deep and goes along the lateral border of the tibialis anterior muscle. Only in the lower portion of its course it adheres directly to tibia. Lateral to it one can position extensor digitorum longus and below extensor hallucis longus muscles. This is why fractures of fibula usually do not compromise the artery, and tibial fractures only in case of injury to the lower tibia. Anterior tibial artery runs in company with two committant veins and deep fibular (peroneal) nerve, which initially runs lateral to the vessels. Only in the lower third of the crus the nerve crosses the vessels and runs medial to them. Thus established neurovascular anterior tibial bundle runs across a line marked by the middle of the distance between the tibial tuberosity and the fibular head and the middle of the distance between both malleoli.

Anterior tibial artery gives off few, relatively weak branches:

a. from upper portion: posterior recurrent tibial artery (within the posterior chamber — toward the genicular rete) and anterior recurrent tibial artery (immediately after entering the anterior chamber — also toward the genicular rete). Posterior recurrent tibial artery is commonly absent. Sporadically it may arise from the popliteal artery (10%) or from the posterior tibial artery (3%).

b. from the lower portion of the anterior tibial artery one can find the following branches:

- anterior medial malleolar artery,
- anterior lateral malleolar artery.

These two branches contribute the medial and lateral malleolar rete. Anterior medial malleolar artery originates slightly above the talocrural joint or at the level of the gap of the junction, sometimes below the dorsal pedal artery. It runs posterior to the tendon of the tibialis anterior muscle toward the medial ankle. Anterior lateral malleolar artery arises usually slightly above the anterior medial and runs posterior to the tendon of extensor digitorum longus toward lateral malleolus. It unites with the perforating branch of the fibular artery. Its anastomoses with the neighboring branches for lateral malleolar rete.

c. anterior tibial artery gives off numerous muscular branches which supply extensors of the shin and fibular muscles. Some of them penetrate the fascia of the shin and supply the skin, whereas the remaining branches pierce the interosseous membrane and anastomose with the ramifications of the posterior tibial and fibular arteries.

d. ending branch of the anterior tibial artery is the dorsal pedal artery.

Dorsal pedal artery begins at the level of the inferior extensor retinaculum. It runs along the dorsum of the foot anteriorly toward the proximal end of the first metatarsal space where it bifurcates and gives off terminal branches — first dorsal metatarsal artery and the deep perforating branch. Relocating anteriorly the artery insignificantly deviates medially (the course of the artery almost parallels the axis of the foot and corresponds to the segment running from the midpoint of the intermalleolar distance toward the proximal end of the first metatarsal space). Dorsal pedal artery lies on the ligaments and bones of the dorsum of foot covered by skin, fascia and inferior arm of the inferior extensor retinaculum. Medial to it one can see the tendon of the extensor hallucis longus, and on the lateral side one can find the tendon of extensor hallucis brevis which crosses the artery next to its end. The artery goes in company with two committant veins and the deep fibular nerve. Nerve is usually positioned medial to the vessels.

Branches of the dorsal pedal artery consist of:

- Medial tarsal arteries — (2–3 small vessels which originate from the medial side of the dorsal pedal artery) — which branch on the medial side of the foot and join the medial malleolar rete.
- Lateral tarsal artery — is one of the bigger branches of the dorsal pedal artery. It originates from its lateral aspect, little below the inferior extensor retinaculum, covered by extensor digitorum brevis muscle. It runs lateral and forward to the base of fifth metatarsal, uniting with the arcuate artery. During its course it gives off branches which together with the branches of the dorsal pedal and the arcuate arteries create dorsal arterial network of foot. Besides it anastomoses with the anterior lateral malleolar and the lateral plantar arteries. It commonly exists in a double form.
- Arcuate artery — is the biggest branch of the dorsal pedal artery. It begins opposite the line of the tarso-metatarsal joints and runs transversely to the lateral border of foot running on the dorsal surface of the proximal ends of four last metatarsals, covered by extensor digitorum brevis muscle. It is positioned 1 cm anterior and almost parallel to the line of tarso-metatarsal joints. The end of the artery is placed on the base of the 5th metatarsal bone, where it unites with the lateral tarsal artery, forming the dorsal tarsal arch. It gives off the posterior branches to the tarsal bones, tarso-metatarsal joints and extensor digitorum brevis muscle, as well as anterior branches — so called dorsal metatarsal arteries (three) which run toward II, III and IV interosseous spaces running along the dorsal aspect of the dorsal interossei muscles. At the level of the distal end of the interosseous space they bifurcate into dorsal digital arteries. Dorsal metatarsal arteries send quite strong posterior perforating branches which enter spaces between proximal ends of adjacent the metatarsal bones and inconstant anterior perforating branches which penetrate distal intermetatarsal spaces. These arteries reach the plantar metatarsal arteries. Arcuate artery may not exist at all (such case was described by Perlinzski [1]), and then arterial blood supply of the foot is derived from the plantar arch by perforating branches.

- Terminal branches: 1st dorsal metatarsal artery, deep plantar branch and ramus sinus tarsi.
- 1st dorsal metatarsal artery is the largest out of the metatarsal arteries. It is a continuation of the dorsal pedal artery. It runs forward on the first dorsal interosseous muscle and divides in the first interosseous space into two branches: one of them runs posterior to the tendon of the extensor hallucis longus muscle and gives branches on the medial side of the big toe, and the next bifurcates below and supplies adjacent margins of the big and second toes.
- Deep plantar branch — descends to the sole of the foot between the proximal ends of the first and second metatarsal bones and unites with the plantar arch.
- Ramus sinus tarsi — runs through the tarsal sinus and joins the posterior tibial artery or medial plantar artery. Commonly originates from the anterior lateral malleolar artery or from lateral tarsal artery or less commonly from perforating branch of fibular artery.

It happens that anterior tibial artery is weak. Dorsal pedal artery is then a continuation of the strong perforating branch of the fibular artery. Following Adachi studies [2] this variation exists in 3% of Europeans and in 7% of Japanese. Perlinzski [1] reports that such variation exists in 6% of cases. In our studies we have observed such type in 1 out of 50 limbs dissected (2%). The dorsal pedal artery may originate from the connection between the anterior tibial and the fibular arteries (1% — Perlinzski [1]). In our studies we did not find such variation. It may happen that dorsal pedal artery does not achieve normal size. In such case the main blood supply of the dorsum of foot arises from the lateral malleolar and fibular arteries. Complete absence of the dorsal pedal artery was observed, too. We did not observe such case in our material.

Dorsal pedal artery play important role in nourishing the muscles and bones of foot, especially tarsal and metatarsal bones. Because of its superficial position and relatively close neighborhood with bony structures it is relatively easy for palpation (one can easily feel the pulse). This situation changes when variation according to origin, course and subdivision occurs — then the pulse may be difficult to feel or completely absent.

Posterior tibial artery is a posterior, stronger branch of the popliteal artery, which is the main continuation of the trunk. It begins at the level of the tendinous arch of the soleus muscle. The vessel ends at the entrance into medial malleolar canal or within the canal between the superficial and deep layers of the flexor retinaculum (on the medial aspect of the calcaneus). This artery runs downward on the deep layer of the flexors of the leg, covered by the deep crural fascia and the triceps surae muscle. Its upper portion is located on the tibialis posterior muscle, but at the moment when the belly of the flexor hallucis longus partially covers this muscle the artery enters the groove limited by the flexor digitorum longus medially and the flexor hallucis longus laterally. In the lower half of the shin the artery is more superficial than in the upper part because triceps surae becomes the Achilles tendon. Above the medial ankle the artery is located medial

to the Achillei tendon and is covered by superficial and deep layer of crural fascia and small amount of fat tissue. This superficial position is preserved until the moment of entering the medial malleolar canal, where it is located between the tendons of tibialis posterior and flexor digitorum longus from one side and the tendon of flexor hallucis longus from another side. It is easy palpable in this position. Posterior tibial artery is accompanied by two committant veins and the tibial nerve, which in upper portion of its course, within the popliteal fossa is located lateral to the vessels, and next beneath the tendinous arch of the soleus muscle it runs medial to them. Finally it crosses the vessels and runs along their lateral aspect until the level of the medial malleolus. In the lower crus the artery redirects anteriorly and embraces the medial ankle from behind running to the medial aspect of the calcaneus, where it gives off its terminal branches the medial and lateral plantar arteries.

Posterior tibial artery gives off few branches:

The main and strongest branch is a fibular artery. It arises below the fibular neck (about 5 cm below the bifurcation of the popliteal artery). It runs quite deep in the flexor compartment. Initially it descends obliquely toward the fibula on the tibialis posterior muscle, next along the medial aspect of the fibula, between the tibialis posterior and flexor hallucis longus muscles. At first the artery is covered by the soleus muscle and the deep layer of crural fascia. In the lower portion of the shin the artery adheres to the interosseous membrane, next to the inferior tibiofibular joint and ends as calcaneal branches, being covered by the flexor hallucis longus muscle. When the belly of this muscle ends the artery runs more superficial being placed lateral to the calcaneal tendon, covered only by superficial and deep crural fascia.

The branches of the fibular artery are the following:

- Muscular branches — which supply soleus, tibialis posterior and flexor hallucis longus and fibular muscles.
- Nutrient fibular artery — which enters the nutrient canal.
- Perforating branch — which penetrates the interosseous membrane of the crus above the inferior tibiofibular joint and reaches the anterior compartment where it anastomoses with the anterior lateral malleolar artery, forming the lateral malleolar rete and the calcaneal rete. This artery in 3% of cases may substitute the dorsal pedal artery, especially when the anterior tibial artery is weak. Its anastomosis with the anterior lateral malleolar artery is situated usually between two bands of the anterior talofibular ligament [3].
- Communicating branch — arises from its terminal portion beneath the tendon of the flexor hallucis longus, runs transversely with respect to the posterior tibial artery and anastomoses with it. It gives off the branches on the posterior aspect of the talocrural joint and the tibia.
- Lateral malleolar branch — is a minute vessel of the communicating branch which crosses posterior aspect of the inferior tibiofibular joint and gives off the branches

to the lateral ankle. Together with the anterior lateral malleolar artery creates the lateral malleolar rete. This branch commonly exists as double vessel.

- Calcaneal branches — are terminal branches of the fibular artery which reach lateral surface of the calcaneus. Together with the calcaneal branches of the anterior tibial artery they create the calcaneal rete.

Quite commonly the fibular artery is stronger than posterior tibial artery (especially when anterior tibial artery is weak). It is quite permanent vessel in comparison to the posterior tibial artery which may atrophy (according to Adachi [2] in 8.5% in Europeans and in 5% of Japanese) or even completely regress. The fibular artery plays then the role of the main continuation of the popliteal artery.

Among the minute branches of the posterior tibial artery one can distinguish:

- Muscular branches — which supply the soleus muscle and deep flexors of the leg; some of these branches penetrate the interosseous membrane and enter the area which is normally supplied by the anterior tibial artery.
- Circumflex fibular branch — which arises from the upper portion of the genicular rete. It may arise from the anterior tibial or posterior tibial recurrent arteries.
- Nutrient tibial artery — which enters the nutrient foramen located slightly below the soleal line of tibia.
- Medial malleolar branch — which arises from the inferior portion of the posterior tibial artery. It surrounds the medial ankle from behind and its branches contribute the medial malleolar rete (together with the anterior malleolar branch). Also this branch is relatively commonly double.
- Calcaneal branches — together with the calcaneal branches of the fibular artery form the calcaneal rete. It has connections with the medial and lateral malleolar rete — and strengthens the arterial blood supply of both ankles.

It occurs that posterior tibial artery is atrophic, and then as quite thin vessel it reaches the lower third of the shin and anastomoses with the communicating branch of the fibular artery or directly with the fibular artery.

Lateral malleolar rete is composed of:

- Anterior lateral malleolar artery — from anterior tibial (Adachi [2] reports that this artery is in 69% stronger than the anterior medial malleolar artery). Anterior lateral malleolar artery may be double (similar to the anterior medial malleolar artery). Quite commonly (in 29%) it may originate from the perforating branch of the fibular artery.
- Perforating branch — from the fibular artery.
- Lateral malleolar branch — from the fibular artery or from communicating branch of the fibular artery — which also commonly is a double vessel.

Lateral malleolar rete connect with the medial malleolar rete (composed of anterior medial malleolar artery and medial malleolar branch of the posterior tibial artery) and with the calcaneal arterial rete (composed of the calcaneal branches of the posterior tibial artery, the fibular artery and the perforating branch of the fibular artery).

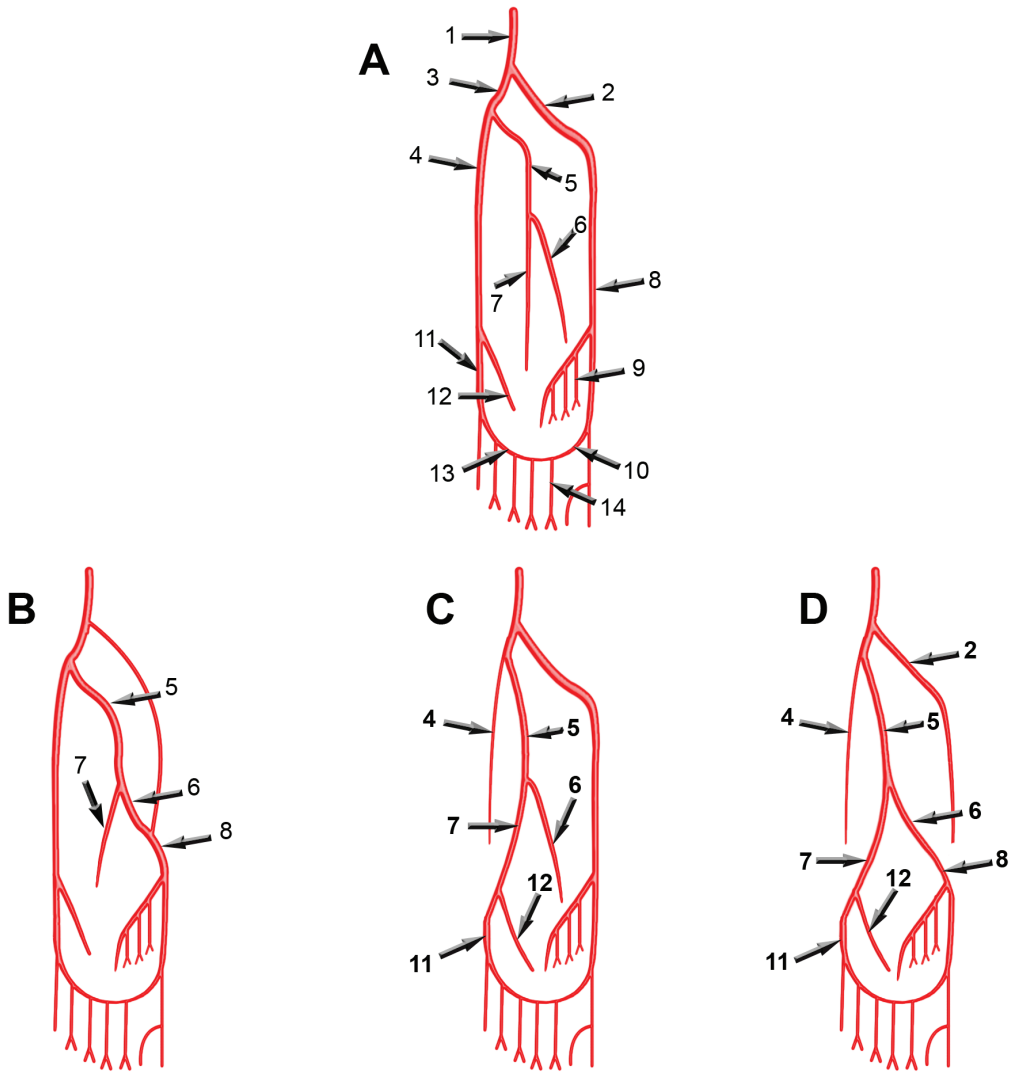


Fig. 1. Variation of the arterial blood supply of leg and foot

A — typical model (1 — popliteal artery, 2 — anterior tibial artery, 3 — tibiofibular trunk, 4 — posterior tibial artery, 5 — fibular artery, 6 — anterior fibular artery, 7 — posterior fibular artery, 8 — dorsal pedal artery, 9 — dorsal metatarsal arteries, 10 — first perforating branch of the interosseous space, 11 — lateral plantar artery, 12 — medial plantar artery, 13 — deep plantar arch, 14 — first plantar metatarsal artery)

B — dorsal pedal artery (8) is a continuation of the anterior fibular artery (6), 5 — fibular artery, 7 — fibular artery

C — posterior fibular artery (7) divides into medial and lateral plantar arteries (11, 12), 4 — incomplete posterior tibial artery, 5 — well developed fibular artery, 6 — anterior fibular artery

D — fibular artery (5) continued by dorsal pedal artery (8) through the anterior fibular artery (6) and into plantar arteries (11, 12) through the posterior fibular artery (7). Anterior tibial artery (2) and posterior tibial artery (4) are incomplete or absent [4].

Vein of the lower limb can be divided into superficial and deep. Main superficial veins of the lower limb are the long and short saphenous veins. The long saphenous vein is the main superficial vessel of the lower limb. It originates anterior to the medial ankle, as a continuation of the medial marginal vein. It receives some superficial branches from the dorsal and plantar venous subcutaneous networks, as well as deep branches from medial plantar veins. It ascends along the medial aspect of shin and next along the antero-medial aspect of the thigh in company with the saphenous nerve, achieving the saphenous hiatus, through which it empties into the femoral vein. During its course it collects the following tributaries:

- On the foot: superficial veins of the dorsal pedal network and medial calcaneal region
- On the shin: superficial veins from the antero-medial surface, nutrient tibial veins and muscular perforating veins
- On the thigh : accessory saphenous vein, superficial epigastric vein, superficial iliac circumflex vein and external pudendal veins

The small saphenous vein arises as continuation of the lateral marginal vein and runs posterior to the lateral ankle. Small superficial dorsal and plantar branches and anastomoses from lateral plantar veins participate in its creation. Running along the postero-lateral aspect of the shin in company with the sural nerve it empties into the popliteal vein. The following tributaries open into small saphenous vein:

- On the foot: superficial veins of the lateral border of foot and from lateral calcaneal region
- On the shin: superficial veins of the posterior-lateral aspect
- In the popliteal fossa: the femoro-popliteal vein

Main deep veins of the shin are double: anterior and posterior tibial, fibular veins which go in company with the analogous arteries. Superficial and deep veins are united by perforating veins.

Human vascular system develops in the end of the third week. The vessels start to arrange in the wall of the yolk sac, within the chorionic mesenchyme and in the yolk stalk. Thus originated vessels join each other and together with simultaneously developing heart they create the beginnings of the cardiovascular system. The blood vessels originate from the mesenchyme cells, which join to form cords, which subsequently recanalize and the elements which line them are transformed into flat endothelial cells. Next vessels develop through sprouting. Differentiation of particular elements of the primary vascular system is stimulated through a number of factors, i.e. hereditary, hydrostatic and hydrodynamic pressure, composition and function of an organ supplied by the vessels.

Arteries arise as first embryonic vessels — in the form of two aortae. The develop in the 4th week of gestation and during development they enter the first pharyngeal arch forming the dorsal aortae. They give rise to the following branches:

- Intersegmental arteries (within the embryonic body wall)
- Vitelline arteries (yolk sac)
- Umbilical arteries (for placenta)

Umbilical arteries are formed of abdominal branches of the dorsal aorta and in course of the development they join the dorsal branches, which form the common iliac arteries. In the caudal segment one can see branches for lower limbs. Proximal fragments of the umbilical arteries give rise to internal iliac. These give rise to sciatic arteries. Branches of the sciatic arteries together with the femoral (from external iliac from umbilical) give rise to arteries of the lower limb — i.e. anterior and posterior tibial arteries. Lower portion of the sciatic artery changes into the fibular artery.

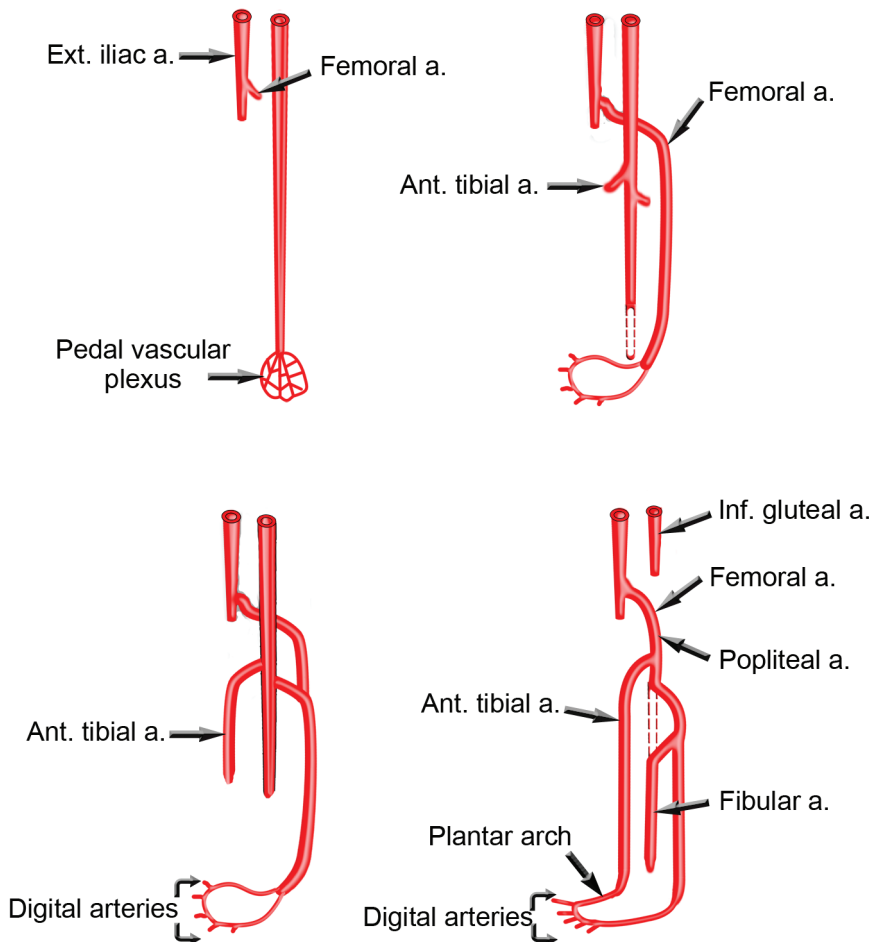


Fig. 2. Schematic drawing of the development of the arteries in the lower limb.

Summing up: arteries of the lower limb arise from two sources: sciatic artery (axial), which is a branch of the umbilical artery and plays the role of main supplier of the lower limb, and the femoral artery — branch of the external iliac. The sciatic and femoral arteries create anastomoses at the level of subsartorial canal. Thus femoral artery becomes the main source of the lower limb. Proximal part of the sciatic artery almost completely regresses, leaving only the committant artery of the sciatic nerve, while middle and distal parts change definitely into popliteal and fibular arteries. Anterior tibial artery arises from the popliteal. Between the popliteal and distal part of the femoral artery there are rising anastomoses which finally create the posterior tibial artery [5–7].

Veins in the lower limb develop simultaneously, and following some sources they use to be first vessels in the growing limb bud. They separate from the vascular network and placental membranes of the embryo. At first vitelline veins (within the yolk sac) arise, umbilical veins (in the chorion) and two symmetrical common cardinal veins (in the embryonic body). Anterior cardinal veins carry blood from cephalic part of the body, while posterior — from portions located below the heart. Posterior cardinal veins have anastomoses with superior and inferior cardinal veins, and the inferior cardinals give rise to the deep veins of the lower limb. Superficial veins originate from the marginal vein, which in the lower limb divides into pre- and postaxial. Preaxial vein gives rise to great saphenous vein and postaxial — to small saphenous.

Materials and methods

The studies were carried out on 50 lower limbs of adult cadavers of both sexes, aged 36 to 76, obtained from autopsies in the Department of Forensic Medicine JU CM. The study was approved by local Bioethical Committee (KBET/167/B/2009). The studies were carried out on specimens which did not show significant macroscopically visible pathological changes.

Obtained material was divided into four groups:

- Group I — 35–36 years old
- Group II — 47–56 years old
- Group III — 57–66 years old
- Group IV — 67–76 years old

Three limbs have not been qualified to the study because of visible necrotic changes.

Table 1. Material divided into four age groups.

Group (age)	Numer of the limbs		Percentage
	Left side	Right side	
I (35–46)	3	2	10.00
II (47–56)	4	3	14.00
III (57–66)	11	12	46.00
IV (67–76)	8	7	30.00
Total	26	24	100.00

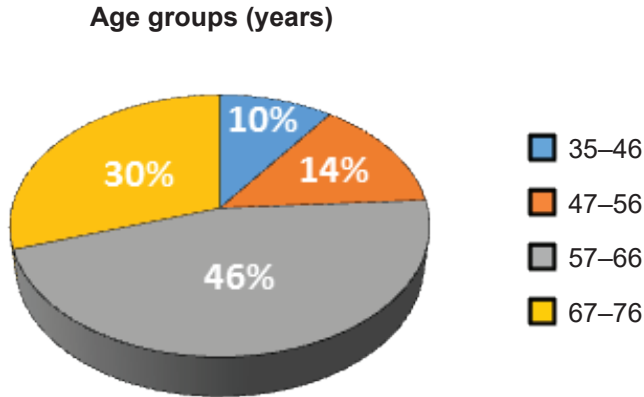


Fig. 3. Subdivision into age groups.

To make the vessels visible, posteriori aspect of the shin was sectioned in the median sagittal plane of the leg (from popliteal fossa till Achilles tendon), to dissect muscles of the posterior group of the leg. Next muscles of the superficial layer of posterior group (gastrocnemius and soleus) were sectioned transversely and gently dissected to visualize main branches of the popliteal artery (anterior and posterior tibial) and study their course.

One could see posterior tibial vessels after disclosure of the deep layer of the leg muscles. Anterior tibial vessels were disclosed after dissection of the tibialis anterior muscle.

Results and discussion

Macroscopic analysis was carried out on 50 limbs — 31 female and 19 male. The main vessels which supplied shin and the malleolar regions were the branches originate from popliteal artery: anterior, posterior tibial arteries and the fibular artery. Usually the popliteal artery was divided into anterior tibial artery and the common trunk (tibio-fibular trunk) which was subsequently giving off the posterior tibial and fibular arteries. Lack of anterior tibial artery was found in 4% of all cases (2 out of 50 limbs). The dorsal pedal artery was a direct continuation of the anterior tibial artery in 96% (48 out of 50 limbs) while in 4% (2 out of 50 limbs) it was extension of the perforating branch of the fibular artery. Posterior tibial artery was found in 100% of cases. Fibular artery in all cases studied was a branch of the posterior tibial artery.

Many authors handled with vascular anatomy of the lower limb, using different injection methods [8–13]. One can find in the literature studies on the caliber of the lower limb arteries — anterior and posterior tibial, fibular arteries [14]. The variability of the mentioned above vessels relatively high. See table 2.

Table 2. Variability of the branching pattern in the lower limb.

Author (year)	Absent or very thin anterior tibial artery	Dorsal pedal artery as a continuation of the anterior tibial artery	Dorsal pedal artery as continuation of the perforating branch of the fibular artery	Absent or very thin posterior tibial artery
Adachi	7.1%			2.0%
Quain (1844)	5.5%			
Salvi (1898)	3.0%			
Dubreuil-Chambardel (1925)	2.4%			
Huber (1941)	3.0%		3.0%	
Kil, Jung (2009)	1.7%			5.1%
Vazquez <i>et al.</i> (2006)		95.7%	1.3%	
Sarrafiian (2011)			5.3%	
Yamada <i>et al.</i> (1993)			6.7%	
Day, Orme (2006)				0.8%
Current studies	4.0%	96.0%	4.0%	0.0%

Attinger *et al.* described [15] connection between the anterior tibial and the fibular artery which were united by anterior (perforating) branch of the fibular artery and by lateral anterior malleolar artery, what agrees with our own findings. Such anastomosis was present in 56% of our material. Anterior tibial artery begins usually below the popliteus muscle in the vicinity of the tendinous arch of the soleus muscle. It ends at the level of the inferior extensor retinaculum — where it continues as dorsal pedal artery.

Yldiz *et al.* [16] described a case where anterior tibial artery originated relatively high as a branch of the popliteal artery and next it descended along the anterior aspect of the popliteus muscle. Similar high origin was denoted by Mauro *et al.*, Berdsley and Staple, Day and Orme [17–19].

Anterior tibial artery may be quite thin vessel in its distal part or it may end on the medial side of the lower limb. The dorsum of foot is supplied then by perforating branch of the fibular artery. Such cases were denoted by many authors [9, 20–26].

Kil and Jung described a case of hypoplastic or completely absent anterior tibial artery (1.7%), which was replaced by fibular artery [27]. Similar malformation has been described by Mavili *et al.* [28] — in such case fibular artery is the only vessel which supplies the distal part of the lower limb.

In our studies anterior tibial artery was absent in 4% — it continued as extension of the perforating branch into dorsal pedal artery.

Jung *et al.* described [29] large fibular artery which replaced all branches of the posterior tibial artery and the dorsal pedal artery. Right popliteal artery ended with subdivision into anterior tibial and large fibular arteries. Anterior tibial artery ended above malleolar region.

Table 3. Frequency of absence of the anterior tibial artery.

Author	Frequency (%)
Adachi	7.1
Quain (1844)	5.5
Salvi (1898)	3,0
Dubreuil-Chambardel (1925)	2.4
Huber (1941)	3,0
Kil, Jung (2009)	1.7
Current studies	4.0

Anterior tibial artery is absent, or very thin in 1.7–7.1% [2, 4, 30–33]. Dorsal pedal artery is usually a continuation of the anterior tibial artery. Following studies of Vasquez *et al.* it takes place in 95.7% of cases [34]. Taser *et al.* described a situation when perforating branch of the fibular artery is extremely large [35]. They have examined a case where dorsal pedal artery was a continuation of the perforating branch of the fibular, after it gave off the anterior lateral malleolar branch. Posterior tibial artery was thinner than usual in this case. Anterior tibial artery was gradually reduced and ended as muscular branches to tibialis anterior and extensor hallucis longus muscle. Fibular artery descended between the fibula and flexor hallucis longus muscle. It adhered to fibula connected to it by bands of loose areolar tissue. Huber [20] found absence of the anterior tibial artery in 3% what was associated with fact that dorsal pedal artery was supplied by perforating branch of the fibular artery. Vasquez *et al.* [34] proved that dorsal pedal artery was a continuation of the perforating branch of fibular artery in 1.3%. In 95.7% it was permanent continuation of the anterior tibial artery.

Kutoglu *et al.* [25] described a case where distal ends of the right anterior tibial artery and the left posterior tibial artery were hypoplastic and both ended at the inferior tibiofibular joint. Atanasova *et al.* [36] showed a case where dorsal pedal artery was a continuation of the posterior tibial artery.

Table 4. Frequency of the dorsal pedal artery as a continuation of the perforating branch of the anterior tibial artery.

Author	Frequency (%)
Huber (1941)	3.0
Sarrafián (2011)	5.3
Yamada <i>et al.</i> (1993)	6.7
Vazquez <i>et al.</i> (2006)	1.3
Current studies	4.0

Conflict of interests

None declared.

References

1. *Perlinzski L.*: Variation of the course and the division of dorsalis pedis artery in man. *Folia Morphol.* 1981; 40: 141–148.
2. *Adachi B.*: Das Arteriensystem der Japaner, Bd. II, Kyoto 1928.
3. *Golanó P, Vega J, de Leeuw P.A.J., Malagelada F, Manzanares M.C., Goötzens V, van Dijk C.N.*: Anatomy of the ankle ligaments: a pictorial essay. *Knee Surg Sports Traumatol Arthrosc.* 2010; 18 (5): 557–569.
4. *Dubreil-Chambardel L.*: Variations des arteres du pelvis et du member inferieur. Paris: Masson et Cie; 1925; 191–271.
5. *Kim D., Orron D.E., Skillman J.J.*: Surgical significance of popliteal arterial variants. A unified angiographic classification. *Ann Surg.* 1989; 210: 776–781.
6. *Senior H.D.*: An interpretation of the recorded arterial anomalies of the human leg and foot. *J Anat* Apr. 1919; 53: 130–171.
7. *Senior H.D.*: The development of the arteries of the human lower extremity. *Am J Anat.* 1919; 25: 55–94.
8. *Salvi G.*: Sull' arteria dorsal pedis. *Atti della societa Toscana di scienze naturally, process verbali.* 1898; 12.
9. *Sarrafián S.K.*: Anatomy of the foot and ankle. Descriptive, topographic, functional. 3rd ed. Lippincott, Philadelphia, 2011, pp. 159–217.
10. *Scurran B.L.*: Foot and Ankle Trauma. Chapter 28, Ankle Fractures by Gumann G. Churchill Livingstone, New York, 1990, pp. 579–625.
11. *Sumalatha S., Periyasamy V., Bhatt R., Dsouza A.S., Hosapatna M.*: Anomalous Branching Pattern of the Popliteal Artery (PA): A Case Report. *J Clin Diagn Res.* 2014; 8 (6): AD01–2.
12. *Walocha J.A., Szczepański W., Miodoński A.J., Gorczyca J., Skrzat J., Bereza T., Ceranowicz P, Lorkowski J., Stachura J.*: Application of acrylic emulsion Liquitex R (Binney and Smith) for the preparation of injection specimens and immunohistochemical studies — an observation. *Folia Morphol.* 2003; 62 (2): 157–161.
13. *Mustapha J.A., Saab F, Diaz-Sandoval L., Karenko B., McGoff T., Heaney C., Sevensma M.*: Comparison between angiographic and arterial duplex ultrasound assessment of tibial arteries in patients with peripheral arterial disease: on behalf of the Joint Endovascular and Non-Invasive Assessment of Limb Perfusion (JENALI) Group. *J Invasive Cardio.* 2013; 25 (11): 606–611.

14. *Poratt D., Tilley G.E.*: Absence of the posterior tibial artery. A case report. *J Am Pediatr Med Assoc.* 1994; 84 (7): 363–364.
15. *Attinger C.E., Evans K.K., Bulan E., Blume P., Cooper P.*: Angiosomes of the foot and ankle and clinical implications for limb salvage: reconstruction, incisions, and revascularization. *Plast Reconstr Surg.* 2006; 117: 261–293.
16. *Yildiz S., Yazar F., Ozan H.*: A high-origin anterior tibial artery and its current clinical importance. *International Journal of Anatomical Variations.* 2010; 3: 180–182.
17. *Mauro M.A., Jacques P.F., Moore M.*: The popliteal artery and its branches: embryologic basis of normal and variant anatomy. *AJR Am J Roentgenol.* 1988; 150: 435–437.
18. *Bardsley J.L., Staple T.W.*: Variations in branching of the popliteal artery. *Radiology.* 1970; 94: 581–587.
19. *Day C.P., Orme R.*: Popliteal artery branching patterns — an angiographic study. *Clin Radiol.* 2006; 61: 696–699.
20. *Huber J.F.*: The arterial network supplying the dorsum of the foot. *Anat Rec.* 1941; 80: 373–391.
21. *Zwass A., Abdelwahab I.F.*: A case report of anomalous branching of the popliteal artery. *Angiology.* 1986; 37: 132–135.
22. *Yamada T., Glocviczki P., Bower T.C., Naessens J.M., Carmichael S.W.*: Variations of the arterial anatomy of the foot. *Am J Surg.* 1993; 166: 130–135.
23. *Tuncel M., Maral T., Çelik H., Taşcıoğlu B.*: A case of bilateral anomalous origin for dorsalis pedis arteries (anomalous dorsalis pedis arteries). *Surg Radiol Anat.* 1994; 16: 319–323.
24. *Ali M.W., Mohajir A.M.*: Dorsalis pedis artery: Variations and clinical significance. *J Indian Med Assoc.* 1996; 94: 417–418.
25. *Kutoglu T., Ulucam E., Mesut R.*: A case of fibular artery variation. *Trakia Journal of Sciences.* 2003; 1: 53–55.
26. *Vaishnani H., Gujar S., Gadekar S., Bondre K.V., Shah G.V.*: An abnormal unilateral origin of dorsalis pedis artery — a case report. *Indian Journal of Applied Basic Medical Sciences.* 2012; 14: 98–103.
27. *Kil S.W., Jung G.S.*: Anatomical variations of the popliteal artery and its tibial branches: analysis in 1242 extremities. *Cardiovasc Intervent Radiol.* 2009; 32: 233–240.
28. *Mavili E., Dönmez H., Kahriman G., Özaşlamacı A., Özcan N., Taşdemir K.*: Popliteal artery branching patterns detected by digital subtraction angiography. *Diagn Interv Radiol.* 2011; 17: 80–83.
29. *Jung W., Oh C.S., Won H.S., Chung I.H.*: Unilateral arteria peronea magna associated with bilateral replaced dorsalis pedis arteries. *Surg Radiol Anat.* 2008; 30: 449–452.
30. *Golec E.*: Epidemiologia uszkodzeń urazowych stawu skokowo-goleniowego. *Kwart Ortop.* 2000; 4: 232–236.
31. *Golec E.*: Odległa ocena kliniczna i radiologiczna stabilności stawu skokowo-goleniowego po ostrym urazowym uszkodzeniu aparatu więzadłowo-torebkowego. *Chir Narz Ruchu Ortop Pol.* 2002; 67: 357–364.
32. *Mulfinger G.L., Trueta J.*: The blood supply of the talus. *J Bone Joint Surg Br.* 1970; 52 (1): 160–167.
33. *Nowak S., Golec J., Szczygieł E., Czechowska D., Milert A., Tomaszewski K., Hładki W.*: Wyniki odległego leczenia operacyjnego i rehabilitacji chorych z uszkodzeniami goleni typu Maisonneuve. *Ostry Dyżur.* 2013; 6: 39–42.
34. *Vazquez T., Rodríguez-Niedenfuhr M., Parkin I., Viejo F., Sanudo J.*: Anatomic study of blood supply of the dorsum of the foot and ankle. *Arthroscopy.* 2006; 22: 287–290.
35. *Taser F., Shafiq Q., Ebraheim N.A., Yeasting R.A.*: Enlarged perforating branch of peroneal artery and extra crural fascia in close relationship with the tibiofibular syndesmosis. *Surg Radiol Anat.* 2006; 28: 108–111.
36. *Atanasova M., Georgiev G.P., Jeleu L.*: Intriguing variations of the tibial arteries and their clinical implications. *International Journal of Anatomical Variations.* 2011; 4: 45–47.

