

Ultrasound in the diagnosis of anatomical variation of anterior and posterior tibial arteries.

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Abstract

Aims: Knowledge about branching pattern of the popliteal artery is very important in any clinical settings involving the anterior and posterior tibial arteries. This study aims to elucidate the anatomical variation patterns and common types of anterior tibial artery (ATA) and posterior tibial arteries (PTA) in the general population in China. **Material and methods:** Anatomical variations of ATA, PTA, and peroneal artery were evaluated with ultrasound in a total of 942 lower extremity arteries in 471 patients. **Results:** Three patterns of course in the PTA were ultrasonographically identified: 1) PTA1: normal anatomy with posterior tibial artery entering tarsal tunnel to perfuse the foot (91.5%), 2) PTA2: tibial artery agenetic, and replaced by communicating branches of peroneal artery entering tarsal tunnel above the medial malleolus to perfuse the foot (5.9%), and 3) PTA3: hypoplastic or aplastic posterior tibial artery communicating above the medial malleolus with thick branches of peroneal artery to form a common trunk entering into the tarsal tunnel (2.4%). In cases where ATA was hypoplastic or aplastic, thick branches of the peroneal artery replaced the anterior tibial artery to give rise to dorsalis pedis artery, with a total incidence of 3.2 % in patients, and were observed more commonly in females than in males. Hypoplastic or aplastic termini of ATA and PTA, with perfusion of the foot solely by the peroneal artery, was identified in 1 case. In another case, both communicating branches of the peroneal artery and PTA entered the tarsal tunnel to form lateral and medial plantar arteries.

Conclusions: Anatomical variation of ATA and PTA is relatively common in the normal population. Caution should be exercised with these variations when preparing a peroneal artery vascular pedicle flap grafting. Ultrasound evaluation provides accurate and reliable information on the variations.

Keywords: posterior tibial artery, anterior tibial artery, peroneal artery, variation, ultrasound

Introduction

The popliteal artery provides not only perfusion to capsule and ligaments of the knee joint via its genicular branches, but also the majority blood supply for the lower extremity [1-5]. Continuing from the femoral artery and passing through the popliteal fossa, it normally splits at the lower border of the popliteus muscle in the anterior and posterior tibial arteries. The anterior tibial ar-

tery most commonly passes between the tibia and fibula, then moves inferiorly down the leg after passing through a gap in the interosseous membrane, and runs down the entire length of the leg into the foot, ending at the dorsalis pedis artery. The posterior tibial artery, usually the larger of the two popliteal artery branches, continues from the popliteal artery along the surface of the tibialis posterior. Accompanied by the tibial nerve, it descends beneath the calf muscle by penetrating the lateral compartment of the leg and enters the sole of the foot via the tarsal tunnel. Normally, the peroneal artery, also known as the fibular artery, arises from the tibial-fibular trunk just below the knee. It supplies the deep posterior, lateral and anterior compartments of the leg and the fibula.

Due to embryological abnormalities of the arterial pattern, variations in anatomy of the lower limb arterial network, such as absence, rudimentary reminders, variant courses and replacement areas of vascularization, are statistically common [6-8]. These variant arterial

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supplies to foot and/or leg are of important anatomical significance and great clinical relevance, especially in plastic and vascular surgeries in an effort to reconstructing lower limb arteries or preparing viable muscle flaps [9-13]. The knowledge of these variations will definitely help reduce the risk of vascular trauma and unnecessary haemorrhage during lower limb surgery.

Anatomical variations of the popliteal artery have been extensively studied [1,9,10,12,14,15] with an impact on the daily clinical practice in the field of surgery and during catheterization. Studies have shown that the popliteal artery can trifurcate, gives high division or hypoplastic-aplastic branches with altered distal supply. In fact, hypoplastic changes have been reported for the anterior tibial, posterior tibial, and peroneal arteries [1,2,9,10,12,14-24]. The information about the anatomy of limb arteries is usually obtained via ultrasonography, computer tomography angiography (CTA), magnetic resonance angiography (MRA), and/or anatomical dissection. CTA and MRA, most performed pre-operatively, provide adequate radiological information about the studied vasculature, but require contrast agents and expensive equipment and are labor-intensive and time-consuming. Anatomical dissection, on the other hand, yields thorough and accurate anatomical information of the investigated structure, but is often limited by the lack of highly trained professionals and specimens. Vascular ultrasonography, with the advantage of noninvasiveness, and low-cost has gained increasing popularity in the examination of lower extremity vascularity. It is especially valuable in the diagnosis of vascular disease in a community hospital setting.

Herein we report results of anatomical variations of the posterior tibial artery, anterior tibial artery and peroneal artery, from 942 limbs in 471 subjects by using this method. Three patterns of course in the posterior tibial artery were identified.

Materials and Methods

Patients

A total of 942 lower extremity arteries in 471 patients (male 226) between ages of 17 to 87 years (average 43.9 years), were examined for lower limb vessels from June 2014 to October 2014 with ultrasound, after excluding cases with indiscernible anterior tibial artery (ATA), posterior tibial artery (PTA), and peroneal artery due to limb swelling, lower extremity arterial occlusive/arteriosclerosis, limb ulcers, skin diseases, and other reasons.

Ultrasound examination

ATA, PTA, and peroneal artery were imaged up to the bifurcation of popliteal artery with the patients in supine

and prone position using Duplex ultrasound (Sequoia 512, SIEMENS Medical Systems) with 4C1 and 8L5 probes.

When the atherosclerotic arteries appeared with deflated occlusion with a diameter less than 1mm, and these patients presented ankle and foot skin lesions and tissue edema, ultrasound examination of the bifurcating branches of the peroneal artery at the junction site to the peroneal artery was limited by unsatisfactory resolution, and the atherosclerotic arteries were excluded from the study.

Arterial aplasia was defined as no artery detected after ruling out the presence of arteriosclerosis obliterans, skin lesions, excessive tissue edema, and other limiting factors for imaging. Arterial hypoplasia was defined as a smooth, small artery with a diameter less than 1 mm, ruling out arterial narrowing secondary to other conditions.

The ultrasound examination was carried out by 2 radiologists specialized in vascular ultrasonography and with an expertise of vascular anatomy of lower extremity and ultrasound imaging.

Statistical analysis

Data were expressed as frequency and percentage (%), statistical differences of percentage between two groups were determined by Chi-square test. SPSS 16.0 software was used for statistical analysis. $p < 0.05$ was considered statistically significant.

Results

In the 471 patients, the relationship of the posterior tibial artery and peroneal artery had three patterns:

1) PTA1 (normal anatomy): The peroneal artery runs medial to the fibula, terminates at the lateral ankle as medial and lateral malleolar branches merging into the anterior and posterior tibial arteries. While the PTA runs between the soleus and deep calf muscle, entering tar-

Table I. Variation of anterior (ATA) and posterior tibial arteries (PTA)

Variation	Unilateral n=48 (%)	Bilateral n=31 (%)	Total n=471(%)
PTA			
PTA2	16(33.3)	19(61.3)	35(74.3)
PTA3	14(29.2)	4(12.9)	18(3.8)
ATA			
ATA2	16(33.3)	6(19.4)	22(4.7)
Other variation	2(4.2) *	2(6.5) ^A	4 (0.8)
Total	/	/	392(83.3)

*Two other patterns of variation were also observed in two cases (see the main text). ^ADifferent variations in the bilateral limbs. In one case, right PTA2 and left PTA3; In the other case, left PTA2 and right ATA2; n – number of patients

sal tunnel to form the medial and lateral plantar arteries, communicating with small branches of the peroneal artery right above the medial malleolar. These normal anatomies of the lower extremity arteries were diagnosed in 414 of 471 patients (87.9%).

2) PTA2: Hypoplastic or aplastic trunk of PTA disappeared before the tarsal tunnel. Thick communicating branches from the peroneal artery enter the tarsal tunnel to provide blood supply to the foot (fig 1a). Medial deviation of the trunk of the peroneal artery was observed in 35 of 471 patients (7.4%), including 3.4% (16/471) patients with the unilateral variation, and 4.0% (19/471) with bilateral variation (as shown in Table I).

3) PTA3: Hypoplastic or aplastic PTA entered the tarsal tunnel with branches from the thick peroneal artery in a common trunk, while perforation branches of the peroneal artery provided a blood supply for the plantar. The cases with the diameter of communicating branches of the peroneal artery no less than that of posterior tibial artery on the same level were assigned to this category (fig 1b). This pattern had an incidence of 3.8% (18/471) patients, including 3.0% (14/471) patients with the unilateral variation, and 0.8% (4/471) with bilateral variation (shown in Table I).

No differences of frequency distribution between the lower extremity arteries of male and female with PTA1, PTA2 and PTA3 were observed ($p>0.05$), and no differences were also observed between left and right lower extremity arteries ($p>0.05$), as shown in Table II.

Overall, 392 (83.3%) of the subjects in this study had a normal three branching pattern of the popliteal artery, a pattern described previously.

The course of the ATA was revealed in two patterns:

1) ATA1 (normal anatomy): After departing from the popliteal artery, the ATA penetrated the interosseous membrane to reach the lateral anterior aspect of the tibia, and became dorsalis pedis in the midpoint between the medial and lateral malleolars. This normal anatomy was found in 447 of 471 patients (94.9%).

2) ATA2: In 22 of 471 (4.7%) patients (16 patients with unilateral and 6 patients with bilateral) ATAs were with fine termini after giving rise to muscle and cutaneous branches. The thick peroneal artery communicated with or even replaced terminal ATAs (fig 1c). In such variations, the dorsalis pedis arteries usually were located medial to the malleolus. Lower extremity arteries with ATA2 were observed more commonly in females than in males (female 5.1%, male 1.1%, $p<0.001$), and no differences were observed between lower extremity arteries of left and right, data were showed in Table III.

In two (0.4%) patients other patterns of variation were observed. In one case, both ATA and PTA were absent, with communicating branches from the peroneal artery supplying the foot. In the other case, the thin trunk of PTA entered the tarsal tunnel with a communicating branch from the peroneal artery (fig 1d), both were palpable in the tarsal tunnel.

Table II. Distributary types of posterior tibial arteries (PTA)

	Frequency of limb	Type (%)			Other variation	p
		PTA1	PTA2	PTA3		
Male	452(48.0)	417(48.4)	28(50.0)	7(30.4)		>0.05
Female	490(52.0)	444(51.6)	28(50.0)	16(69.6)	2(100) ^{A*}	
Left	471(50.0)	425(49.4)	30(53.6)	15(65.2)	1(50) ^A	0.05
Right	471(50.0)	436(50.6)	26(46.4)	8(34.8)	1(50)*	
Total(%)	942	861(91.5)	56(5.9)	23(2.4)	2(0.2)	

^AOn the left side of the ankle canal, branch of peroneal artery and the posterior tibial artery coexist; *The right side of the peroneal artery branch replaced the pretibial artery and posterior tibial artery

Table III. Distributary types of ATA

	Frequency of limb	Type (%)		Other variation	P
		ATA1	ATA2		
Male	452(48.0)	446(49.0)	5(16.7)		< 0.01
Female	490(52.0)	465(51.0)	25(83.3)	1(100)*	
Left	471(50.0)	456(50.0)	14(46.7)		>0.05
Right	471(50.0)	455(50.0)	16(53.3)	1(100)*	
Total(%)	942	911(96.7)	30(3.2)	1(0.1)	

*The right branch of the peroneal artery replaced the pretibial artery and posterior tibial artery

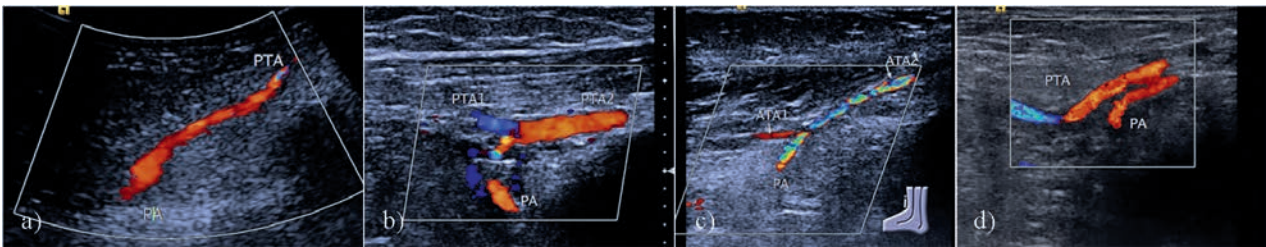


Fig 1. a) Peroneal artery (PA) completely replaced posterior tibial artery (PTA) forward lined into the ankle tube, the ramus communicans went straight; b) Ramus communicans of the Peroneal artery (PA) and the endpiece of the posterior tibial artery (PTA1) merged into the ankle district of the posterior tibial artery (PTA2); c) End piece of the anterior tibial artery (ATA2) converged by the anterior tibial artery (ATA1) and ramus communicans of the peroneal artery (PA); d) Two arteries in the ankle district, the upper one was the posterior tibial artery (PTA), the one below was the ramus communicans of the peroneal artery (PA)

Discussions

The lower limb arteries are derived from an embryonic vessel that supplies the lower limbs, namely the primitive middle and distal segments of the sciatic artery [25-27].

Normally, after starting at the edge of the popliteal muscle, the PTA normally passes between the shallow and deep muscle groups, enters into the tarsal tunnel on the medial edge of the Achilles tendon to divide into plantar and lateral arteries. The peroneal artery usually starts slightly below the very beginning part of the posterior tibial artery, descends along the inner side of the fibula, ending at the rear of the lateral malleolus rami, with small communicating branches connecting anterior and posterior arteries at the level of 3 to 8 cm above ankle. However, the prevalence of anatomic variability in the lower limb arteries is common due to persistent primitive arterial segments, abnormal fusions, segmental hypoplasia, or the absence of these arteries.

Lippert et al classified the anatomical variation of the popliteal artery in males according to the starting position of the popliteal artery, anterior tibial artery, posterior tibial artery and the peroneal [28]. Kim et al modified Lippert's classification, and described the third variation of the popliteal artery [29]. In the population studied, we found that 83.3% of the individuals presented a normal three branching pattern of the popliteal artery.

Arterial anatomies of lower limb have great radiological and surgical importance. Reportedly, the variation rate can be as high as 13% [1,9,21,30,31], which necessitates thorough examination of the vascular anatomy in the lower extremity prior to any intervention. Without a precise knowledge of anatomic variations in the branching pattern of the popliteal artery, it can be limb-threatening during a number of procedures in the lower limb, including arterial reconstructions in femoro-distal bypass graft procedures, embolectomy, and catheterization to

treat lower limb ischemia in diabetic and ankle arthroscopy.

In the present study, economic and convenient ultrasonography was chosen to visualize lower limb vasculature. By virtue of ultrasound vascular examination, we identified 3 different patterns of course of PTA, described above. The incidences of PTA1, PTA2 and PTA3 in the studied population were 91.5%, 5.9%, and 2.4%, respectively. We also found that under circumstances of hypoplastic or aplastic ATA, or hypoplastic or aplastic PTA, the thick communicating branches or truck of the peroneal artery merged into or even replaced the narrowed anterior or posterior tibial artery to secure plantar arterial blood supply. The incidence of replacement of the PTA by the peroneal artery was 5.9%, consistent with the reported incidence of 3.8% to 5.1% on angiography [1,9].

The peroneal artery is an important vessel for the preparation of the fibular graft and gastrocnemius muscle flap. Preoperative determination of adequacy of the blood supply of the foot after blocking the peroneal artery is also very important. It is very limb-threatening to sacrifice the peroneal artery when the termini of ATA and PTA as the peroneal artery may function as the sole blood supply of the foot [1,9,12,32-34]. In the past, blood supply of the foot was determined by the preoperative observation of the pulse of the PTA and dorsalis pedis artery. In recent years, angiography and CTA technology are applied for the evaluation of lower extremity vessels. Although angiography and CTA scans can clearly discern variations in the popliteal artery and its branches, but due to its invasive nature and potential adverse reaction to the contrast agents, their clinical popularity is significantly comprised [1,9,35,36].

Our study had technical limitations. Due to its location, the terminal segment of ATA is not readily resolved on ultrasound. In addition, the ATA is obscured by the tibia when travelling between the tibia and fibula. These factors adversely affect ultrasound examination of the

full length of the artery, which could explain the higher rate (3.0%) of the absence of terminal ATA in this study, comparing to that of 1.6% -1.7% in Kin and Sung's series [29,37,38]. Moreover, ultrasound is unable to differentiate absence from the narrowing of the ATA at the lower tibial area. Therefore, ability of ultrasound to probe variation of ATA in the lower tibial area is limited. Other limitations: lack of comparison with other imaging techniques, lack of interobserver and intraobserver agreements.

In **conclusion**, our results suggest that ultrasound examination of the lower extremity arteries should be applied prior to any intervention in these vessels to prevent undesirable damage. The variant patterns identified in this study have prominent clinical significance.

Conflict of interest: none

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