# Circumventing the difficulties induced by popliteal artery variation during tibial endovascular intervention

Omar A. El Kashef, Mohammed Ali, Hossam Zaghloul, Hossam El Mahdy, Mahmoud Naser, Samir Abou Zeid

Department of Vascular Surgery, Faculty of Medicine, Cairo University, Cairo, Egypt

Correspondence to Mohammed Ali, MD, Department of General Surgery, Faculty of Medicine, Cairo University, Cairo, Egypt.
Tel: 0100589979 - 23667260-1015;
fax : 23644383;
e-mail: surgerycairouniversity@gmail.com

**Received** 4 February 2018
**Accepted** 26 February 2018

**The Egyptian Journal of Surgery**
2018, 37:248–255

**Aim**
The aim was to provide schematic assessments for the popliteal artery variation in order not to misinterpret the vessel of interest as collateral or occluded artery and consequently increase the efficiency of the territorial revascularization.
**Materials and methods**
This is a prospective observational study conducted over a period of 2 years including 452 patients who underwent popliteal and infrapopliteal endovascular angioplasty.
**Results**
A total of 437 (98.2%) patients had the usual pattern of popliteal artery branching, which usually correlates with the current published data. There were two (0.44%) patients with type Ib, two (0.44%) patients with type Ic, one (0.22%) patient with type IIa, one (0.22%) patient with type IIb, six (1.32%) patients with type IIIa pattern, and three (0.66%) patients with type IIIb.
**Conclusion**
With adequate preoperative assessment and applying the steps of our technique, the incidence to misinterpret the variation and consequently missing a chance for territorial revascularization become very low.

**Keywords:**
anatomical variants, infrapopliteal angioplasty, peripheral vascular disease

Egyptian J Surgery 37:248–255

1110-1121

## Introduction

Embryologically, the popliteal artery is formed by union of two arterial systems, the deep popliteal artery derived from the sciatic system and the superficial popliteal artery derived from the femoral system, and during the embryological development, the distal portion of the deep popliteal segment regresses, whereas the superficial popliteal artery fuses with the proximal portion of the deep popliteal segment behind the popliteal muscle eventually forming the truly mature popliteal artery [1].

The anterior and posterior tibial arteries (PTs) are derived from the femoral system. At the lower border of the popliteus muscle, a perforating branch ‘ramus communicans’ arises from the sciatic system and communicates with the femoral artery and passes anteriorly between the tibia and fibula which later on becomes the anterior tibial artery (AT) [2–5]. The PT is formed through the communication between the distal femoral artery and the popliteal artery [2,6].

Persistent primitive arterial segments, abnormal fusions, segmental hypoplasia, or the absence of these arteries give rise to anatomic variability. This special embryological sequence of events is thought to be the etiological background of popliteal artery variations [7].

Below-the-knee arterial disease is a predominant causative lesion in critical limb ischemia (CLI) especially in diabetic and in renal impairment patients, in whom the disease may be extensive.

An added difficulty of below-knee arterial disease is the wide range of anatomic variation which may adversely affect the revascularization procedures [8].

Because of these variations, underdiagnosis of the infrapopliteal variant may pose a barrier for optimizing the interventional outcome and limb salvage. Hence, knowledge of the anatomical variations of the popliteal artery branching is important. The treating physicians should be aware of these anatomical variations and be ready with different tools and equipment to effectively manage these lesions and improve their outcome [9].

The anatomical variations have been described by many authors. Kim *et al*. [10] documented a classification of the anatomical variation of the popliteal artery based on the angiographic appearance.

In this classification, type I indicates a normal level of popliteal arterial branching, including the usual pattern, trifurcation, and the anterior tibioperoneal trunk. Type II indicates a high division of popliteal artery branching including the AT, PT, and peroneal artery (PR) all arising at or above the knee joint. Type III indicates hypoplastic or aplastic branching with an altered distal supply, including a hypoplastic aplastic PT, AT, or both [10].

The incidence of infrapopliteal artery variations showed type III being the most common variant (1.0–7.6%), followed by type II (1.6–7.5%) [11].

Unfortunately, physical examination is not helpful in anticipation and detection of anatomic variations of the popliteal artery branching pattern [12,13].

Noninvasive imaging of the arterial tree using computed tomography angiography (CTA), magnetic resonance angiography, and duplex scanning could be useful for these situations. However, both CTA and magnetic resonance angiography have their own limitations like the need of a contrast injection, excessive calcification of crural arteries, patients with claustrophobia, cardiac pacemaker and metal-implants, and the need for long examination time [14–16].

The presence of severe calcification does not allow adequate visualization of the crural arteries using duplex ultrasonography [17].

The assessment of infrapopliteal vessel variations with chronic total occlusion (CTO) by these noninvasive modalities does not appear to be a realistic method. Accordingly, invasive angiography including digital subtraction angiography remains the gold standard in the evaluation of severely affected infrapopliteal vessels in the setting of CLI [6,18].

## Materials and methods

We performed a prospective observational study to detect the true incidence of variation in popliteal artery branching and to test the efficacy of the proposed protocol of interventional angiography in detecting these variations, as mentioned later on. In this study, over a period of 2 years between August 2015 and September 2017, 452 patients who were candidates for popliteal and infrapopliteal endovascular angioplasty either alone or associated with supragenicular lesions were recruited and analyzed for their branching variations. This protocol has passed the surgical department ethical committee.

Most of the cases required ipsilateral antegrade access; however, contralateral retrograde cross-over access was required in patients with supragenicular lesion according to routine preoperative investigations.

In order not to miss the anatomical variations, we followed a diagnostic angiography protocol which is applied for all patients, and it consists of the following steps.

A 4–5-Fr diagnostic catheter (better with curved tip) is to be placed in the upper popliteal artery. Injection of the contrast material is done, and different views are obtained of the popliteal artery. It is recommended to obtain different views with another injection at the lower popliteal segment and at the foot [9,19].

For better assessment and angiographic evaluation of the arterial branching, ipsilateral oblique view of the upper popliteal segment and contralateral oblique view for the lower popliteal segment are extremely helpful, as they can differentiate between the popliteal genicular branches and the high take-off tibial arteries ‘type II variations’. Tracing the course and direction of these arteries around the knee makes their identification much more easier, as the genicular branches can take a lateral direction away from the tibia and fibula and may end up in a cork screw fashion unlike the high take off, the ‘type II variation’, which will follow their course in the corresponding anatomical leg compartment.

The contralateral view at the lower popliteal segment can provide a better view of the popliteal branches as it widens the space between the origins of the overlapped branches and can be helpful in identification of popliteal variations especially type Ib ‘true trifurcation’ and type Ic ‘anterior tibioperoneal trunk’.

In cases of CTO or ostial lesions of the tibial artery, angiography may not be helpful to allow identification of all variations [9,19].

Angiography of the distal leg segment and the foot should be performed at least in two views, ‘anteroposterior and ipsilateral oblique views’, as the termination of PR is the clue to identify popliteal variations especially type III.

As type III variant being the most predominant, the differentiation between an occluded tibial artery in normal anatomy and hypoplasia/aplasia of tibial artery in type III presents a serious challenge because the distal branching pattern of the dominant vessel could be misinterpreted as a collateral pathway circulation [9,20].

Many angiographic findings may raise the suspicion for anticipating type III arterial pattern. The treating physician should note that the hypertrophied PR may get connected to the dorsalis pedis or paramalleolar PT, and also gradual tapering of the hypoplastic tibial artery, interruption of the aplastic tibial artery, and lack of collateral circulation distally are good diagnostic clues to detect this variation [9,20].

This is a commonly used term describing successful passage of the wire into the target vessel with the aid of road mapping to be achieved using 4-Fr curved tip catheter and careful crossing of the occlusive lesion with either subintimal angioplasty using the 'J loop technique' or transluminal passage with a 0.014–0.018 inch guide wire supported by a 2.5–3 mm over-the-wire balloon made along the imaged tract of the occluded segment this is followed by balloon dilatation [19].

## Results

Applying the aforementioned protocol proved to be successful in the detection of many anatomical variations. Among 452 patients who underwent popliteal and infrapopliteal endovascular angioplasty, we found the usual branching pattern 'type Ia' in 437 (98.2%) patients, whereas type Ib was found in two (0.44%) patients, and two (0.44%) patients with type Ic, type IIa in one (0.22%) patient, type IIb in one (0.22%) patient, type IIIa pattern in six (1.32%) patients, and type IIIb in three (0.66%) patients (Table 1).

Although preoperative CTA was helpful in anticipating the anatomical variations in most of the cases, we found that eight patients were diagnosed as an occlusion by CTA, whereas during the intervention and by applying the aforementioned protocol, we unrevealed the variations.

We successfully identified one patient with type IIa 'high take off of AT', which was misdiagnosed as a genicular branch of the upper popliteal segment by applying an ipsilateral projection. We also successfully identified one patient with type Ib and one patient with type Ic, which was not properly visualized in preoperative CTA owing to an overlapped origin giving a false impression of a usual pattern or collateral branch, by applying a contralateral projection at the lower popliteal segment.

According to our protocol, angiographic visualization of the distal leg and the foot with anteroposterior and ipsilateral oblique views, five patients with type III variations were identified, and they was previously misdiagnosed as occluded anterior and PTs.

## Discussion

Tibial plateau was used as reference landmark for the classification of popliteal artery branching, whereas in anatomical cadaver studies, the popliteus muscle was used as the reference muscle [11,20–22].

In this study, we followed a predetermined special angiography protocol in order not to miss the anatomical branching variations, and subsequently we can effectively calculate the true incidence of

**Table 1 Incidence of popliteal branching pattern**

| Types | Angiographic | | | Cadaveric | This study |
|---|---|---|---|---|---|
| | Kim *et al.* [10] | Kil and Jung [8] | Mavili *et al.* [2] | Ozgur *et al.* [11] | |
| Type I | | | | | |
| a: Usual pattern | 92.2 | 89.2 | 82.4 | 90 | 98.2 |
| b: Trifurcation | 2 | 1.5 | 5.4 | 2.5 | 0.44 |
| c: Anterior tibioperoneal trunk | 1.2 | 0.1 | 0.4 | NA | 0.44 |
| Type II | | | | | |
| a: AT arise at knee | 3.7 | 1.2 | 3.9 | 5 | 0.22 |
| b: PT arise at knee | 0.8 | 0.4 | 1.5 | 2.5 | 0.22 |
| c: PR arise at knee | 0.16 | 0 | NA | NA | NA |
| Type III | | | | | |
| a: Hypoplastic PT | 3.8 | 5.1 | 3.7 | NA | 1.32 |
| b: Hypoplastic AT | 1.6 | 1.7 | 2.2 | NA | 0.66 |
| c: Hypoplastic AT and PT | 0.2 | 0.8 | 0.2 | NA | NA |

AT, anterior tibial artery; PR, peroneal artery; PT, posterior tibial artery.

these anatomical variations and compare our results with the published data, and also we can detect the missed or the misdiagnosed branching variations of the preinterventional CTA. This eventually will improve the clinical outcome of the endovascular intervention for limb salvage.

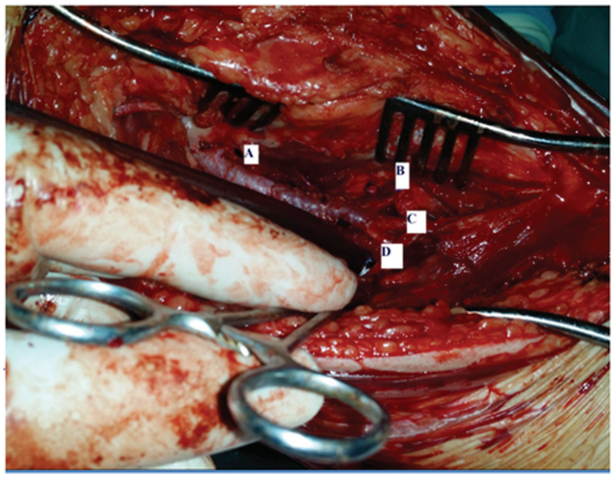
In this study, the usual branching pattern 'type Ia' was found in 98.2% of patients, whereas type Ib was found in 0.44% of patients and type Ic in 0.44% of patients, type IIa in 0.22% of patients, type IIb in 0.22% of patients, type IIIa pattern in 1.32% of patients, and type IIIb 0.66% of patients, which almost correlate with the current published data [2,8,10,23].

The usual popliteal branching pattern ranges between 88 and 96% [4,7,23]. However, Demirtas *et al.* [22] have found in their study many patients with long tibioperoneal trunk, and they consider them as type Id.

Although type IIa and type IIb patterns are relatively uncommon, type IIc pattern is quite rare [3,4,6,7,10,23].

Mavili *et al.* [2] have described type IId, which is a modification of the branching pattern previously described by Kim *et al.* [10], and it involves high division of the popliteal artery with a trifurcation pattern and AT with an initial medial course and a distal lateral course.

**Figure 1**



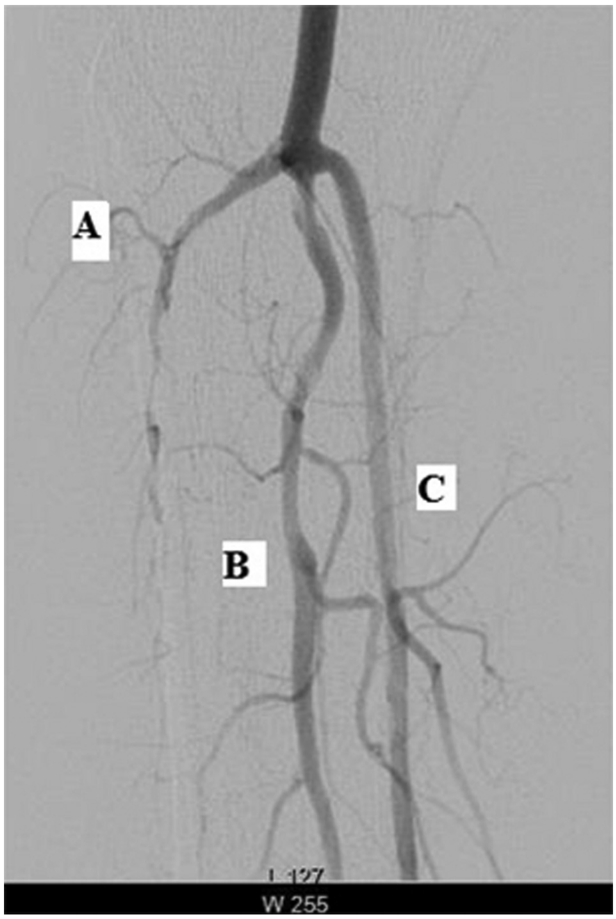

Classification of popliteal artery variations. Adapted from Kawarada *et al.* [9].

Kim *et al.* [10] have encountered type III variation in 5.6% of limbs, but Day and Orme [23] have reported type III in only 1% of patients. This could be attributed to the difficulty in distinguishing between congenital and acquired arterial abnormalities especially in atherosclerotic vessels.

As shown in Figs 1–6, a hypertrophied PR without transitional tapering at the ankle joint that may be partially or entirely occluded is a particularly important clue suggesting the type III variant.

Moreover, as shown in Figs 7–9, the angiographic appearance that the straight nonundulating course of the distal PR reaches the dorsalis pedis or paramalleolar PT with surrounding collaterals may serve as a hallmark for the presence of the type III variant.

**Figure 2**




Operative finding of a trifurcation pattern, type Ib. (a) Popliteal artery, (b) anterior tibial artery, (c) peroneal artery, (d) posterior tibial artery.

**Table 2 Percentage of detected variations by computed tomography angiography**

| Variations | Type Ia | Type Ib | Type Ic | Type IIa | Type IIb | Type IIc | Type IIIa | Type IIIb | Type IIIC |
|---|---|---|---|---|---|---|---|---|---|
| Yanik *et al.* [24] | 83.6 | 0.8 | 4.4 | 5.2 | 2.6 | NA | 3.4 | NA | NA |
| Calisir *et al.* [25] | 87 | 4.2 | 0.2 | 3.6 | 1.4 | NA | 2.7 | 0.9 | NA |

**Figure 3**


Angiographic finding of a trifurcation pattern, type Ib. (a) Anterior tibial artery, (b) peroneal artery, (c) posterior tibial artery.

**Figure 4**


Angiographic finding of anterior tibioperoneal trunk pattern, type Ic. (a) anterior tibial artery, (b) peroneal artery, (c) posterior tibial artery.

**Figure 5**

Angiographic finding of high-origin anterior tibial artery rising above the knee, type IIa.

**Figure 6**

Computed tomography angiography showing high-origin posterior tibial artery rising above the knee, type IIb.

**Figure 7**

Angiographic finding of hypoplastic posterior tibial artery, type IIIa.

**Figure 8**

Angiographic finding of a hypoplastic anterior tibial artery, type IIIb. From Kawarada *et al*. [9].

Demirtas *et al*. [22] have found PR hypoplasia that was occluded shortly after its origin and not considered this to be an artifact of stenosis. However, they have assigned this observation as type IIId [22].

Using 64-section MDCT angiography as a preoperative assessment, Yanık *et al*. [24] did not observe type IIb, IIc, or IIIc patterns, whereas Calisir *et al*. [25] reported that they did not found any type IIc or IIIc patterns (Table 2).

In this study, we found that eight patients were misdiagnosed as an occlusion by preinterventional CTA, but by applying the aforementioned protocol, we successfully identified the branching variations. There was one patient with type IIa 'high take off of AT', which was misdiagnosed as a genicular branch of the upper popliteal segment, but the variation was identified by obtaining an ipsilateral oblique projection. Moreover, there was one patient with type Ib and one patient with type Ic, which was not properly visualized in preoperative CTA owing to an overlapped origins, giving rise to a false impression of a usual pattern or collateral branch; however, by obtaining a contralateral oblique projection at the lower popliteal segment, the variation was clearly identified. There were five patients previously misdiagnosed as occluded AT and PT, but by obtaining an anteroposterior and ipsilateral oblique views at the distal leg and foot, we successfully detect type III variation.

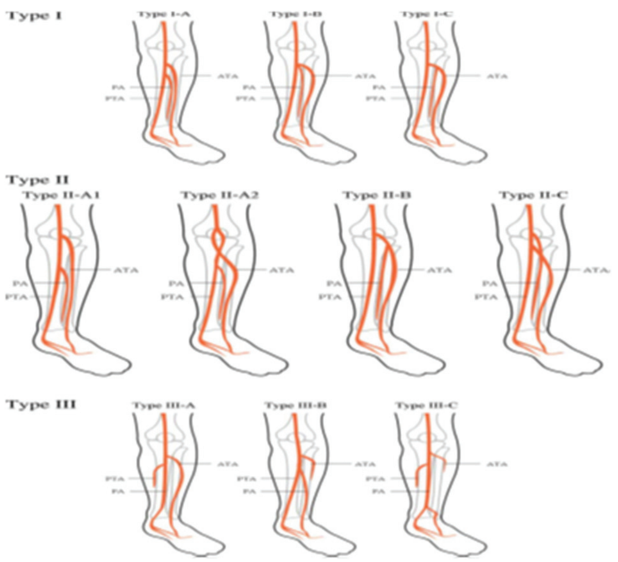
These differences between the preoperative CTA and the diagnostic angiography could be explained by the presence of an ostial lesion or the CTO of the tibial arteries, which add an extra difficulty to the real diagnosis. Moreover, it is worth mentioning that CTA may not be obtained in the ideal views for proper evaluation of the branching pattern.

According to Kil and Jung [8], when infrapopliteal variation is noted in one limb, there is a 28–50% probability the other side will likely be a variant pattern. This finding would be of importance in the setting of bilateral CLI as shown in Fig. 10 [7,8,11,26].

**Figure 9**

Angiographic finding of hypoplastic both anterior and posterior tibial arteries, type IIIC. From Kawarada *et al*. [9].

**Figure 10**




Computed tomography angiography showing bilateral popliteal anomaly; on the right side, there is high-origin posterior tibial artery, type IIb, whereas on the left side, there is anterior tibioperoneal trunk, type Ic.

If a patient shows a type III pattern, it might be necessary to change the extremity angioplasty technique in balloon catheter angioplasty. Moreover, adequate planning is required when considering fibular free flap in patients showing type III pattern [18,21,22,27].

Patients with a high-origin AT located behind the popliteus muscle are more vulnerable to injuries particularly during orthopedic procedures [5,6].

## Conclusion

With adequate preoperative assessment and applying the steps of our technique, the incidence to misinterpret the variation and consequently missing a chance for territorial revascularization becomes very low.

Keeping the infrapopliteal variant vessels in mind is the key to a successful and optimal tibial intervention. Similarly, increased experience in performing femoropopliteal intervention will offer much experience with infrapopliteal variant.

### Financial support and sponsorship

Nil.

### Conflicts of interest

There are no conflicts of interest.

## References

1 Red-Horse K, Crawford Y, Shojaei F, Ferrara N. Endothelium microinviroment interactions in the developing embryo and in the adult. Dev Cell 2007; 12:181–194.

2 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.

3 Jung W, Oh CS, Won HS, Chung IH. Unilateral arterial peroneal magna associated with bilateral replaced dorsalis pedis arteries. Surg Radiol Anat 2008; 30:449–452.

4 Szpinda M. Digital-image analysis of the angiographic patterns of the popliteal artery in patients with aorto-iliac occlusive disease (Leriche syndrome). Ann Anat 2006; 188:377–382.

5 Klecker RJ, Winalski CS, Aliabadi P, Minas T. The aberrant anterior tibial artery: magnetic resonance appearance, prevalence, and surgical implications. Am J Sports Med 2008; 36:720–727.

6 Tindall AJ, Shetty AA, James KD, Middleton A, Fernando KW. Prevalence and surgical significance of a high-origin anterior tibial artery. J Orthop Surg 2006; 14:13–16.

7 Mauro MA, Jaques PF, Moore M. The popliteal artery and its branches: embryologic basis of normal and variant anatomy. Am J Roentgenol 1988; 150:435–437.

8 Kil SW, Jung GS. Anatomical variations of the popliteal artery and its tibial branches: analysis in 1242 extremities. Cardiovasc Intervent Radiol 2009; 32:233–240.

9 Kawarada O, Yokoi Y, Honda Y, Fitzgerald PJ. Awareness of anatomical variations for infrapopliteral intervention. Catheter Cardiovas Interv 2010; 76:888–894.

10 Kim D, Orron DE, Skillman JJ. Surgical significance of popliteal arterial variants. A unified angiographic classification. Ann Surg 1989; 210:776–781.

11 Ozgur Z, Ucerler H, Aktan Ikiz ZA. Branching patterns of the popliteal artery and its clinical importance. Surg Radiol Anat 2009; 31:357–362.

12 Khan NA, Rahim SA, Anand SS, Simel DL, Panju A. Does the clinical examination predict lower extremity peripheral arterial disease? JAMA 2006; 295:536–546.

13 Piral T, Germain M, Princ G. Absence of the posterior tibial artery: Implications for free transplants of the fibula. Surg Radiol Anat 1996; 18:155–158.

14 Roditi GH, Harold G. Magnetic resonance angiography and computed tomography angiography for peripheral arterial disease. Imaging 2004; 16:205–229.

15 Met R, Bipat S, Legemate DA, Reekers JA, Koelemay MJ. Diagnostic performance of computed tomography angiography in peripheral arterial disease: a systematic review and metaanalysis. JAMA 2009; 301:415–424.

16 Leiner T, Kessels AG, Nelemans PJ, Vasbinder GB, de Haan MW, Kitslaar MW, *et al.* Peripheral arterial disease: comparison of color duplex US and contrast-enhanced MR angiography for diagnosis. Radiology 2005; 235:699–708.

17 Avenarius JK, Breek JC, Lampmann LE, van Berge Henegouwen DP, Hamming JF. The additional value of angiography after color-coded duplex on decision making in patients with critical limb ischemia. A prospective study. Eur J Vasc Endovasc Surg 2002; 23:393–397.

18 Chow LC, Napoli A, Klein MB, Chang J, Rubin GD. Vascular mapping of the leg with multi-detector row CT angiography prior to free-flap transplantation. Radiology 2005; 237:353–360.

19 Kawarada O, Yokoi Y. Dorsalis pedis artery stenting for limb salvage. Catheter Cardiovasc Interv 2008; 71:976–982.

20 Lippert H, Pabst R. Arterial variations in man: classification and frequency. Munchen: J.F. Bergmann Verlag; 1985; 154:98.

21 Singla R, Kaushal S, Chabbra U. Popliteal artery branching pat-tern: a cadaveric study. Eur J Anat 2012; 16:157–162.

22 Demirtas H, D?girmenci B, Çelik AO, Umul A, Kara M, Aktas AR, Parpar T. Anatomic variations of popliteal artery: Evaluation with 128-section CT-angiography in 1261 lower limbs. Diagn Interv Imaging 2016; 97:635–642.

23 Day CP, Orme R. Popliteal artery branching patterns – an angiographic study. Clin Radiol 2006; 61:696–699.

24 Yanik B, Bulbul E, Demirpolat G. Variations of the poplitealartery branching with multidetector CT angiography. Surg Radiol Anat 2015; 37: 223–230.

25 Calisir C, Simsek S, Tepe M. Variations in the popliteal arterybranching in 342 patients studied with peripheral CT angiog-raphy using 64-MDCT. Jpn J Radiol 2015; 33:13–20.

26 Bardsley JL, Staple TW. Variations in branching of the popliteal artery. Radiology 1970; 94:581–587.

27 Pernès JM, Auguste M, Borie H, Kovaesky S, Bouchareb A, Despujole C, Coppé G. Infrapopliteal arterial recanalization: a true advance for limb salvage in diabetics. Diagn Interv Imaging 2015; 96:423–434.