

The Association between Popliteal Artery Variation and Atherosclerosis Risks and its Benefits in Preoperative CTA for Surgical Planning in Fibular Free Flap Harvest

Karnkawin Patharateeranart

Mahidol University

Natthapong Kongkunnawat

Mahidol University

Chanya Sinmaroeng

Mahidol University

Nutcha Yodrabum (✉ n.yodrabum@gmail.com)

Mahidol University

Research Article

Keywords: Popliteal vasculature variation, CTA, atherosclerosis risk factors, fibular free flap

Posted Date: February 3rd, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1298615/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Introduction: Popliteal artery has several branching variations, understanding its vasculature is substantial for fibular free flap (FFF) harvest. The atherosclerosis affects popliteal vasculature and leads to some acquired variants, which preclude FFF harvest. This study determined the variation of popliteal artery by computed tomography angiography (CTA) and association between atherosclerosis risks and stenosis of the popliteal vasculature to determine the benefit of preoperative CTA for surgical planning in FFF harvest.

Materials and methods: The data and CTA images of legs from 443 patients, who underwent CTA of legs between January 2016 and December 2020, were retrieved and retrospectively reviewed. Popliteal artery branching patterns were classified according to the systems proposed by Kim, *et al.* and Abou-Foul and Borumandi. Then, we analyzed the correlation between atherosclerosis risks and degree of vessel stenosis.

Results: The most common patterns were type I-A (90.5%), III-A (4.3%), and III-B (1.8%), and the prevalence of acquired variant was 4.3%. The mean diameter of anterior tibial artery, posterior tibial artery, and peroneal artery was 4.1 ± 1.1 mm, 3.5 ± 1.0 mm, and 3.7 ± 1.0 mm, respectively. Popliteal artery branches were susceptible to different risk factors. Stenosis of the anterior tibial artery was influenced by peripheral arterial disease (PAD), hypertension (HT), and diabetes mellitus (DM); stenosis of the posterior tibial artery was influenced by PAD, chronic kidney disease (CKD), and DM; and, stenosis of peroneal artery was influenced by CKD and coronary artery disease.

Conclusion: Although CTA is not a routine preoperative investigation in this setting, the results of this study suggest its benefit in patients with risk factors for atherosclerosis to determine the suitable limb for FFF harvest with consideration of cost-effectiveness and prevalence of variations in population.

Introduction

The reconstruction of defects requiring vascularized bone using a fibular free flap (FFF) was established by Taylor and colleagues¹⁻³. This vascularized bone flap is supplied by the peroneal artery, which arises from the popliteal artery, and it is suitable for reconstruction of defects that require multiple osteotomy sites^{2,4,5}.

The anterior tibial artery branches off first followed by the tibioperoneal trunk, which later divides into the posterior tibial artery and peroneal artery. The anterior tibial artery, posterior tibial artery, and peroneal artery are the main suppliers of blood to the distal lower limb^{5,6}. However, these arteries vary in their branching patterns due to the abnormal development of lower limb vasculature during the embryonic period⁷.

The first system to classify patterns of popliteal artery branching was reported in 1985 by Lippert and colleagues⁸. Kim, *et al.* then proposed a different classification system in 1989, which was modified from

Lippert's study⁶. The classification system that is now most widely used is one that combines the system from Kim, *et al.* with the system proposed by Abou-Foul and Borumandi in 2015.^{5,6,9-11} This combination system classifies popliteal artery variants into 4 main types with 12 subtypes.

In general, the anterior and posterior tibial arteries supply majority of pedal circulation whereas the peroneal artery contributes less¹². However, some popliteal artery variations have the peroneal artery as the main supplier of pedal circulation (type III variant) instead of the anterior or posterior tibial artery. This variant, in which the peroneal artery becomes the sole blood supplier of pedal perfusion, is called 'peronea arteria magna' or PAM. The variants that have the peroneal artery as a supplier of pedal perfusion are susceptible to compromise of blood supply to the distal limb after FFF harvest^{6,13,14}. Furthermore, the popliteal artery variants, which have a hypoplastic or aplastic peroneal artery, impede vascularized FFF harvest^{3,13-15}. Therefore, enhanced understanding of these variants and their prevalence is important for preoperative planning and decision-making in a FFF harvest to reduce the serious adverse events.

Ongsiriporn and colleagues reported the significant difference of type III and IV variants prevalence between modes of study (cadaveric versus angiographic study). This difference may be a consequence of atherosclerosis, which obliterates the vascular lumen, is less likely to affect the peroneal artery, and results in some acquired variants⁶. The underlying cause of this manifestation is that angiographic study is an intraluminal study that can be easily confounded by intraluminal change caused by atherosclerotic plaque. Alternatively, the results of angiographic study may serve as a functional surrogate of blood supply through the vessels of the lower limbs since the flow of contrast media is demonstrated within the non-obiterated vessel (Figure 1).

The use of preoperative computed tomography angiography (CTA) of the leg (CTA leg) has not yet been established as part of the preoperative work-up before FFF harvest, except for evaluation of tumor or work-up for metastasis. However, preoperative CTA leg may be beneficial for determining the most suitable leg for FFF harvest. Some plastic surgeons have a routine policy of performing preoperative CTA leg, and there are other who do not. The factors that limit the use of CTA include patients with renal insufficiency who are at risk for contrast-induced nephropathy, excessive contrast media volume due to simultaneous preoperative tumor imaging with donor site evaluation, and cost of CTA performing^{12,16}.

The aim of this study was to determine the prevalence of popliteal artery variation as visualized by CTA, and to investigate for association between atherosclerosis risks and stenosis of the popliteal artery to determine the benefit of preoperative CTA leg for surgical planning FFF harvest.

Methods

Study population

This retrospective study retrieved data from patients who underwent CTA leg between January 2016 and December 2020. The demographic data, body mass index, smoking status, comorbidities, atherosclerosis risks, and CTA leg images were collected. Diabetes mellitus (DM), hypertension (HT), chronic kidney disease (CKD), atrial fibrillation (AF), coronary artery disease (CAD), and cerebrovascular disease (CVD) patients were defined as those with a prior diagnosis of these conditions before data retrieval. Peripheral artery disease (PAD) was defined as those with a prior diagnosis of PAD at locations other than the lower limbs. The protocol for this study was approved by the Siriraj Institutional Review Board (SIRB) (approval no. 754/2563). Written informed consent to participate was not obtained from study patients due to the retrospective nature of this study. All methods were performed in accordance with the relevant guidelines and regulations including the Declaration of Helsinki.

Imaging technique

CT scans were performed using one of three multidetector CT scanners (1. Somatom Definition dual source CT; Siemens, Forchheim, Germany or 2. Discovery CT 750HD; GE Healthcare, Milwaukee, USA or 3. Revolution CT, GE Healthcare, Milwaukee, USA). The CTA protocol including the abdominal aorta and the arteries of the lower extremities (from hepatic dome to feet), and consisted of contrast-enhanced CTA phase, and delayed phase (in some patients) using 120 kVp tube voltage. The CTA phase was used by bolus-tracking technique with a threshold of 150 Hounsfield units (HUs) at abdominal aorta. One hundred milliliters (ml) of iodinated contrast was used at a flow rate of 4-5 ml/second followed by 20 ml of normal saline solution injected by power injector. Image reconstruction was performed using 1.25 mm slice thickness. Delayed phase was performed immediately after CTA phase in patients who had inadequate enhancement of the distal arteries.

CTA parameters

The radiographic parameters from CTA leg included the type(s) of popliteal artery branching; acquisition of variations due to atherosclerosis change; diameter of anterior tibial artery, posterior tibial artery, and peroneal artery; distance from the tibial plateau to the branching point of the anterior tibial artery; and the distance of the tibioperoneal trunk. To assess the severity of atherosclerosis, the radiologist and well-trained physicians used the grading system proposed by Rutherford, *et al.*, which defines less than 20% of the greatest stenosis as grade 0; 20–49% of the greatest stenosis as grade 1; 50–99% of the greatest stenosis as grade 2; and, total vessel occlusion as grade 3^{17, 18}.

Classification of popliteal artery branching

Popliteal artery branching patterns were classified according to the combination system that comprises the systems from Kim, *et al.* and Abou-Foul and Borumandi, which categorizes branching patterns into 4 main types and 12 subtypes^{5, 6}. Acquired variants were defined radiologically by visualization of contrast filling in vessels as one pattern, whereas the original framework (outlining wall of vessel) was another pattern (e.g., contrast filling manifest the type III-A pattern, but the original (congenital) vascular pattern was type I-A).

The surgical significance of type III-C, which has a dominant peroneal artery with an obliterated anterior and posterior tibial artery, is associated with the risk of distal limb ischemia after FFF harvest since the peroneal artery solely supplies pedal circulation. Type IV-A (hypoplastic peroneal artery) and type IV-B (aplastic peroneal artery) preclude FFF harvest due to unusable vascularized fibular flap. In this study, the stenosis degree that equal or greater than 50% of vascular lumen was considered as significant stenosis. The association between known atherosclerosis risks and significant stenosis degree of the popliteal artery and its branches was analyzed.

Statistical analysis

SPSS Statistics version 26.0 (SPSS, Inc., Chicago, IL, USA) was used to perform all statistical analyses. Categorical data are reported as number and percentage. Continuous data are reported as mean \pm standard deviation (SD) for normally distributed data, and as median and interquartile range (IQR) for non-normally distributed data. Generalized estimating equation (GEE) was used to estimate the correlation between atherosclerosis risk factors and stenosis of popliteal vessels. The results of univariate GEE are shown as crude odds ratio (OR) with 95% confidence interval (CI), and the findings of multivariate GEE are given as adjusted odds ratio (aOR) and 95%CI. A *p*-value equal to or less than 0.05 was considered statistically significant for all tests.

Results

CTA leg images were obtained from 443 patients (male 58.5%, female 41.5%). The median age was 63 years (IQR: 50-74). The mean body mass index (BMI) of patients was 23.6 ± 4.6 kg/m² (range: 14.2-41.3). Most patients were non-smokers (61.9%). The comorbidities associated with atherosclerosis are shown in Table 1. HT, DM, and CKD was found in 65.8%, 45.0%, and 29.2% of patients, respectively.

According to Kim, *et al.* and Abou-Foul and Borumandi classification, the most common pattern observed in this study was type I-A pattern (90.5%), followed by type III-A (4.3%) and type III-B (1.8%). A list of the branching patterns found in this study is shown in Table 2. The prevalence of acquired variant was 4.3%.

The mean distance from the branching point of the anterior tibial artery to the tibial plateau was 48.9 ± 8.3 mm, and the mean length of the tibioperoneal trunk (the common trunk of the posterior tibial artery and the peroneal artery) was 26.3 ± 11.3 mm. The mean diameter of the anterior tibial artery, posterior tibial artery, and peroneal artery was 4.1 ± 1.1 mm, 3.5 ± 1.0 mm, and 3.7 ± 1.0 mm, respectively.

Stenosis grading of popliteal artery and its branches is shown in Figure 2. Regarding grading of stenosis of popliteal artery, grade 1 stenosis was most often found (36.3%), followed by grade 2 stenosis (29.4%) and grade 0 stenosis (20.8%). The anterior tibial artery was totally occluded in 30.1%, followed by grade 1 stenosis (26.8%) and grade 2 stenosis (25.6%). For the posterior tibial artery, grade 1 stenosis was most often found (27.9%), followed by grade 3 stenosis (26.0%) and grade 2 stenosis (25.9%). The peroneal artery had grade 1 stenosis in 37.4%, grade 0 stenosis, in 24.7%, and grade 2 stenosis in 24.0%. Interestingly, the peroneal artery had a lower percentage of grade 3 (totally occluded) vessels when

compared to the anterior tibial artery and the posterior tibial artery (14.0% vs. 30.1% and 26.0%, respectively).

The known risk factors for atherosclerosis were analyzed for association with significant stenosis of the popliteal artery and its collaterals. The factors identified as being significantly associated with significant stenosis of the popliteal artery in univariate analysis were DM, HT, CKD, CAD, CVD, and PAD. When those factors were entered into multivariate analysis, the results showed smoking (aOR: 2.51, 95%CI: 1.61-3.90; $p<0.01$), DM (aOR: 1.62, 95%CI: 1.07-2.43; $p<0.05$), HT (aOR: 3.05, 95%CI: 1.73-5.36; $p<0.01$), CKD (aOR: 1.60, 95%CI: 1.01-2.53; $p<0.05$), and PAD (aOR: 2.17, 95%CI: 1.26-3.75, $p<0.01$) to be independently associated with significant stenosis of the popliteal vessel (Figure 3A).

The factors identified as being significantly associated with significant stenosis of the anterior tibial artery in univariate analysis were DM, HT, CKD, CAD, CVD, and PAD. Multivariate analysis that included all of those factors revealed DM (aOR: 2.03, 95%CI: 1.24-3.32; $p<0.01$), HT (aOR: 1.81, 95%CI: 1.01-3.23; $p<0.05$), and PAD (aOR: 2.28, 95%CI: 1.25-4.15; $p<0.01$) to be independently associated with significant stenosis of the anterior tibial artery (Figure 3B).

The factors that were found to be significantly associated with significant stenosis of the posterior tibial artery in univariate analysis were DM, HT, CKD, CAD, and PAD. Multivariate analysis for this artery showed DM (aOR: 1.97, 95%CI: 1.25-3.12; $p<0.05$), CKD (aOR: 2.05, 95%CI: 1.29-3.28; $p<0.05$), and PAD (aOR: 1.82, 95%CI: 1.05-3.14; $p<0.05$) to be independently associated with posterior tibial artery stenosis (Figure 3C).

For the peroneal artery, which is the main supplier of blood to the fibula, the factors found to be significantly associated with significant stenosis in univariate analysis were DM, HT, CKD, and AF. Subsequent multivariate analysis revealed CAD (aOR: 0.56, 95%CI: 0.34-0.92; $p<0.05$) and CKD (aOR: 2.15, 95%CI: 1.37-3.38; $p<0.01$) to be independently associated with significant stenosis of the peroneal artery (Figure 3D).

The acquired variants found in this study were type III-A (51.5%), type III-B (27.3%), type IV-B (12.1%), and type IV-A (9.1%). All of the aforementioned acquired variants had type I-A as congenital (native) pattern. All of these acquired variants precluded selection of the fibula due to impairment of distal limb perfusion (type III pattern) or unusable flap (type IV pattern) after FFF harvest (Figure 4).

Discussion

The most common popliteal artery branching pattern found in this study was I-A pattern (90.5%), which is consistent with the findings of previous studies^{5,6,10,11,19}. The type III variants, which had aplasia or hypoplasia of the anterior tibial artery, posterior tibial artery, or both, compromise distal lower limb perfusion after FFF harvest since there is only a single vessel left in type III-A and III-B, and a lack of blood supply to the distal lower limb in type III-C. The prevalence of type III pattern in the present study was 6.1%. The reported prevalence of type III pattern in previous studies ranged from 1-7.6%²⁰⁻²². The

percentage of type III variants in the present study is higher than that reported from cadaveric study¹⁹ due to the sensitivity of angiographic study for detecting intraluminal changes.

Preoperative planning of FFF harvest is necessary in patients with type III pattern because the peroneal artery, which supplies blood to the foot, might be damaged potentially resulting in impairment of distal limb perfusion. Furthermore, the vascular procedures, such as endovascular or angioplasty technique of the infrapopliteal area should be considered in this variant type^{19, 20, 23}.

In our study, the mean distance from the branching point of the anterior tibial artery to the tibial plateau was 48.9 ± 8.3 mm, and the mean length of the tibioperoneal trunk was 26.3 ± 11.3 mm. The diameter of the anterior tibial artery, posterior tibial artery, and peroneal artery was 4.1 ± 1.1 mm, 3.5 ± 1.0 mm, and 3.7 ± 1.0 mm, respectively. The tibioperoneal trunk length has an important role in the surgical planning and selection of adequate endovascular treatment, especially in infrapopliteal bypass surgery^{24, 25}. The mean length of the tibioperoneal trunk in this study was shorter than previously published lengths (30.3 ± 16.2 mm and 2-5 cm)^{10, 26}. This difference between and among studies is likely due to ethnic differences among the study populations.

Knowledge regarding popliteal artery branching pattern is important in several clinical fields and procedures, such as endovascular procedure; vascular findings during radiological examinations; orthopedic interventions, such as total knee arthroplasty and arthroscopy; and FFF harvest^{25, 27}.

The prevalence of acquired variants in the present study was 4.3%. Acquired variants were found in type III-A, type III-B, type IV-A, and type IV-B – all of which have surgical significance since they are all associated with increased risk of impairment of distal limb perfusion or unusable flap after FFF harvest. All of the aforementioned acquired variants had type I-A as the original framework, which supports the hypothesis of Ongsiriorn and colleagues that acquired variants develop from atherosclerosis¹⁹.

In addition to the coronary arteries, atherosclerosis diffusely affects several vessels, including the cerebrovascular arterial system and peripheral arterial system. Several studies reported a lower extremity atherosclerotic occlusive disease, which affects the viability of FFF after harvest since significant occlusion of the peroneal artery precludes FFF harvest. Moreover, occlusion of either the anterior tibial artery or posterior tibial artery is associated with increased risk of distal limb ischemia after FFF harvest^{6, 13, 14, 28, 29}.

Concerning vessel stenosis, each of the different types of vessels had different degrees of stenosis, and each of the different types of vessels was influenced by a different set of factors. Interestingly, the peroneal artery had relatively low percentage of grade 3 stenosis (total occlusion) compared to the anterior tibial artery and posterior tibial artery. This is consistent with a previous study that reported the sparing effect of the peroneal artery from atherosclerosis⁶. This difference may be explained by differences in blood flow pattern, shear stress, and local factors affecting each vessel^{28, 30}. We hypothesized that the difference in the degree of stenosis among vessels can be explained by the fact

that the peroneal artery branches off from the tibioperoneal trunk, which is also the common trunk of the posterior tibial artery, and supplies a smaller group of muscles than the posterior tibial artery. The lower the number of muscles to supply blood to, the relatively lower volume of blood that flows through the peroneal artery, which results in less endothelial injury.

The known risk factors for atherosclerosis were analyzed for their association with significant stenosis of popliteal artery and its branches. Interestingly, each of the evaluated vessels were influenced by a different set of factors. Popliteal artery stenosis was independently associated with smoking, DM, HT, CKD, and PAD. Significant stenosis of the anterior tibial artery was independently associated with DM, HT, and PAD. Significant stenosis of the posterior tibial artery was found to be independently associated with DM, CKD, and PAD. Finally, significant stenosis of the peroneal artery was independently associated with CKD and CAD. Interestingly, CAD had an adjusted odds ratio 0.56, which might suggest that the peroneal artery is spared from atherosclerosis.

The aforementioned risk factors lead to a significantly higher probability of having significant stenosis of the popliteal artery and/or its branches. Therefore, the preoperative CTA leg might be considered in patients with these risk factors in case of mandatory preoperative CTA policy is not available at first place.

Conclusion

The most common branching pattern was type I-A, followed by type III-A and III-B. The acquired variants as visualized by CTA were mainly type III and IV, which substantially influences surgical planning and decision-making in FFF harvest. Furthermore, the difference in degree of stenosis and susceptibility to atherosclerosis risks among vessels is found. Therefore, the patients with atherosclerosis risks should undergo preoperative CTA leg, which is not a routine investigation in this setting, the results of this study suggest its benefit in patients with risk factors for atherosclerosis to determine the suitable limb for FFF harvest.

Declarations

Acknowledgements

The authors gratefully acknowledge Parkpoom Piyaman from the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University for data analysis. Jirapat Tianrunroj and Jirapat Prathyajuta from the Division of Plastic Surgery, Department of Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University for their assistance with data collection.

Conflict of interest declaration

All authors hereby declare no personal or professional conflicts of interest relating to any aspect of this study.

Funding disclosure

This was an unfunded study.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

References

1. Taylor GI, Miller GD, Ham FJ. The free vascularized bone graft. A clinical extension of microvascular techniques. *Plastic and Reconstructive Surgery* 1975;55:533–44.
2. Taylor GI, Wilson KR, Rees MD, Corlett RJ, Cole WG. The anterior tibial vessels and their role in epiphyseal and diaphyseal transfer of the fibula: experimental study and clinical applications. *British Journal of Plastic Surgery* 1988;41:451–69.
3. Young DM, Trabulsky PP, Anthony JP. The need for preoperative leg angiography in fibula free flaps. *Journal of Reconstructive Microsurgery* 1994;10:283–7.
4. Hidalgo DA. Fibula free flap: a new method of mandible reconstruction. *Plastic and Reconstructive Surgery* 1989;84:71–9.
5. Abou-Foul AK, Borumandi F. Anatomical variants of lower limb vasculature and implications for free fibula flap: Systematic review and critical analysis. *Microsurgery* 2015;36:165–72.
6. Kim D, Orron DE, Skillman JJ. Surgical significance of popliteal arterial variants. A unified angiographic classification. *Annals of Surgery* 1989;210:776–81.
7. Mauro MA, Jaques PF, Moore M. The popliteal artery and its branches: embryologic basis of normal and variant anatomy. *AJR Am J Roentgenol* 1988;150:435–7.
8. Lippert H, Pabst R. Arterial variations in man: classification and frequency. 1 ed: J.F. Bergmann-Verlag München; 1985.
9. Muhammad A, Muhammad R. Variations in popliteal artery branching patterns. *International Journal of Integrative Biology* 2012;13.
10. Ozgur Z, Ucerler H, Aktan Ikiz ZA. Branching patterns of the popliteal artery and its clinical importance. *Surgical and Radiologic Anatomy* 2009;31:357–62.
11. Demirtaş H, Değirmenci B, Çelik AO, Umul A, Karaa M, Aktaş AR, et al. Anatomic variations of popliteal artery: Evaluation with 128-section CT-angiography in 1261 lower limbs. *Diagnostic and Interventional Imaging* 2016;97:635–42.
12. Blackwell KE. Donor site evaluation for fibula free flap transfer. *Am J Otolaryngol* 1998;19:89–95.

13. 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;237:353–60.
14. Hölzle F, Ristow O, Rau A, Mücke T, Loeffelbein DJ, Mitchell DA, et al. Evaluation of the vessels of the lower leg before microsurgical fibular transfer. Part I: anatomical variations in the arteries of the lower leg. *British Journal of Oral and Maxillofacial Surgery* 2011;49:270–4.
15. Lutz BS, Wei F-C, Ng S-H, Chen I-H, Chen SHT. Routine donor leg angiography before vascularized free fibula transplantation is not necessary: A prospective study in 120 clinical cases. *Plastic and Reconstructive Surgery* 1999;103:121–7.
16. Rosson GD, Singh NK. Devascularizing complications of free fibula harvest: peronea arteria magna. *J Reconstr Microsurg* 2005;21:533–8.
17. Burusapat C, Nanasilp T, Kunaphensaeng P, Ruamthanthong A. Effect of Atherosclerosis on the Lateral Circumflex Femoral Artery and Its Descending Branch: Comparative Study to Nonatherosclerotic Risk. *Plastic and Reconstructive Surgery – Global Open* 2016;4:e856.
18. Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S, et al. Recommended standards for reports dealing with lower extremity ischemia: revised version. *J Vasc Surg* 1997;26:517–38.
19. Ongsiriporn M, Jongpradubgiat P, Pisittrakoonporn S, Kongkunnawat N, Panyaatisin K, Yodrabum N. The congenital popliteal vasculature patterns in fibular free flap reconstruction by means of surgical anatomy in cadavers. *Sci Rep* 2021;11:19584.
20. Day CP, Orme R. Popliteal artery branching patterns – an angiographic study. *Clin Radiol* 2006;61:696–9.
21. Kil SW, Jung GS. Anatomical variations of the popliteal artery and its tibial branches: analysis in 1242 extremities. *Cardiovasc Intervent Radiol* 2009;32:233–40.
22. Ozgur Z, Ucerler H, Aktan Ikiz ZA. Branching patterns of the popliteal artery and its clinical importance. *Surg Radiol Anat* 2009;31:357–62.
23. Pernès JM, Auguste M, Borie H, Kovarsky S, Bouchareb A, Despujole C, et al. Infrapopliteal arterial recanalization: A true advance for limb salvage in diabetics. *Diagn Interv Imaging* 2015;96:423–34.
24. Celtikci P, Ergun O, Durmaz HA, Conkbayir I, Hekimoglu B. Evaluation of popliteal artery branching patterns and a new subclassification of the 'usual' branching pattern. *Surg Radiol Anat* 2017;39:1005–15.
25. Oner S, Oner Z. Popliteal Artery Branching Variations: A Study on Multidetector CT Angiography. *Sci Rep* 2020;10:8147.
26. Sanders RJ, Alston GK. Variations and anomalies of the popliteal and tibial arteries. *Am J Surg* 1986;152:531–4.
27. Atanasova M, Georgiev GP, Jelev L. Intriguing variations of the tibial arteries and their clinical implications. *IJAV* 2011;4:45–7.
28. Dieter RS, Chu WW, Pacanowski JP, Jr., McBride PE, Tanke TE. The significance of lower extremity peripheral arterial disease. *Clin Cardiol* 2002;25:3–10.

29. Santos VP, Caffaro RA, Pozzan G, Saieg MA, Castelli Júnior V. Comparative histological study of atherosclerotic lesions and microvascular changes in amputated lower limbs of diabetic and non-diabetic patients. *Arq Bras Endocrinol Metabol* 2008;52:1115–23.
30. Worthley SG, Helft G, Zaman AG, Fuster V, Badimon JJ. Atherosclerosis and the vulnerable plaque—pathogenesis: Part I. *Aust N Z J Med* 2000;30:600–7.

Tables

Table 1. Demographic data of patients		
Gender	n (%)	
Female	184 (41.5%)	
Male	259 (58.5%)	
	Median (IQR)	Range
Age (years)	63 (50-74)	18-104
	Mean±SD	Range
Body mass index (kg/m²)	23.6±4.6	14.2-41.3
Smoking status	n (%)	
Non-smoker	274 (61.9%)	
Smoker	169 (38.1%)	
Comorbidity		
Diabetes mellitus	198 (45.0%)	
Hypertension	290 (65.8%)	
Chronic kidney disease	128 (29.2%)	
Atrial fibrillation	39 (8.9%)	
Coronary artery disease	96 (21.9%)	
Cerebrovascular disease	49 (11.2%)	
Peripheral artery disease	83 (18.9%)	

Table 2. Variation in popliteal artery branching and length/diameter of its collateral vasculature			
Branching type ^a	Left leg	Right leg	Total
	n (%)	n (%)	n (%)
I-A	390 (92.2%)	380 (88.8%)	771 (90.5%)
I-B	6 (1.4%)	7 (1.6%)	13 (1.5%)
I-C	1 (0.2%)	0 (0.0%)	1 (0.1%)
II-A1	1 (0.2%)	1 (0.2%)	2 (0.2%)
II-B	1 (0.2%)	4 (0.9%)	5 (0.6%)
III-A	15 (3.5%)	22 (5.1%)	37 (4.3%)
III-B	5 (1.2%)	10 (2.3%)	15 (1.8%)
IV-A	1 (0.2%)	2 (0.5%)	3 (0.4%)
IV-B	3 (0.7%)	2 (0.5%)	5 (0.6%)
Parameter	Left leg	Right leg	Total
	(mean±SD)	(mean±SD)	(mean±SD)
AT to TbP distance (mm)	48.5±9.0	49.3±7.6	48.9±8.3
TPT length (mm)	25.2±10.9	27.5±11.6	26.3±11.3
AT diameter (mm)	4.1±1.0	4.1±1.2	4.1±1.1
PT diameter (mm)	3.5±1.0	3.5±1.0	3.5±1.0
PR diameter (mm)	3.7±1.0	3.7±1.0	3.7±1.0
^a Only the branching types found in this study are listed			
Abbreviations: SD, standard deviation; AT, anterior tibial artery; TbP, tibial plateau; TPT, tibioperoneal trunk; PT, posterior tibial artery; PR, peroneal artery			

Figures

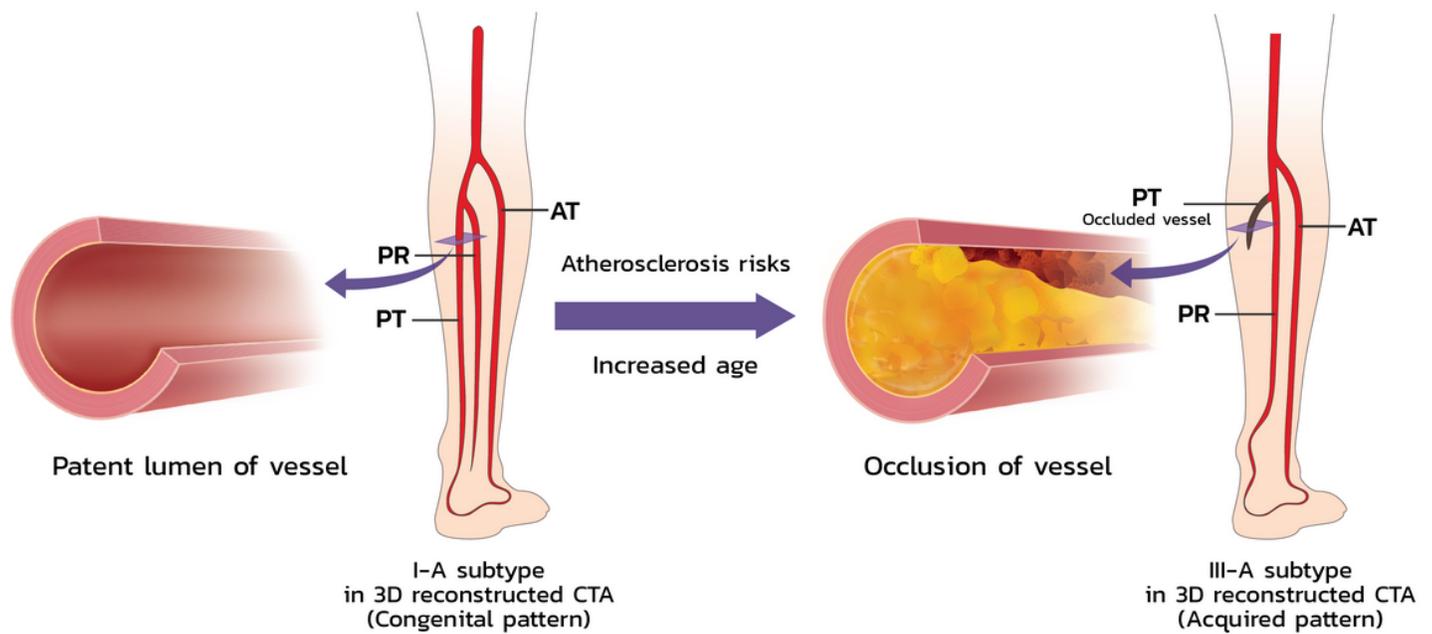


Figure 1

An acquired variant from intraluminal obliteration. Atherosclerotic changes cause intraluminal narrowing and obstruction of vessels resulting in acquired variant of popliteal vasculature. In this figure, the patient had a I-A branching pattern, which is a common pattern, as the congenital branching pattern. However, atherosclerosis occluded the posterior tibial artery, which resulted in an acquired type III-A branching pattern in 3D reconstructed CTA.

Abbreviations: AT, anterior tibial artery; PT, posterior tibial artery; PR, peroneal artery, CTA, computed tomography angiography; 3D, 3-dimensional

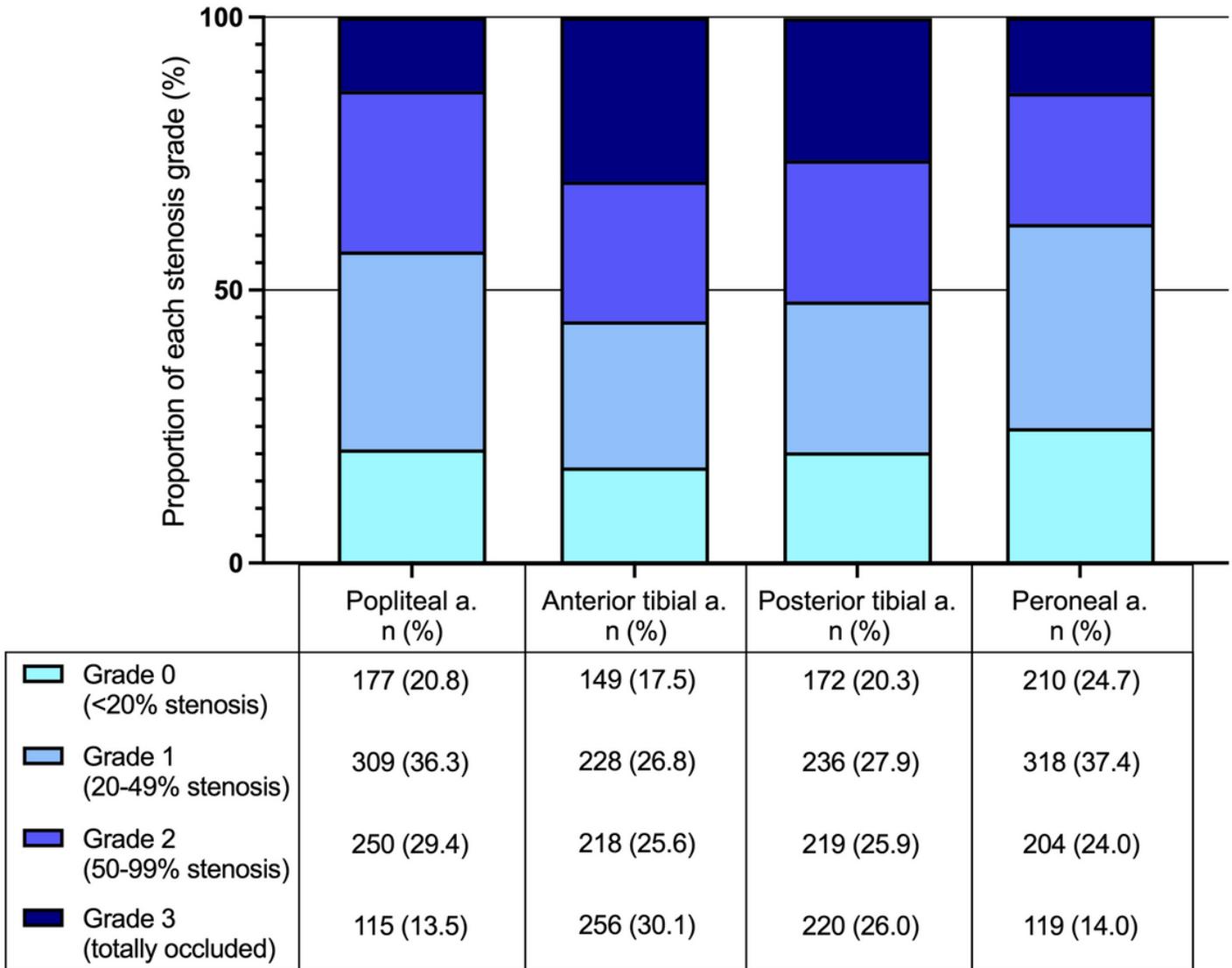


Figure 2

Stenosis grading of popliteal artery and its collaterals. Degree of stenosis was different among vessels. The peroneal artery had lower percentage of grade 3 stenosis (totally occluded) than the anterior tibial artery and the posterior tibial artery, which might support the sparing effect of peroneal artery from atherosclerosis.

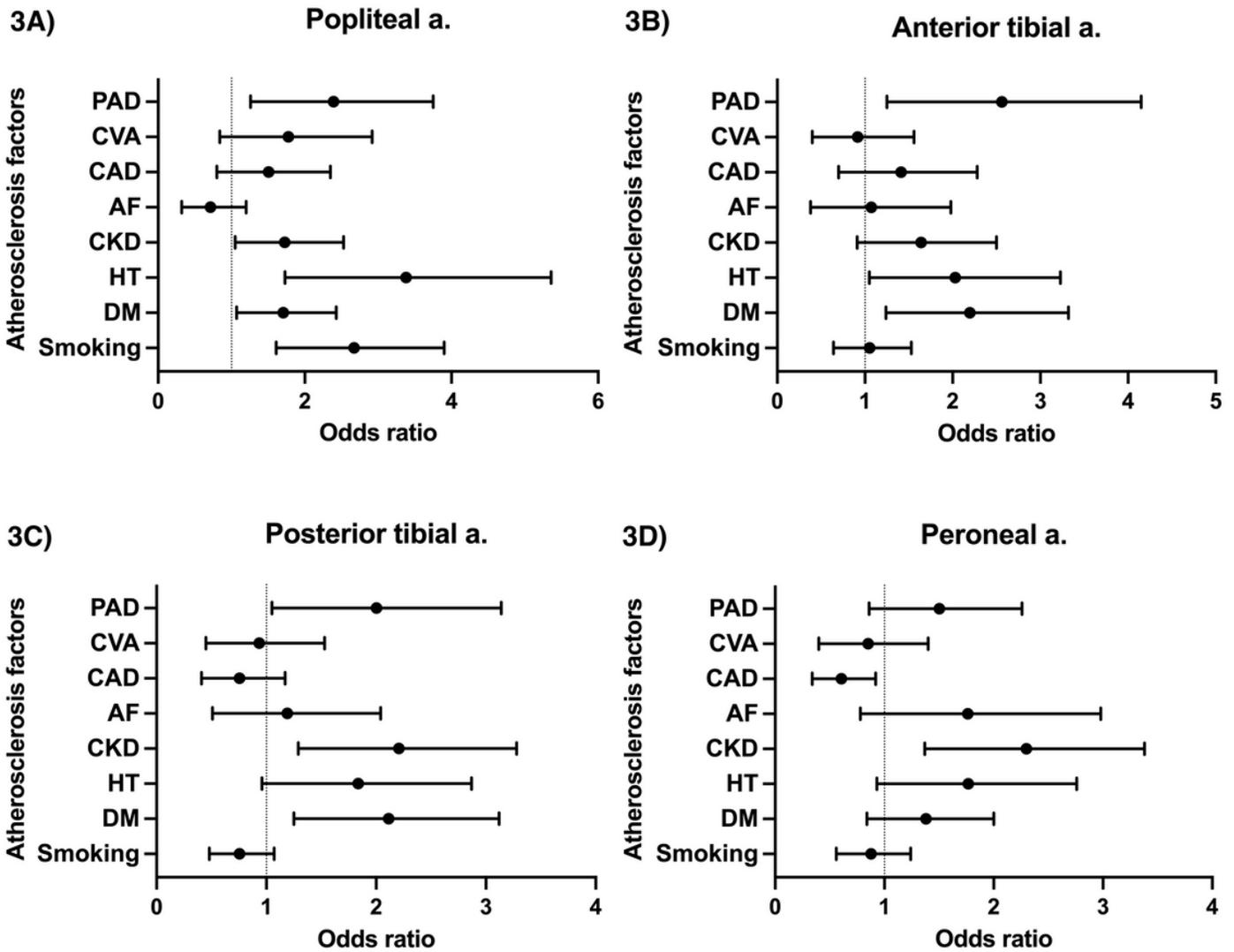


Figure 3

Adjusted odds ratio and 95% confidence interval for the association between atherosclerosis risk factors and stenosis of popliteal vessels. The factors independently associated with popliteal artery stenosis were PAD, CKD, HT, DM, and smoking (3A). Stenosis of the anterior tibial artery was influenced by PAD, HT, and DM (3B). Stenosis of the posterior tibial artery was influenced by PAD, CKD, and DM (3C). Stenosis of the peroneal artery was influenced by CKD and CAD, the latter of which had an odds ratio of <1 (3D).

Abbreviations: PAD, peripheral artery disease; CVA, cerebrovascular disease; CAD, coronary artery disease; AF, atrial fibrillation; CKD, chronic kidney disease; HT, hypertension; DM, diabetes mellitus

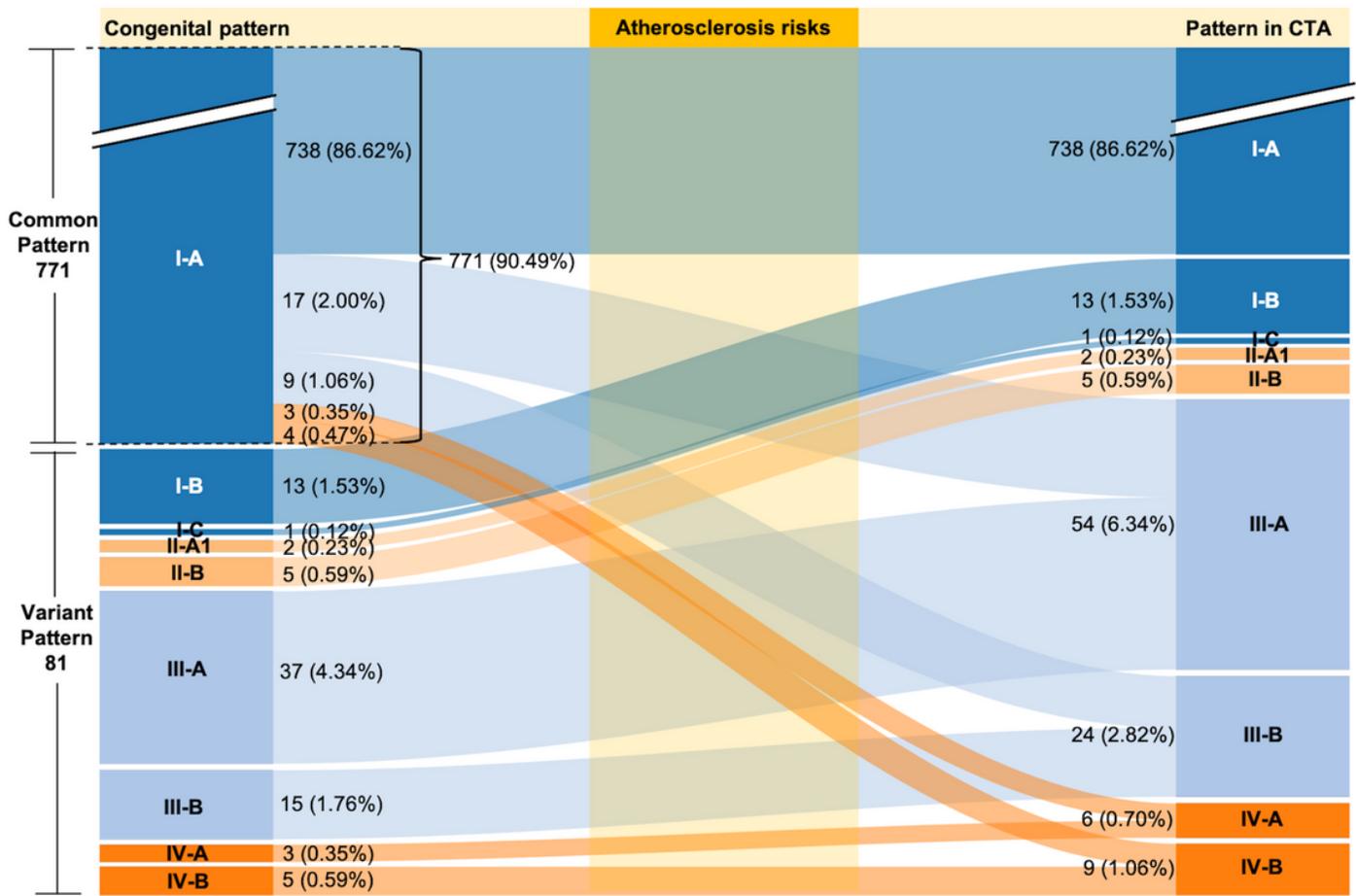


Figure 4

A Sankey diagram of acquired popliteal variants as visualized by CTA. The acquired variants were type III-A, III-B, IV-A, and IV-B. All of aforementioned variants had type I-A as the congenital (native) pattern. These variants were found to significantly influence the surgical planning of fibular free flap harvest due to the increased risk of compromised distal limb perfusion, and increased risk of compromised blood supply to the flap in type III and IV branching pattern, respectively.

Abbreviation: CTA, computed tomography angiography