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The Versatility of Atherosclerotic Cardiovascular Disease Risk Score in Determination of Popliteal Artery Branches Patency in Computed Tomography Angiography

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Background: The atherosclerotic cardiovascular disease (ASCVD) risk score is used to estimate coronary artery disease and stroke risk. Atherosclerosis affects arteries throughout the body, including the legs, causing peripheral arterial disease. Atherosclerosis causes luminal stenosis in popliteal artery branches, which affects operative decisions such as intravascular surgery, and lower limb reconstruction. The objective was to investigate the relationship between the ASCVD risk score and degree of stenosis among the popliteal artery and its branches.

Methods: The data regarding all patients who underwent computed tomography angiography (CTA) of the legs during 2016–2021 with complete data for ASCVD risk score assessment were recruited. The association between luminal stenosis from CTA and calculated ASCVD risk score was analyzed.

Results: A total of 383 limbs of 117 men and 81 women, averaged 66.5 years old, were studied. Common comorbidities included hypertension (84.3%), diabetes mellitus (61.1%), and chronic kidney disease (34.3%). Average 10-year ASCVD risks in the greater than or equal to 50% stenosis group of popliteal, anterior tibial, and posterior tibial arteries were significantly higher than the less than 50% stenosis group ($P < 0.01$). The peroneal artery had no significant difference between stenosis groups. The popliteal artery had significantly higher lifetime ASCVD risks than in the greater than or equal to 50% stenosis group ($P < 0.01$), but the other arteries showed no statistically significant difference.

Conclusions: The 10-year ASCVD risks showed significant higher values in the greater than or equal to 50% stenosis group of popliteal, anterior tibial, and posterior tibial arteries. These findings can establish the further study on how ASCVD risks can be applied to predict the stenosis of these arteries and guide the rationale of preoperative leg CTA for FFF harvest. *(Plast Reconstr Surg Glob Open 2023; 11:e4791; doi: 10.1097/GOX.0000000000004791; Published online 27 January 2023.)*

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The study was conducted in accordance with the Declaration of Helsinki, and approved by the institutional review board of Faculty of Medicine Siriraj Hospital, Mahidol University (certificate of approval no. 754/2563).

The data that support the findings of this study are available from the corresponding author, Nutcha Yodrabum, MD, upon reasonable request.

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INTRODUCTION

Luminal stenosis of arteries, which is one of the manifestations of atherosclerosis, results in impaired end-organ perfusion, such as coronary artery disease (CAD), cerebrovascular disease (CVD), and peripheral arterial disease (PAD).[1–4] PAD develops due to atherosclerotic changes of the arteries in the arms and legs. PAD can lead to stenotic or occluded arteries of the legs, including the popliteal artery, anterior tibial artery, posterior tibial artery, and peroneal artery.[5–7]

Blood flow to the lower leg is supplied by the infrapopliteal arteries, including the anterior tibial artery, posterior tibial artery, and peroneal artery. The patency of these vessels is critical and crucial for surgical consideration regarding the patency of these arteries, such

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as vascular procedures, endovascular intervention, and reconstruction of lower limb. Furthermore, the peroneal artery mainly supplies the fibula, which is important when considering reconstruction using a fibular free flap (FFF).[1,3–5,7–10] Preoperative computed tomography angiography (CTA) of the lower extremities could guide the choice of a suitable limb for FFF harvest and the appropriate intravascular approach to perform a vascular procedure. However, no recommendation/guideline that is specific to preoperative CTA of the lower extremities prior to FFF harvest has been established.[5] Furthermore, the risk of contrast-induced nephropathy (CIN) in chronic kidney disease patients is an important consideration before ordering CTA of the lower extremities. The atherosclerotic cardiovascular disease (ASCVD) risk score was established to estimate an individual's risk of developing CAD, and it has been widely used and accepted in clinical practice.[11–13]

The aim of this study was to investigate the association between ASCVD risk score and luminal stenosis of the popliteal artery and its branches. The results of this study will move us closer to having a decision-making tool for determining whether preoperative CTA of the lower extremities is indicated before different clinical practice settings, such as vascular bypass procedures, reconstruction requiring donor site from lower extremity, and reconstruction of lower limb.

Takeaways

Question: Can the atherosclerotic cardiovascular disease (ASCVD) risk score predict luminal stenosis of the popliteal artery and its branches?

Findings: The computed tomography angiography images of the legs were reviewed. The ASCVD risk score were analyzed for association of the score and vascular stenosis. The result showed the ASCVD risk score was significantly higher in the stenosis group than in the nonstenosis group of the popliteal artery and its branches.

Meaning: The ASCVD risk score could be a potential tool for predicting luminal stenosis of the popliteal artery and its branches.

MATERIALS AND METHODS

Study Population

This retrospective study was conducted at the Division of Plastic and Reconstructive Surgery of the Department of Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand. The protocol for this study was approved by the Siriraj institutional review board (certificate of approval no. 754/2563). Written informed consent to participate was not obtained from study participants due to the retrospective, anonymous nature of this study.

Demographic and clinical data, atherosclerosis risk factors, and CTA images of the lower extremities of 443 patients who underwent CTA of the lower extremities during January 2016 to January 2020 were collected. Comorbidities, such as diabetes mellitus, hypertension, and chronic kidney disease, were defined as comorbidities that were diagnosed before study enrollment. PAD was defined as PAD that was diagnosed before study enrollment and that occurred in limbs other than the affected leg that was enrolled in this study.

The ASCVD Risk Scores

The ASCVD risk score was published in the 2013 American College of Cardiology/American Heart Association Guideline on the Assessment of Cardiovascular Risk. Atherosclerosis risk factor-related data were calculated to generate the ASCVD risk scores. The data for calculation including demographic data such as sex, age, and race, blood cholesterol, smoking status, systolic blood pressure, and treatment for hypertension. This study included both the 10-year ASCVD risk score and the lifetime ASCVD risk score for analysis.

CTA Protocol and Stenosis Grading

CT scans were performed using one of three multidetector CT scanners, including Discovery CT 750HD (GE Healthcare, Chicago, Ill.), Somatom Definition Dual Source CT (Siemens, Erlangen, Germany), or Revolution CT (GE Healthcare). The CTA protocol included the abdominal aorta from the dome of liver to the distal arteries of the lower extremities and comprised of a contrast-enhanced phase and a delayed phase using 120 kVp tube voltage. The contrast-enhanced phase was done by using the bolus-tracking technique with 150 Hounsfield units threshold at the abdominal aorta. Iodinated contrast media was infused at 5 mL/s for 100 mL followed by 20 mL of normal saline solution using a power injector. For patients who had inadequate enhancement of the peripheral arteries, the delayed phase was performed immediately after the CTA phase. Image reconstruction was performed using 1.25-mm slice thickness.

The stenosis severity of the popliteal artery and its branches was collected from CTA and categorized with the revised version of Rutherford et al classification. Each outflow artery was likewise allocated a resistance value which could be categorized into four levels, including grade 0 (the luminal stenosis <20% of the greatest luminal stenosis), grade 1 (the luminal stenosis at 20%–49% of the greatest luminal stenosis), grade 2 (the luminal stenosis at 50%–99% of the greatest luminal stenosis), and grade 3 (total occlusion).[1,7] The authors modified the Rutherford classification into two groups. Less than 20% stenosis (grade 0) was defined as the nonstenosis group, and greater than or equal to 20% stenosis (grade 1 to 3) was defined as the stenosis group. ASCVD risk scores were compared between the nonstenosis and stenosis groups.

Statistical Analysis

Descriptive statistics were employed to summarize and report patient characteristics. All statistical analyses were performed using SPSS Statistics for Windows version 26.0 (SPSS, Inc., Chicago, Ill.). Categorical data are reported as number and percentage. Continuous data are reported as mean ± SD for normally distributed data, and as median and interquartile range (IQR) for non-normally distributed data. Student's t test and Mann–Whitney U test were used to compare normally distributed and non-normally distributed continuous variables between groups. Generalized estimating equations were used to evaluate for significant association between ASCVD risk scores and the presence of luminal stenosis. An exact sign test was used to compare the differences in grading of stenosis between peroneal and nonperoneal arteries in patient with ASCVD risk score categorized as low risk, borderline risk, and intermediate risk. In the same manner, a Wilcoxon-signed rank test was applied to the patient in high risk ASCVD group. A P value less than or equal to 0.05 was considered statistically significant for all tests.

RESULTS

Data from 443 cases were retrieved during the study period, but only 198 patients had complete information for ASCVD risk calculation. Of those, there were 117 men (59.1%) and 81 women (40.9%). The mean age and body mass index of all patients were 66.5 ± 12.9 years and 23.5 ± 4.3 kg/m^2, respectively. The mean systolic and diastolic blood pressure were 141.7 ± 24.8 and 73.6 ± 12.4 mmHg, respectively. Patient comorbidities included hypertension (84.3%), diabetes mellitus (61.1%), chronic kidney disease (34.3%), CAD (33.8%), PAD (23.2%), cerebrovascular disease (17.2%), and atrial fibrillation (14.6%). Just under half (47.5%) of patients were current smokers (Table 1).

Table 1. Demographic and Clinical Characteristics of the Enrolled Study Patients (198 Patients, 383 Limbs)

Characteristics	Values
Age (y), mean ± SD	66.5 ± 12.9
Body mass index (kg/m^2), mean ± SD	23.5 ± 4.3
Systolic blood pressure (mmHg), mean ± SD	141.7 ± 24.8
Diastolic blood pressure (mmHg), mean ± SD	73.6 ± 12.4
Gender, n (%)	
Male	117 (59.1%)
Female	81 (40.9%)
Comorbidity, n (%)	
Diabetes mellitus	121 (61.1%)
Hypertension	167 (84.3%)
Chronic kidney disease	68 (34.3%)
Atrial fibrillation	29 (14.6%)
CAD	67 (33.8%)
Cerebrovascular disease	35 (17.2%)
PAD	46 (23.2%)
Current smoker	94 (47.5%)

Stenosis of the popliteal artery and its branches was graded on patients' CTA. All 383 limbs were graded. For the popliteal artery, the nonstenosis group was found at 11.5% and the stenosis group was found at 88.5% of the patients. The nonstenosis group of the anterior tibial artery was found at 10.2% and the stenosis group was found at 89.8%. The nonstenosis group of the posterior tibial artery was found at 12.8% and the stenosis group was found at 87.2%. The nonstenosis group of the peroneal artery was found at 16.7% and the stenosis group was found at 83.3% (Table 2).

The ASCVD risk scores included the lifetime ASCVD risk score and the 10-year ASCVD risk score. Both ASCVD risk scores were compared between the stenosis and nonstenosis groups for each of the four evaluated vessels. All of the mean (±SD) ASCVD lifetime risk scores for all of the evaluated vessels were significantly lower in the nonstenosis group than in the stenosis group [popliteal artery, 41.0 ± 19.1% versus 52.6 ± 14.2%; anterior tibial artery, 43.5 ± 15.1% versus 52.1 ± 15.7%; posterior tibial artery, 42.3 ± 11.2% versus 52.0 ± 16.2%; and peroneal artery, 42.3 ± 11.2% versus 52.0 ± 16.2%—all $P < 0.05$) (Table 3). The average 10-year ASCVD risk scores for the popliteal artery, anterior tibial artery, and posterior tibial artery were significantly lower in the nonstenosis group than in the stenosis group [popliteal artery, 7.6% (2.7%–25.4%) versus 31.4% (15.9%–46.7%); anterior tibial artery, 11.5% (2.0%–32.1%) versus 30.6% (14.5%–46.5%); and posterior tibial artery, 17.7% (6.2%–35.9%) versus 30.7% (14.3%–46.4%)—all $P < 0.01$]. The 10-year ASCVD risk score for the peroneal artery showed no statistically significant difference between the nonstenosis and stenosis groups ($P = 0.073$) (Table 3).

Regarding our analysis of ASCVD risk scores between the nonstenosis and stenosis groups using generalized estimating equations, we found significant association between the 10-year ASCVD risk score and the popliteal artery, and the anterior tibial artery. The baseline 10-year ASCVD risk score in our study was 32.9%. A 10-year ASCVD risk score greater than 41.4% was found to be significantly associated with the presence of stenosis (>20% luminal stenosis) in the anterior tibial artery, and a 10-year ASCVD risk score greater than 48.3% was found to be significantly associated with the presence of stenosis in the popliteal artery. Furthermore, a 10-year ASCVD risk score greater than 56.8% was found to be significantly associated the presence of stenosis in both the popliteal and anterior tibial arteries.

Table 2. Stenosis Grading of the Popliteal Artery and Its Branches (383 Limbs in Total)

Degree of Stenosis	Popliteal Artery, n (%)		Anterior Tibial Artery, n (%)		Posterior Tibial Artery, n (%)		Peroneal Artery, n (%)	
Grade 0 (<20% stenosis)	44 (11.5%)		39 (10.2%)		49 (12.8%)		64 (16.7%)	
Grade 1 (20%–49% stenosis)	133 (34.7%)	339 (88.5%)	88 (23.0%)	344 (89.8%)	101 (26.4%)	334 (87.2%)	159 (41.5%)	319 (83.3%)
Grade 2 (50%–99% stenosis)	150 (39.2%)		121 (31.6%)		116 (30.3%)		96 (25.1%)	
Grade 3 (100% occlusion)	56 (14.6%)		135 (35.2%)		117 (30.5%)		64 (16.7%)	

Table 3. Lifetime and 10-year ASCVD Risk Scores for Each of the Evaluated Vessels

		Stenosis Status*		
Artery	**ASCVD Risk**	**Nonstenosis (<20%)**	**Stenosis (≥20%)**	***P***
Popliteal artery	Lifetime risk	41.0 ± 19.1	52.6 ± 14.2	0.001†
	10-y risk	7.6 (2.7–25.4)	31.4 (15.9–46.7)	0.000†
Anterior tibial artery	Lifetime risk	43.5 ± 15.1	52.1 ± 15.7	0.011†
	10-y risk	11.5 (2.0–32.1)	30.6 (14.5–46.5)	0.000†
Posterior tibial artery	Lifetime risk	42.3 ± 11.2	52.0 ± 16.2	0.003†
	10-y risk	17.7 (6.2–35.9)	30.7 (14.3–46.4)	0.002†
Peroneal artery	Lifetime risk	42.3 ± 11.2	52.0 ± 16.2	0.003†
	10-y risk	26.2 (6.9–43.7)	30.5 (12.6–46.5)	0.073

*Data shown as mean ± standard deviation or median and interquartile range.
†A *P* value <0.05 indicates statistical significance.

The patients were categorized into four groups according to the ASCVD categories (0%–4.9%, low risk; 5%–7.4%, borderline risk; 7.5%–20%, intermediate risk; and >20%, high risk). The stenosis statuses of each vessel were calculated as a percentage for each ASCVD group, as shown in Figure 1. The percentages of stenosis grading in the peroneal and nonperoneal arteries were also analyzed. As compared to the stenosis of the peroneal arteries, the stenosis of the nonperoneal arteries caused a statistically significant median increase in the degree of stenosis[1] in high ASCVD risk patients, with *P* values less than 0.0001 (Fig. 2).

DISCUSSION

Atherosclerosis adversely affects arteries throughout the body and causes several types of organ dysfunction. The arteries of the lower extremities can also be affected by intraluminal narrowing. The ASCVD risk score was established in the 2013 American College of Cardiology/American Heart Association Guideline on the Assessment of Cardiovascular Risk, and it includes the 10-year ASCVD risk score and the lifetime ASCVD risk score. It has been widely accepted and is used in routine clinical practice to estimate a person's risk of developing cardiovascular disease and cerebrovascular disease.[11–13] In addition to CAD and cerebrovascular disease, PAD of the lower limbs results in stenosis or occlusion of the popliteal artery and its branches.

Based on the aforementioned pathophysiology of atherosclerosis, the ASCVD risk scores may predict stenosis of the arteries of the lower leg. If this were found to be true, the ASCVD risk scores could benefit preoperative decision-making in different clinical practice settings, such as vascular bypass procedures; intravascular surgery; reconstruction requiring donor site from lower extremity, such as fibular free flap (FFF); anterolateral thigh (ALT) flap, and wound healing regarding arterial insufficiency.[4–6,10,14–17]

The lifetime ASCVD risk scores for the popliteal artery and all of its branches were significantly lower in the nonstenosis group than in the stenosis group ($P < 0.05$). Accordingly, the 10-year ASCVD risk scores of all evaluated arteries, except the peroneal artery, were significantly lower in the nonstenosis group than in the stenosis group ($P < 0.01$). As such, it can be inferred that atherosclerosis affects different arteries of the lower extremities in different degrees.

According to Rutherford et al scoring system, a vessel that was completely occluded was given three resistance units, a vessel with a stenosis of 50%–99% was given two units, a vessel with a stenosis of 20%–49% was given one unit, and a vessel that was widely patent was given zero units. To represent the overall case severity in the series, this simplified classification was provided as a compromise for usage when runoff grading is taken into account in the analysis together with other risk factors.[1,7] As evidenced by low runoff scores, a better runoff will predict hemodynamic success after bypass, according to Biancari et al.[18] In contrast to all other runoff score categories, patients with widely patent and less affected vessels (runoff score, 1) had excellent patency rates. In addition to being able to predict the relationship between the ASCVD score and the stenotic percentages, this cut point may also be helpful for future management in vascular selection and other appropriate procedures. Using the mentioned runoff score or variations thereof, several other series have reported outcomes that are comparable.[19,20]

It is believed that no grading system for runoff is flawless and will be universally accepted. However, a grading system with a reasonable degree of correlation with outcome is desired. The proposed method has the benefit of being applicable to any level of anastomosis. Due to the scoring complexity, it is not frequently utilized. Nonetheless, because no other superior approach has emerged in the recent decade to replace it, it has been preserved in these guidelines, with modifications to reflect variations and clarifications for easier comprehension and implementation.

Our analyses using generalized estimating equations revealed significant association between the 10-year ASCVD risk score and luminal stenosis in the popliteal artery, and between the 10-year ASCVD risk score and luminal stenosis in the anterior tibial artery. The mean baseline 10-year ASCVD risk score among all 198 patients included in that analysis was 32.9%. The cutoff scores that predict luminal stenosis in the anterior tibial artery, in the popliteal artery, and in both the anterior tibial artery and the popliteal artery were 41.4%, 48.3%, and 56.8%, respectively. A 10-year ASCVD risk score greater than or equal to 20% is considered high

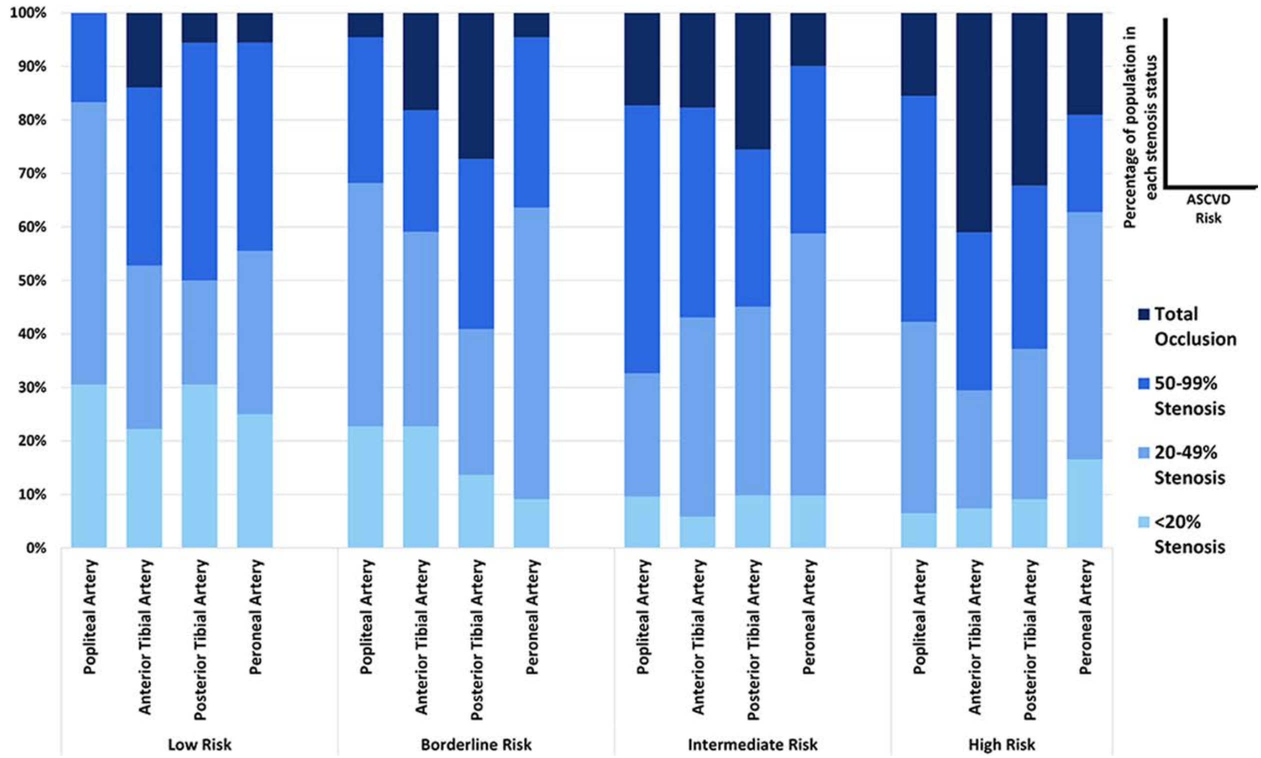

Fig. 1. The ratio of the stenosis status in each vessel of the patient categorized by ASCVD risk score.

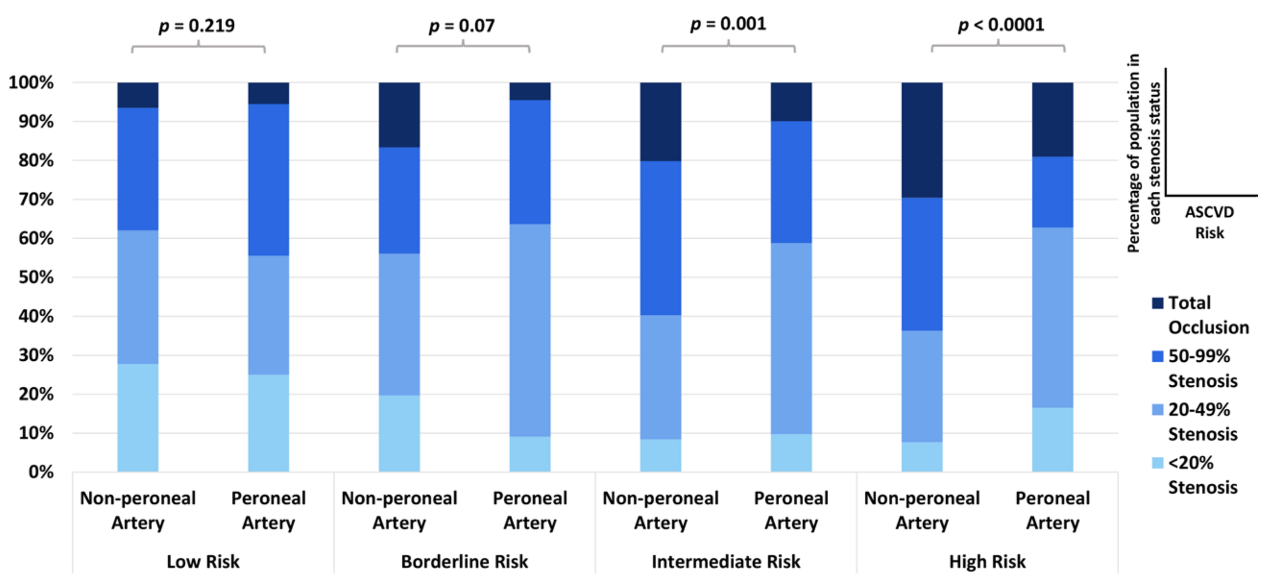

Fig. 2. Comparison of the percentage of stenosis status in the patient's nonperoneal artery and peroneal artery based on ASCVD risk score. In intermediate and high ASCVD risk patient, the stenosis of nonperoneal arteries elicited a statistically significant median increase in degree of stenosis[1] compared to the stenosis of peroneal arteries, $P = 0.001$ and $P < 0.0001$, respectively.

risk for developing a cardiovascular event, including CAD or stroke.[11–13] Furthermore, the 10-year ASCVD risk cut points identified in this study might be used to guide decision-making regarding preoperative CTA or other types of imaging before reconstructive surgery involving the lower leg or harvest of FFF. The 10-year ASCVD risk score cut points for the popliteal artery and its branches in our study are greater than the cut points from the proposed risk score in ASCVD recommendation for developing CAD and stroke, which might indicate that the lower extremity arteries might be less affected by atherosclerosis. Another hypothesis of this manifestation is race; the patients included in the present study were all Asian, which might be a factor that alleviates the effect of atherosclerosis.

In contrast to the other popliteal artery branches, the peroneal artery had a 10-year ASCVD score that was nonsignificantly different between the nonstenosis and stenosis groups, which suggests that the stenosis of the peroneal artery was not associated with a higher risk of developing cardiovascular accidents. This finding supports the hypothesis that the peroneal artery is less likely to be affected by atherosclerosis according to previous study.[5] The factors reported to influence this hypothesis include the amount of muscle supply, the blood flow pattern, and local vessel-related factors.[5,8,21]

Limitations

This study has some mentionable limitations. First, our study's retrospective design renders it vulnerable to both missing and/or incomplete data and to certain biases. Second, the number of patients in this study is relatively small, and this may have limited the statistical power of our study to identify all statistically significant differences and associations. Finally, this study enrolled only the Asian patients, which may limit the generalizability of our findings and cut points to patients of other races. Further study with a larger population that includes patients of various races is, therefore, warranted.

CONCLUSIONS

The ASCVD risk score was found to be a potential tool for predicting luminal stenosis of the popliteal artery and its branches. A 10-year ASCVD risk score greater than 41.4%, 48.3%, and 56.8% significantly predicts luminal stenosis in the anterior tibial artery, popliteal artery, and both the popliteal and anterior tibial arteries, respectively. Moreover, data from this study can guide the rationale of preoperative leg CTA imaging before lower leg vascular surgery and lower extremity reconstruction.

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