Proximal Superficial Femoral Artery Occlusion, Collateral Vessels, and Walking Performance in Peripheral Artery Disease

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Abstract

Objective—We studied associations of MRI-measured SFA occlusions with functional performance, leg symptoms, and collateral vessel number in PAD. We studied associations of collateral vessel number with functional performance in PAD.

Background—Associations of magnetic resonance imaging (MRI)-detected superficial femoral artery (SFA) occlusion and collateral vessel number with functional performance among individuals with peripheral artery disease (PAD) have not been reported.

Methods—457 participants with an ankle brachial index (ABI) < 1.00 had MRI measurement of the proximal SFA with twelve consecutive 2.5 millimeter cross-sectional images. An occluded SFA was defined as an SFA in which at least one segment was occluded. A non-occluded SFA was defined as absence of any occluded slices. Collateral vessels were visualized with magnetic resonance angiography (MRA). Lower extremity functional performance was measured with the

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six-minute walk, four-meter walking velocity at usual and fastest pace, and the short physical performance battery (SPPB) (0-12 scale, 12=best).

Results—Adjusting for age, sex, race, comorbidities, and other confounders, the presence of an SFA occlusion was associated with poorer six-minute walk performance (1,031 vs. 1,169 feet, P=0.006), slower fast-paced walking velocity (1.15 vs. 1.22 meters/second, P =0.042), and lower SPPB score (9.07 vs. 9.75, P=0.038) compared to the absence of an SFA occlusion. More numerous collateral vessels were associated with better six-minute walk performance (0-3 collaterals-1,064 feet, 4-7 collaterals-1,165 feet, 8 collaterals-1,246 feet, P trend=0.007), faster usual-paced walking speed (0-3 collaterals-0.84 meters/second, 4-7 collaterals-0.88 meters/second, 8 collaterals-0.91 meters/second, P trend=0.029), and faster rapid-paced walking speed (0-3 collaterals-1.17 meters/second, 4-7 collaterals-1.22 meters/second, 8 collaterals-1.29 meters/second, P trend=0.002), adjusting for age, sex, race, comorbidities, ABI, and other confounders.

Conclusions—Among PAD participants, MRI-visualized occlusions in the proximal SFA are associated with poorer functional performance, while more numerous collaterals are associated with better functional performance.

Clinical Trial ID—NCT00520412

Keywords

atherosclerotic plaque; intermittent claudication; peripheral arterial disease; physical functioning

CONDENSED ABSTRACT

Among 457 men and women with peripheral artery disease (PAD), we studied associations of magnetic resonance imaging (MRI)-measured occlusions in the superficial femoral artery (SFA) and lower extremity collateral vessel number with functional performance in PAD. The presence of an occluded SFA was associated with poorer six-minute walk performance, slower walking velocity at rapid pace, and a lower short physical performance battery (SPPB) score. More numerous collateral vessels were associated with better six-minute walk performance and faster walking velocity at usual and fastest pace.

Data from humans and animals demonstrate that pre-existing collateral vessels enlarge in response to shear stress following lower extremity arterial occlusions (1-3). Collateral vessels serve as a natural bypass system, are thought to protect against critical limb ischemia, and may reduce leg symptoms in people with PAD (1-3). Occlusion of a major lower extremity artery is a primary stimulus to the enlargement of pre-existing collateral vessels, and the superficial femoral artery (SFA) is the most common site of lower extremity arterial occlusions (4). However, these collateral vessels typically do not restore lower extremity perfusion to normal (2). Whether larger or more numerous lower extremity collateral vessels protect against functional impairment and functional decline in people with PAD is unknown.

Among individuals with PAD, we studied associations of occlusions in the SFA with leg symptoms, functional performance, and collateral vessel characteristics. We hypothesized that occlusions in the SFA would be associated with more leg symptoms and greater functional impairment. However, we also hypothesized that larger and more numerous lower extremity collateral vessels would mitigate against PAD-related functional impairment. Specifically, we hypothesized that for a given level of PAD severity, more numerous and larger collateral vessels would be associated with better functional performance in PAD.

METHODS

Subjects

Participants were those in the Walking and Leg Circulation Study (WALCS) III cohort (5). Participants were identified from among consecutive PAD patients in four Chicago-area medical centers. Participants were also identified from among lists of consecutive patients with a diagnosis of PAD in the vascular surgery, cardiology, endocrinology, general medicine, and geriatric practices at Northwestern Medical Faculty Foundation and in the vascular surgery practice at the Jesse Brown Veterans Administration. A small number of participants were identified from among men and women age 70 and older in Northwestern's largest general internal medicine practice who were screened with the ABI and found to have an ABI <1.00. The protocol was Institutional Review Board-approved by Northwestern University and all participating sites. Participants gave written informed consent. Rates of participation and reasons for exclusion among those contacted for WALCS III participation have been reported (5).

Inclusion and Exclusion Criteria

The inclusion criterion was an ABI < 1.00. This criterion was selected because normal ABI values are 1.10-1.40 (6).

Exclusion Criteria

Potential participants with dementia or a mini-mental status examination score < 23 (7) were excluded. Nursing home residents, wheelchair-bound patients, and patients with foot or leg amputations were excluded because of severely impaired functioning. Non-English-speaking patients were excluded because investigators were not fluent in non-English languages. Individuals who required oxygen therapy, had contraindications to MRI testing, stopped the six-minute walk test due to shortness of breath, had recent major surgery, or with severe knee osteoarthritis were excluded (8). Potential participants with bilateral SFA stents were excluded, because stents interfere with plaque imaging.

Ankle Brachial Index Measurement

After participants rested supine for five minutes, a hand-held Doppler probe (Nicolet Vascular Pocket Dop II, Golden, CO) was used to measure systolic pressures in the right brachial, dorsalis pedis, and posterior tibial arteries and left dorsalis pedis, posterior tibial, and brachial arteries. Pressures were repeated in reverse order. The ABI was calculated in each leg by dividing average pressures in each leg by the average of the four brachial pressures (9). Average brachial pressures in the arm with highest pressure were used when one brachial pressure was higher than the opposite brachial pressure in both measurement sets, and the two brachial pressures differed by 10 or more mm Hg in at least one measurement set.

Magnetic Resonance Imaging

We imaged the SFA because it is the most common site of lower extremity atherosclerosis (10) and because it supplies calf muscle, which is typically symptomatic in patients with PAD. The leg with lowest ABI was imaged. If the leg with lowest ABI had an SFA stent, the opposite leg was imaged. MRI data were obtained with a 1.5 Tesla (Siemens) platform using four-element phased-array surface coils. The bifurcation of the common femoral artery served as the reference point. Twelve consecutive 2.5 millimeter cross-sectional images were obtained, moving distally from the most proximal point of the SFA, using 2-dimensional bright blood time-of-flight and proton-density weighted images. Fat

suppression was applied in black-blood sequences to improve image quality. This method has excellent test re-test reliability (5).

CASCADE software (Seattle, WA) was used by two physician reviewers to trace the outer boundary and the lumen of each cross-sectional image of the SFA. A non-occluded SFA was defined as absence of any occluded segments in the imaged proximal SFA. An occluded SFA was defined as presence of at least one occluded segment.

Images for each participant were assigned to one primary reviewer, and arterial tracings were reviewed by the second reviewer to ensure accuracy. A six percent subsample of participants returned on a second day for test re-test reliability assessment of MRI measurements. The coefficient of variation percent values for these test re-test reliability assessments were 5.7 for mean plaque area, 8.9 for maximum plaque area, 8.0 for mean percent lumen area, and 12.9 for minimum percent lumen area (5).

Magnetic Resonance Angiography

A 1.5T Siemens Espree (Siemens Medical Solutions, Erlangen, Germany) MRI scanner was employed for MRA image acquisition. A 12 channel surface array coil (Siemens Medical Solutions, Erlangen, Germany) was used for signal reception. Dynamic MRA images from one station, the groin to the knee, were acquired from both legs, including the common femoral artery, the profunda femoris, the SFA, and the popliteal artery. Dynamic Images were acquired with the TWIST (Time resolved angiography With Interleaved Stochastic Trajectories) pulse sequence (11). Parallel imaging with Generalized Autocalibrating Partially Parallel Acquisitions (12) image reconstruction provided a 2-fold increase in frame rate. Following a three-plane localizer image, the TWIST sequence was applied in the coronal orientation. A 10 ml bolus of nondiluted gadopentetate dimeglumine (0.5 mmol/mL, Magnevist; Berlex, Montville, NJ, USA) was administered intravenously at 2 mls/sec. Imaging parameters were: TR/TE/Flip angle = 3.3 ms/TE, 1.3 ms/25°; rectangular field of view (rFOV), 246×375 mm; matrix, 210×320; 88 partitions; voxel size after zero interpolation, $1.2 \times 1.2 \times 1.2$ mm^3 (true voxel size, $1.2 \times 1.2 \times 2.0$ mm^3); acceleration factor: 2.

MRA Image Analysis

A single radiologist (AK), blinded to all other participant characteristics, read all MRA images on a workstation (GE Healthcare, Milwaukee, Wis, USA). A validated scoring system was used to grade the number and size of collateral vessels, based on previous study (13,14). This method has excellent intra-rater reliability (mean 85.7% agreement) (14). Based on previously reported methods (13,14), small collaterals were defined as those occupying less than 25% of the length of the imaged thigh and less than 50% of the diameter of the SFA. Large collaterals were defined as occupying more than 25% of the length of the imaged thigh and greater than 50% of the diameter of the SFA. Categories were used to classify the number and size of collateral vessels, based on previous study (13,14). For collateral vessel size, Grade 1 was defined as ≤ 5 small collateral vessels, Grade 2 was defined as > 5 small collateral vessels, Grade 3 was defined as ≤ 5 large ± small collateral vessels, and Grade 4 was defined as > 5 large ± small collateral vessels (18). For collateral vessel number, Category 1 was defined as 0-3 collateral vessels, Category 2 was defined as 4-7 collateral vessels, and Category 3 was defined as ≥ 8 collateral vessels (14). Our MRA analyses did not include identifying proximal SFA occlusions.

FUNCTIONAL MEASURES

Six-minute walk

Participants walk up and down a 100-foot hallway for six minutes after instructions to cover as much distance as possible (5,15).

Four-meter walking velocity

Walking velocity was measured with a four-meter walk performed at "usual" and "fastest" pace, based on previous study (5,15). Each walk was performed twice. The faster walk in each pair was used in analyses.

Short Physical Performance Battery

The SPPB combines data from usual paced four-meter walking velocity, time to rise from a seated position five times, and standing balance (16). Individuals receive a zero score for each task they are unable to complete. Scores of one to four are assigned for remaining tasks, according to established methods. Scores are summed to obtain the SPPB, ranging from 0 to 12 (16).

Repeated chair rises—Participants sit in a straight-backed chair with arms folded across their chest and stand five times consecutively as quickly as possible. Time to complete five chair rises is measured (16).

Standing balance: Participants are asked to hold three increasingly difficult standing positions for ten seconds each: the side-by-side stand, semi-tandem stand (standing with feet parallel and the heel of one foot touching the base of the 1st toe of the opposite foot), and the full tandem stand (standing with one foot directly in front of the other) (16). Scores range from zero (unable to hold the side-by-side stand for ten seconds) to four (able to hold the full tandem stand for ten seconds) (19).

Comorbidities

Algorithms developed for the Women's Health and Aging Study and the Cardiovascular Health Study were used to document comorbidities (17). These algorithms combine data from patient report, physical examination, medical record review, medications, laboratory values, and a primary care physician questionnaire (17). Comorbidities assessed were angina pectoris, diabetes mellitus, myocardial infarction, stroke, heart failure, pulmonary disease, cancer, spinal stenosis, and disk disease. Criteria from the American College of Rheumatology were used to diagnose knee and hip osteoarthritis (8,18).

Leg Symptoms

Leg symptoms were classified using the San Diego claudication questionnaire (19). Intermittent claudication was defined as exertional calf pain that does not begin at rest, causes the participant to stop walking, and resolves within ten minutes of rest (15,19). Participants without any exertional leg pain were classified as asymptomatic (15,19). Participants with exertional leg pain who walked through their pain were classified as "leg pain carry on", those with exertional leg pain that sometimes begins at rest were classified as "pain on exertion and rest." Remaining participants with exertional leg symptoms who did not meet criteria for the aforementioned leg pain categories were classified as "atypical exertional leg pain" (15,19).

Other Measures

Height and weight were measured at the study visit. Body mass index (BMI) was calculated as weight (kg)/(height (meters))^2. Cigarette smoking history was measured with self-report.

Statistical Analyses

Clinical characteristics were compared between PAD participants with vs. without an occluded SFA using chi square tests for categorical variables and analyses of variance for continuous variables. Clinical characteristics and functional performance measures were compared between participants with vs. without an occluded SFA using analyses of covariance, adjusting for age, sex, and race (Model 1). Analyses involving nominal variables were performed using logistic regression. Functional performance analyses were repeated with additional adjustment for comorbidities, BMI, and smoking (Model 2). Finally, Model 2 was additionally adjusted for the ABI (Model 3).

Functional performance measures were compared across collateral vessel size (grade) and collateral vessel number (category), adjusting for age, sex, race, smoking, diabetes, BMI, comorbidities, and ABI. These analyses were repeated separately among participants with vs. without SFA occlusions. Because of small sample size in the 0-3 collateral vessel group among participants with an SFA occlusion, participants with an SFA occlusion and 0-3 collateral vessels were combined with those with 4-7 collateral vessels.

RESULTS

Of 473 PAD participants in the WALCS III cohort with SFA imaging, 457 had good quality images and are included in this report. Of these, 59 (12.9%) had an occluded SFA. Mean ages were 68.3 ± 9.1 and 69.4 ± 10.3 (P=0.409), the prevalence of males was 72.9% vs. 64.3% (P=0.197), and the prevalence of African-Americans was 35.6% vs. 32.9% (P =0.684) among participants with vs. without one or more occlusions in the proximal SFA, respectively. Figure 1 shows an occluded SFA with corresponding collateral vessels.

Adjusting for age, race, and sex, participants with one or more occlusions in the proximal SFA had a lower ABI, a lower prevalence of asymptomatic PAD, a higher prevalence of leg pain/carry-on, higher mean plaque area and lower mean lumen area, compared to participants without any occlusions (Table 1).

Among the 457 participants with PAD, 291 were eligible for and consented to an MRA. Participants who underwent MRA were younger (68.5 ± 10.4 vs. 70.7 ± 9.6, P=0.025), included a higher proportion of men (70.5% vs. 56.6%, P=0.003), and included a higher proportion of current smokers (28.6% vs. 17.5%, P=0.008) compared to those who did not undergo MRA. Adjusting for age, sex, and race, participants with an occlusion in the proximal SFA had a higher prevalence of large collateral vessels (i.e. Grade 3 and Grade 4) and a lower prevalence of smaller collateral vessels (i.e. Grade 1), compared to participants without occlusions (Table 1). Adjusting for age, sex, and race, participants with an occlusion in the proximal SFA had a lower prevalence of 0-3 collateral vessels and a higher prevalence of   8 collateral vessels, compared to participants without proximal SFA occlusions (Table 1).

Presence of an occlusion in the proximal SFA was associated with shorter six-minute walk distance, compared to individuals without any occlusions, adjusting for age, sex, and race (Model 1, Table 2). After additional statistical adjustment for comorbidities, BMI, and cigarette smoking (Model 2), participants with an occlusion in the proximal SFA had poorer six-minute walk performance, slower fast-paced four-meter walking velocity, and lower SPPB scores compared to participants without any occlusions (Table 2, Model 2). When

Model 2 results in Table 2 were additionally adjusted for the ABI, there were no significant associations of an occluded SFA with functional performance (data not shown). Thus, after taking into account differences in ABI values between participants with vs. without SFA occlusions, there were no significant associations of SFA occlusions with functional performance.

Within the entire cohort, more numerous collateral vessels were associated with better six-minute walk performance and faster walking velocity at usual and fastest pace, adjusting for age, sex, race, smoking, comorbidities, ABI, and BMI (Table 3). Similar findings were observed among participants without SFA occlusions (Table 3). Among PAD participants with an SFA occlusion, more numerous collateral vessels were associated with better six-minute walk performance (953 feet for participants with < 8 collateral vessels vs. 1,335 feet for participants with 8 collateral vessels, p=0.027) and faster rapid-paced four-meter walking velocity (1.07 meters/second for participants with < 8 collateral vessels vs. 1.43 meters/second for participants with 8 collateral vessels, p<0.001), adjusting for age, sex, race, comorbidites, smoking, ABI, and BMI. There were no associations of collateral vessel number with usual-paced four-meter walking velocity (data not shown) or the SPPB score (9.17 vs. 10.82, p=0.082) among participants with an SFA occlusion.

There were no significant associations of collateral size (grade) with functional impairment (data not shown).

DISCUSSION

Among 457 participants in the WALCS III cohort with ABI < 1.00, 13% had one or more occlusions in the proximal SFA of the leg with lowest ABI. There were no differences in age, race, sex, or prevalence of smoking or diabetes mellitus between PAD participants with an occlusion and those without any occlusions. PAD participants with an occlusion in the proximal SFA had poorer six-minute walk performance, slower fast-paced walking velocity, and a lower SPPB score, compared to PAD participants without any proximal SFA occlusions after adjusting for age, sex, race, BMI, smoking, diabetes, comorbidities, and other confounders. Our results also show that presence of more numerous collateral vessels is associated with better functional performance compared to fewer collateral vessels among participants with PAD. In contrast, we found no significant associations of collateral size (grade) with functional performance.

Occlusions are relatively common in lower extremity arteries and are an important stimulus to the development of collateral vessels. Yet to our knowledge, no prior studies have evaluated associations of MRI-visualized occlusions or collateral vessels with functional performance measures in individuals with PAD. Collaterals develop from pre-existing arterioles that enlarge in response to sheer stress forces precipitated by arterial occlusion (20). Sheer stress activates mechanosensors, resulting in molecular signaling, modulation of gene expression, and cytokine release including monocyte chemoattractant protein-1, granulocyte-macrophage colony-stimulating factor and cellular adhesion molecules (21-23). Influx of inflammatory cells is followed by release of vascular growth factors, remodeling of the vessel wall, enlargement of vessel diameter, and migration of smooth muscle cells into the artery wall (23,24). Animal evidence suggests that following arterial occlusion, vessels first increase rapidly in number and later enlarge in diameter (23). In animal models, exercise training is associated with collateral vessel enlargement and increased collateral vessel compliance (2). In animals, maximal collateral vessel enlargement occurs during exercise (3). This phenomenon may explain our finding that greater collateral vessel number, but not collateral vessel size (i.e. diameter), was associated with better functional

performance in PAD, since our images were obtained during rest and thus may not have captured maximal vessel diameter.

Our study has limitations. First, data are cross-sectional. Associations reported cannot be construed as causal. Second, we imaged a short segment of the SFA. We did not image atherosclerotic plaque in the aorto-iliac or femoro-popliteal arterial segments. Nonetheless, we found that presence of any occluded segments in the proximal SFA was associated with greater functional impairment than absence of occluded segments in the proximal SFA. Third, our collateral vessel data are limited to those who were eligible for and consented to MRA. Our findings regarding collateral vessels may not be generalizable to individuals who did not undergo MRA testing. Fourth, a relatively small proportion of participants had occlusions of the proximal SFA, limiting statistical power to detect meaningful differences between participants with vs. without occlusions in the proximal SFA. Fifth, MRA has lower spatial resolution than computed tomographic angiography or digital subtraction angiography. Some collateral vessels may be too small for identification on MRA (25). Sixth, lack of collateral vessel measurement during exercise may have limited our ability to identify associations of vessel size with functional performance.

Our results demonstrate that PAD participants with one or more occluded segments in the proximal SFA have greater functional impairment than PAD participants without proximal SFA occlusions. More numerous collateral vessels are associated with better functional performance in PAD. Our findings are important in part because of current interest in identifying therapies to increase lower extremity perfusion in individuals with PAD.

Abbreviation List

MRI magnetic resonance imaging

SFA superficial femoral artery

PAD peripheral artery disease

ABI ankle brachial index

WALCS walking and leg circulation study

**SPPB** short physical performance battery

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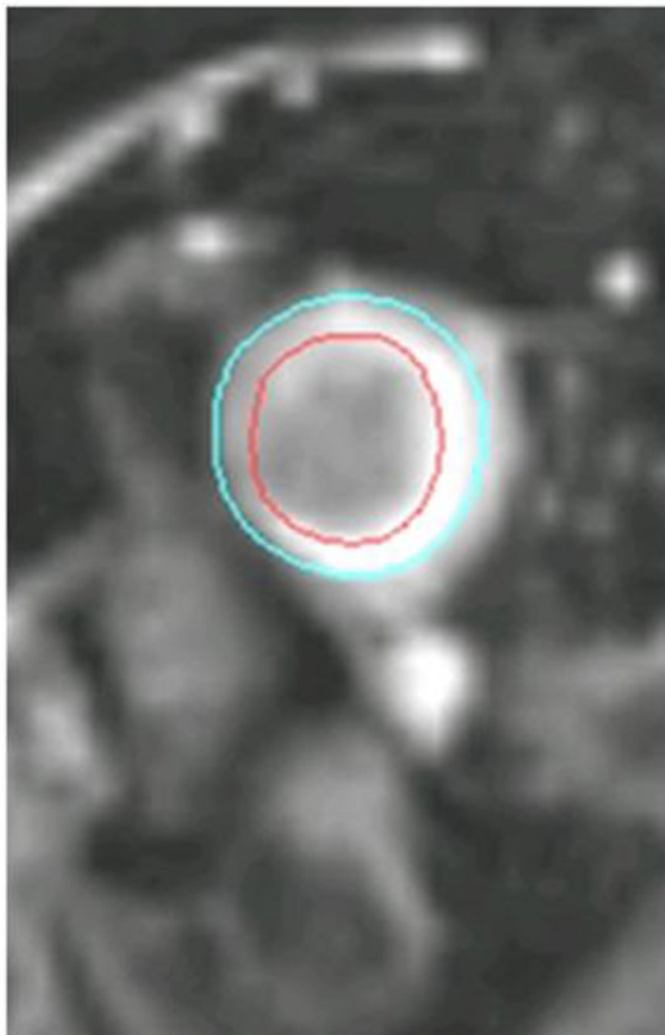
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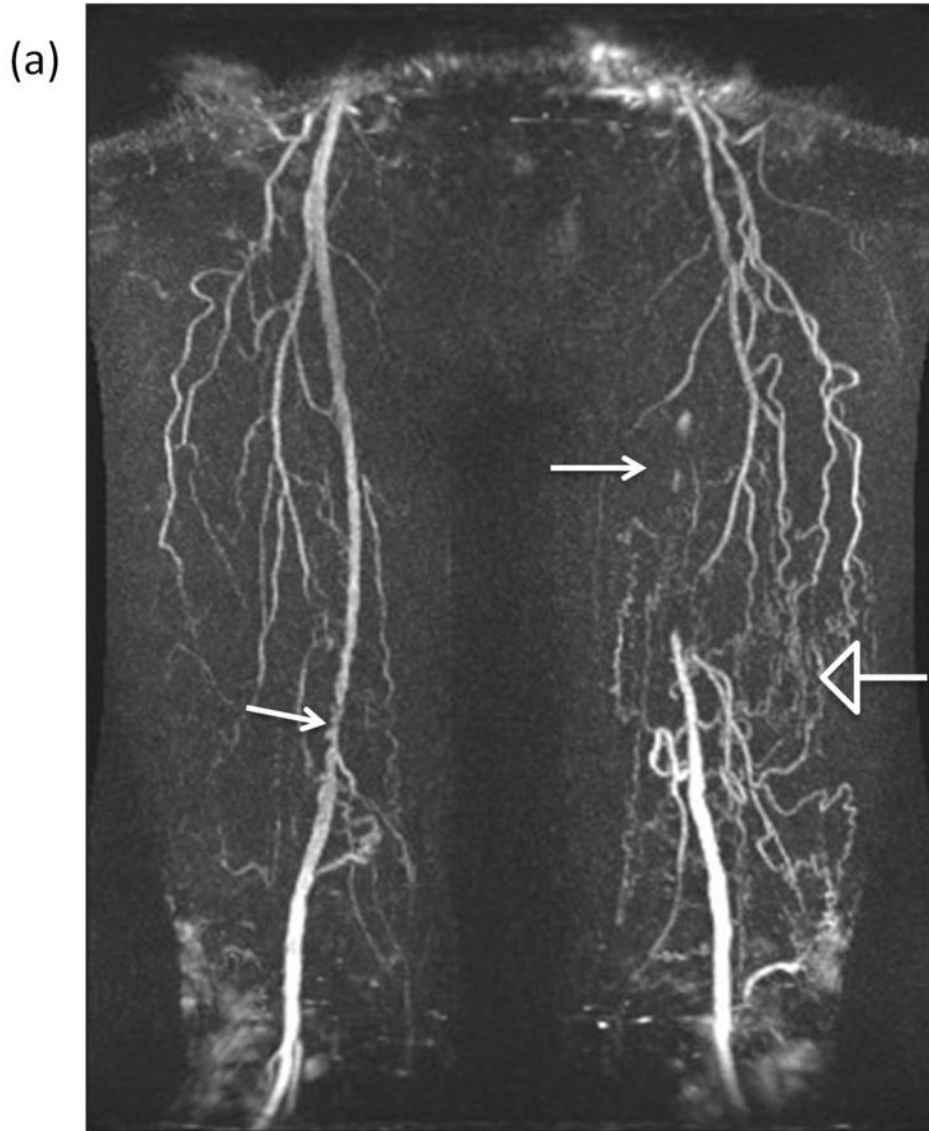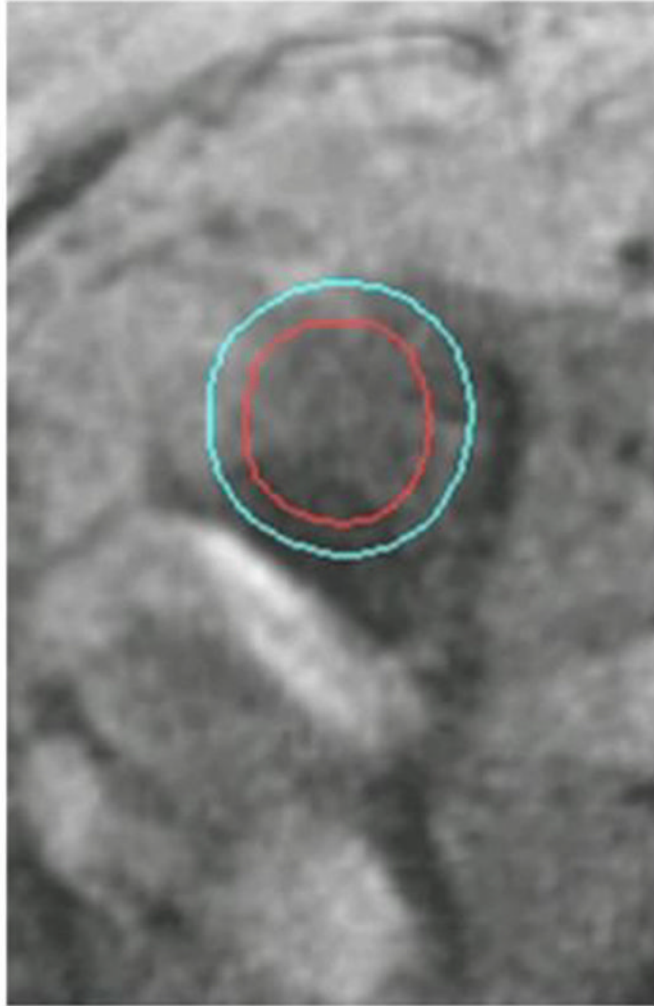
Figure 1. Representative images of an occluded superficial femoral artery and corresponding collateral vessels

(a) Contrast enhanced magnetic resonance angiogram (MRA) shows segment of irregular severe narrowing in distal right superficial femoral artery (solid arrow) and complete occlusion of left superficial femoral artery (solid arrow). Multiple large and small collateral vessels (open arrow) reconstitute left superficial femoral artery at level of adductor canal. Cross sectional images acquired at the SFA bifurcation in the same patient with (b) Time-of-Flight (TR/TE=38 ms/8.7 ms) and (c) proton-density weighting (TR/TE= 2160 ms/5.7 ms) are shown with the corresponding inner (red- outlining lumen) and outer (blue)-outlining outer vessel wall) contours. Note that the lack of intravascular signal in the TOF image resulting from the lack of blood flow in the occluded SFA does not compromise the ability to quantify wall lumen and wall areas.

Table 1

Adjusted Associations of Participant Characteristics and Superficial Femoral Artery Occlusion among Individuals with Peripheral Artery Disease (N=457) [*]

	No occlusions in the superficial femoral artery (N= 398)	One or more occlusions in the superficial femoral artery (N=59)	P value
Ankle brachial index	0.68 (0.01)	0.58 (0.02)	<0.001
Body Mass Index	29.3 (0.3)	28.9 (0.8)	0.573
Diabetes Mellitus	39.4% (2.4%)	34.3% (6.3%)	0.453
Hypertension	90.7% (1.5%)	88.4% (3.8%)	0.566
Current Smoking	24.2% (2.0%)	26.9% (5.2%)	0.577
Angina	21.6% (2.1%)	28.5% (5.4%)	0.238
Myocardial infarction	19.8% (2.0%)	30.8% (5.3%)	0.053
Heart failure	12.6% (1.7%)	15.0% (4.4%)	0.597
Stroke	16.6% (1.9%)	16.5% (4.9%)	0.993
Mean plaque volume	0.65 (0.01)	1.04 (0.01)	<0.001
Mean lumen area	0.36 (0.01)	0.08 (0.01)	<0.001
Leg Symptoms			
Intermittent claudication	22.1% (2.1%)	30.5% (5.5%)	0.159
Asymptomatic	22.2% (1.9%)	5.93% (5.1%)	0.007
Pain/Carry on	8.8% (1.5%)	17.1% (3.9%)	0.049
Atypical exertional leg pain	19.9% (2.0%)	18.3% (5.2%)	0.782
Pain on exertion and rest	27.0% (2.2%)	28.2% (5.7%)	0.833
Collateral Grade [†]			
	No occlusions in the superficial femoral artery (N= 251)	Occlusions in superficial femoral artery (N=40)	
Grade 1	50.5% (2.9%)	11.7% (7.4%)	<0.001
Grade 2	18.6% (2.4%)	9.01% (6.0%)	0.158
Grade 3	6.00% (1.7%)	20.0% (4.2%)	0.004
Grade 4	24.9% (2.8%)	59.3% (6.9%)	<0.001
Collateral Vessel Number [†]			
0-3 collateral vessels	24.5% (2.5%)	6.56% (6.3%)	0.02
4-7 collateral vessels	51.0% (3.2%)	47.2% (8.0%)	0.649
8 or more collateral vessels	24.5% (2.7%)	46.3% (6.8%)	0.003

[*] Mean values (standard error) are shown after adjustment for age, sex, and race.

[†] 291 participants underwent a magnetic resonance angiogram for measuring collateral vessels.

Table 2

Adjusted Associations of Superficial Femoral Artery Occlusion and Functional Performance among Individuals with Peripheral Artery Disease (N=457)*

	No SFA Occlusions (N=398)	SFA Occlusions (N=59)	P value
Six Minute Walk			
Model I	1168 (20)	1029 (51)	0.012
Model II	1169 (18)	1031 (47)	0.006
Usual-Paced Four-Meter Walking Velocity			
Model I	0.88 (0.01)	0.85 (0.02)	0.177
Model II	0.88 (0.01)	0.85 (0.02)	0.157
Fast-Paced Four-Meter Walking Velocity			
Model I	1.22 (0.01)	1.15 (0.04)	0.054
Model II	1.22 (0.01)	1.15 (0.03)	0.042
Short Physical Performance Battery			
Model I	9.74 (0.12)	9.12 (0.32)	0.073
Model II	9.75 (0.12)	9.07 (0.30)	0.038

Mean values (standard error) are shown after statistical adjustment. Model I adjusts for age, sex, and race. Model II adjusts for variables in Model I and also comorbidities, BMI, and smoking.

Table 3

Adjusted Associations of Collateral Vessel Number and Functional Performance in Participants with Peripheral Artery Disease

	0-3 Collateral Vessels (N=64)	4-7 Collateral Vessels (N=146)	8 Collateral Vessels (N=80)	Trend P value
All Study Participants				
Six-minute walk (feet)	1,064 (47)	1,165 (28)	1,246 (41)	0.007
Four-meter walking velocity (usual pace) (meters/second)	0.84 (0.02)	0.88 (0.01)	0.91 (0.02)	0.029
Four-meter walking velocity (fastest pace) (meters/second)	1.17 (0.03)	1.22 (0.02)	1.29 (0.03)	0.002
Short Physical Performance Battery	9.21 (0.33)	9.80 (0.19)	10.11 (0.27)	0.059
Participants without Superficial Femoral Artery Occlusion				
	0-3 Collateral Vessels (N=62)	4-7 Collateral Vessels (N=127)	8 Collateral Vessels (N=61)	
Six-minute walk (feet)	1,046 (46)	1,193 (30)	1,249 (45)	0.003
Four-meter walking velocity (usual pace) (meters/second)	0.83 (0.02)	0.88 (0.01)	0.90 (0.02)	0.033
Four-meter walking velocity (rapid pace) (meters/second)	1.15 (0.04)	1.24 (0.02)	1.27 (0.03)	0.010
Short Physical Performance Battery (0-12 scale, 12=best)	9.17 (0.33)	9.84 (0.21)	10.03 (0.32)	0.064

*Mean values (standard error) are shown after statistical adjustment. Model adjusts for age, sex, race, comorbidities, smoking, ankle brachial index, and BMI.