Arterial dissection during peripheral vascular interventions

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ABSTRACT

Objective: Arterial dissection (AD) is a known complication of peripheral vascular interventions (PVIs), but its incidence and significance have not been well-characterized. This study examines AD in the Vascular Quality Initiative database for patients treated for peripheral arterial disease. Our hypothesis is that AD is associated with decreased patency and worse limb outcomes.

Methods: The Vascular Quality Initiative PVI registry (2016-2021) was reviewed. Patients were divided based on the presence or absence of reported AD during the procedure. Trend of incidence and management of AD was derived. The characteristics and outcomes of patients with and without AD were compared. The primary endpoint was primary patency.

Results: There was a total of 177,790 cases, and 3% had AD. The incidence of AD significantly increased over the study period from 2.4% to 3.6% ($P = .007$). Endovascular therapy was used to treat AD in 83.7% of cases, 14.5% were treated medically, and only 1.8% required open surgery. Patients with AD were significantly more likely to be female (47.4% vs 39.7%; $P < .001$). Patient with AD were more likely to have a history of smoking (79.7% vs 77.2%; $P < .001$), but were significantly less likely to be on dialysis (8.2% vs 9.3%; $P < .001$) compared with patients without AD. Patients with AD were more likely to have femoropopliteal disease (45.2% vs 38.0%; $P < .001$) and undergo treatment of more complex disease as denoted by higher mean number of lesions treated (1.95 ± 1.01 vs 1.71 ± 0.89; $P < .001$), longer occlusion length (8 ± 16 vs 7 ± 15 cm; $P < .001$), and more severe TransAtlantic Inter-Society Consensus grade (Grade D: 36.2% vs 29.1%; $P < .001$). The proportion of stenting as a treatment modality was higher in the dissection group (55.4% vs 41.1%; $P < .001$). After a mean follow-up of 828 days, patients with AD had significantly lower primary patency than patients without AD. Kaplan-Meier curves demonstrated that the AD group had lower primary patency (86.9% vs 91%; $P < .001$) and reintervention-free survival (79.5 % vs 84.1%; $P < .001$) at 1 year with difference in amputation-free survival. Cox proportional hazard regression confirmed the independent association of AD with primary patency and reintervention-free survival.

Conclusions: AD is more common in women and is more likely to occur during treatment of the femoropopliteal segment. AD is associated with decreased primary patency and reintervention-free survival after PVI for peripheral arterial disease. (J Vasc Surg 2024;79:339-47.)

Keywords: Arterial dissection; Peripheral arterial disease; Peripheral vascular interventions

Arterial dissection (AD) is an acute complication that is commonly observed with endovascular treatment of peripheral arterial disease (PAD) due to the intrinsic mechanism of the various modalities of treatment. Balloon oversizing, especially in complex calcified lesions, was found to be associated with acute dissection that often requires adjunctive therapy such as prolonged balloon inflation or bail-out stenting.[1,2] Furthermore, dissection following angioplasty has been reported to be associated with decreased patency.[3] Several technical strategies have been introduced to prevent dissection by using long balloons, prolonged inflation times, or the use of scoring balloons.[4-6]

In the literature, the reported incidence of AD is highly variable, ranging from 7.4% to 84% depending on the vascular bed and the treatment modality.[1,7,8] Further, factors associated with AD and its effect on both short-term and long-term outcomes remain inconclusive and limited to institutional series. This study aims to determine the incidence of AD during lower extremity

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peripheral vascular interventions (PVIs) for the treatment of PAD, associated factors, and its impact on the outcomes of revascularization. Our hypothesis is that AD during PVI is associated with inferior primary patency.

METHODS

This retrospective cohort study used deidentified information from participating institutions in the Vascular Quality Initiative (VQI). The study was exempt by the institutional review board for research, and no patient consent was needed.

Data source. The PVI files (2016-2021) of the VQI database were reviewed. The VQI is a prospectively collected multicenter registry database from more than 900 participating hospitals.[9] The data are collected under the auspices of the Society for Vascular Surgery Patient Safety Organization, which governs the VQI database and performs regular audits at participating centers to supervise the quality measure analysis and data sharing.[10,11]

Patient population. Patients undergoing PVI were divided into two groups based on the presence or absence of AD on the target lesion. AD was defined as a postoperative dissection complication of the target lesion. Patients with missing data on the AD variable were excluded. Patients with concomitant use of chronic total occlusion device to cross the occlusion or re-enter the lumen through the adventitial layer were also excluded. Only patients with occlusive disease were included, and patients with aneurysms were excluded.

Baseline characteristics. Demographic information compared between the two groups included age, sex, and race. The following comorbidities were compared: hypertension, diabetes, smoking, chronic obstructive pulmonary disease, coronary artery disease (CAD), congestive heart failure, history of coronary artery bypass graft or percutaneous coronary intervention surgery, end-stage renal disease (ESRD), history of major amputation and carotid intervention, ambulatory status, and preoperative medication usage.

The two groups were also compared for the indication for revascularization, treatment urgency, laterality of the treated lesion, number of treated arteries, fluoroscopy time, and anticoagulant use. Other procedural characteristics that were compared included anatomic location of the treated artery divided into aortoiliac, femoropopliteal, tibial, and multilevel (if more than one of the prior three levels were treated during the same PVI), TransAtlantic Inter-Society Consensus (TASC) classification of the first treated artery, and the total length of the lesion and occlusion. The type of treatment, which was divided into stenting, balloon angioplasty, atherectomy, and combined atherectomy and stenting was also compared.

Outcomes. Periprocedural outcomes included technical success, defined as residual stenoses below or equal to 30%. Postprocedural complications such as cardiac, pulmonary, renal, and access site complications were compared.

Long-term outcomes compared in this study were primary patency, reintervention, major amputation, and mortality. Patency was defined as a state where the artery is free from stenosis. Reintervention was defined as any repeat revascularization procedure related to the initial PAD intervention.

Subgroup analysis. Subgroup analysis was performed to evaluate factors that are potentially associated with AD in an optimal balloon angioplasty procedure. Sensitivity analysis was carried out on patients with femoropopliteal artery as the first artery treated only using balloon angioplasty and excluded patients with bailout stenting, which defined as unplanned stent placement following suboptimal balloon angioplasty or atherectomy.

Statistical analysis. Frequencies and mean and standard deviation were used to present categorical and continuous variables, respectively. Categorical variables of the demographic and procedural characteristics were compared using the Pearson χ^2 test, whereas continuous variables were compared using the *t*-test. Multivariable regression was performed to explore the predictors of AD. Periprocedural outcomes were compared using bivariate analyses. Primary patency, reintervention-free survival, amputation-free survival, and freedom from amputation were estimated and compared using the Kaplan-Meier curve and multivariable Cox proportional hazard regression adjusting significant covariates on demographic and procedural characteristics. A P value of $< .05$ was considered statistically significant, and tests were two-sided. All analyses were performed using R statistical software version 4.0.4 (The R Foundation).

RESULTS

Incidence. The overall incidence of AD during PVI was 3% (n = 5348/177,790). AD significantly increased during

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective review of prospectively collected Vascular Quality Initiative data
- **Key Findings:** Of 181,798 patients undergoing peripheral vascular interventions, 3.2% had arterial dissection (AD). Risk factors associated with AD included female sex, higher TransAtlantic Inter-Society Consensus classification, and stenting. AD was associated with lower primary patency and reintervention-free survival.
- **Take Home Message:** Developing AD after peripheral vascular interventions portends a higher risk of reintervention or mortality.

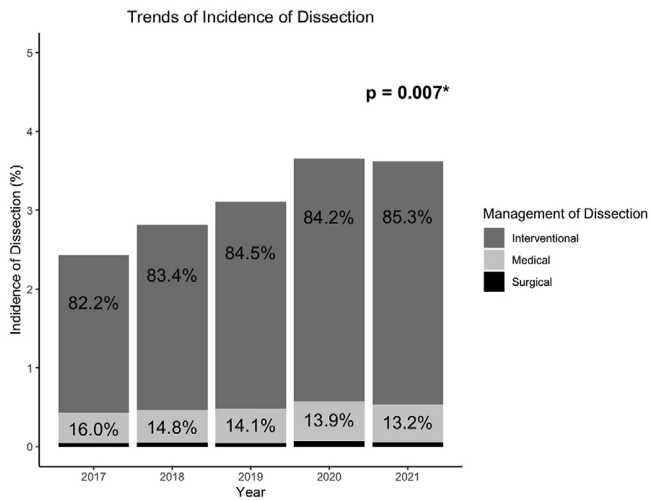

Fig 1. Trend of incidence of dissection per year over study period. *P* value denotes increasing incidence of dissection from 2.3% in 2017 to 3.6% in 2021.

the study period from 2.4% in 2017 to 3.6% in 2021 ($P = .007$) (Fig 1). Among patients with AD, 83.7% required endovascular intervention, 14.5% did not require any additional treatment, and 1.8% required open surgery.

Patient characteristics. Patients who developed AD during PVI were more likely female, Black, and have a history of smoking (Table I) In contrast, patients with AD were less likely to have a history of CAD (32.7% vs 35.2%; $P < .001$), amputation, and require dialysis (8.2% vs 9.3%; $P < .001$). Patients who had interventional or surgically managed AD were more likely to have a history of smoking, and less likely to have CAD compared with patients with medically managed AD (Supplementary Table I, online only).

Procedural characteristics. Patients with AD were more likely treated for chronic limb-threatening ischemia (57.6% vs 55.2%; $P < .001$) and on an elective basis (85.0% vs 82.6%). The incidence of AD was associated with a higher number of arteries being treated, as demonstrated by the higher incidence of AD among patients with three or more arteries treated ($P < .001$) (Table II). Procedures that had AD had significantly longer fluoroscopy time and higher mean number of treated arteries and greater intravascular ultrasound (IVUS) use ($P < .001$). Patients with AD were more likely to have the femoropopliteal arteries or multiple levels of disease treated. Procedures with AD were more likely to involve TASC II C and D ($P < .001$) and longer mean length of the lesion and longer mean occlusion length ($P = .005$). Stenting was found significantly higher among patients who had developed AD compared with those with no AD ($P < .001$).

Compared with patients who had medically managed AD, patients with AD requiring interventional or surgical procedures were more likely to have longer fluoroscopy time, underwent stenting procedures, longer lesion length, and more likely to use IVUS (Supplementary Table I, online only).

Periprocedural outcomes. Technical success was significantly lower in the AD group compared with procedures in the group without AD (92.6% vs 94.1%; $P = .001$) (Table III). Comparison of post-procedural complications demonstrated higher proportions of cardiac (2.1% vs 1.2%; $P < .001$) and pulmonary complications among patients with AD. However, the total hospital length of stay was significantly shorter in the AD group (3 ± 6.8 vs 3.6 ± 21.3 days; $P < .001$).

Long-term outcomes. The mean follow-up time was longer in patients with AD compared with those with no AD. Patients with AD had significantly lower primary patency (86.6% vs 89.9%; $P < .001$). At 1 year, primary patency was significantly lower in the AD group (86.9% vs 91%; $P < .001$) (Fig 2). For patients with AD, reintervention-free survival was 79.5% at 1 year compared with 84.1% in patients without AD ($P < .001$) (Fig 3).

Subgroup analysis of femoropopliteal artery intervention with balloon angioplasty. Patients treated for femoropopliteal artery disease with AD were more likely female (53.2% vs 44.8%; $P < .001$) and taking aspirin (77.6% vs 73.5%; $P = .03$), and less likely to have a history of CAD (32.1% vs 37%; $P < .018$) and taking anticoagulation (16% vs 20.5%; $P < .009$) (Supplementary Table II, online only).

Comparison of procedural characteristics indicated higher incidence of AD with a higher number of arteries being treated (Supplementary Table III, online only). Interventions with AD were more likely to have longer mean fluoroscopy time, longer total lesion length (14 ± 16 vs 11 ± 14 cm; $P < .001$), longer total occlusion length (7 ± 15 vs 5 ± 11 cm; $P < .001$), and more likely to have more severe lesions (TASC II D: 19.6% vs 15.5%; $P < .001$).

Periprocedural outcomes of patients with undergoing femoropopliteal artery intervention with balloon angioplasty showed higher proportions of pulmonary (1.3% vs 0.4%; $P = .032$) and access site complications (6.3% vs 2.4%; $P < .001$) in patients with AD. (Supplementary Table IV, online only) There was no difference in major amputation and overall mortality between the two groups.

Multivariable regression analysis of factors associated with AD. Multivariable regression analyses showed female sex and number of arteries treated were associated with the incidence of AD (Table IV). More severe lesions were associated with AD as demonstrated by significant association in higher TASC class (Class C: odds ratio [OR], 1.45; 95% confidence interval [CI], 1.27-1.67; $P < .001$ and Class D: OR, 1.55; 95% CI, 1.35-1.78; $P < .001$). Stenting (OR, 1.53; 95% CI, 1.39-1.68; $P < .001$) was associated with AD

Table I. Patients' characteristics

Characteristic	Dissection (n = 5580)	No dissection (n = 176,218)	*P* value[a]
Age, years	69 ± 11	69 ± 11	.6
Female sex	2642 (47.3)	69,689 (39.5)	**<.001**
Race			**<.001**
White	4162 (74.7)	132,442 (75.2)	
African American	1030 (18.5)	29,473 (16.7)	
Other	381 (6.8)	14,245 (8.1)	
Hypertension	4952 (89.7)	155,800 (88.9)	.069
Diabetes	3172 (56.9)	98,039 (55.7)	.076
History of smoking	4445 (79.7)	135,974 (77.2)	**<.001**
COPD	1561 (28.0)	47,101 (26.7)	**.040**
Coronary artery disease	1823 (32.7)	62,181 (35.3)	**<.001**
Congestive heart failure	1163 (20.9)	37,933 (21.5)	.2
CABG/PCI	1980 (36.3)	62,912 (36.4)	.9
ESRD			**<.001**
Normal kidney	5092 (91.3)	157,853 (89.6)	
Kidney transplant	40 (0.7)	2004 (1.1)	
Dialysis	448 (8.0)	16,283 (9.2)	
Prior amputation	976 (17.5)	32,922 (18.7)	**.024**
Prior carotid intervention	449 (8.2)	13,765 (8.0)	.5
Ambulatory status			.4
Ambulatory	3761 (67.9)	118,144 (68.1)	
Ambulatory with assistance	1346 (24.3)	42,792 (24.7)	
Wheelchair	407 (7.3)	11,783 (6.8)	
Bedridden	26 (0.5)	765 (0.4)	
ASA	4090 (73.3)	125,532 (71.3)	**<.001**
P2Y12 inhibitor	2510 (45.0)	77,375 (43.9)	.12
Statin	4229 (75.8)	132,798 (75.4)	.5
Anticoagulation	965 (17.3)	35,838 (20.4)	**<.001**

ASA, Aspirin; *CABG/PCI*, coronary artery bypass graft/percutaneous coronary intervention; *COPD*, chronic obstructive pulmonary disease; *ESRD*, end-stage renal disease.
Data are presented as number (%) or mean ± standard deviation.
Boldface *P* values indicate statistical significance ($P < .05$).
[a]Welch two-sample *t*-test; Pearson χ^2 test.

compared with balloon angioplasty. In contrast, history of CAD was protective on the occurrence of AD (OR, 0.84; 95% CI, 0.79-0.91; $P < .001$).

On subgroup analyses of patients undergoing femoropopliteal intervention with balloon angioplasty, female and higher TASC class ($P = .011$) were associated with the incidence of AD (Supplementary Table V, online only). Similar to the general population, patients with a history of CAD had a lower risk of developing AD.

Multivariable Cox proportional hazard model was done by adjusting covariates of sex, CAD, preoperative aspirin, preoperative anticoagulation, indication, treated artery, TASC, and treatment type. The analysis indicated AD was independently associated with lower primary patency (adjusted hazard ratio, 0.78; 95% CI, 0.67-0.92; $P = .002$) and reintervention-free survival (adjusted hazard ratio, 0.81; 95% CI, 0.71-0.93; $P = .002$) (Supplementary Table VI, online only). There was no difference in amputation-free survival between the two groups (Fig 4), and there was no difference in long-term outcomes between patients with interventional or surgically managed AD and patients with medically managed AD (Supplementary Figs 1 and 2, online only)

DISCUSSION

This paper demonstrates that AD during PVI for PAD has increased from 2.3% in 2017 to 3.6% in 2021 in the VQI database. AD was associated with female sex, smoking history, and more severe lesions but was less likely in patients on dialysis. AD was independently associated with lower primary patency and reintervention-free survival.

Table II. Procedural characteristics

Characteristic	Dissection (n = 5580)	No dissection (n = 176,218)	*P* value[a]
Indication			**<.001**
CLTI	2860 (59.0)	85,726 (58.0)	
Claudication	1962 (39.4)	61,233 (39.5)	
Acute limb ischemia	160 (3.2)	7934 (5.1)	
Urgency			**<.001**
Elective	4749 (85.2)	145,697 (82.7)	
Urgent/emergent	827 (14.8)	30,403 (17.3)	
Laterality			.2
Right	2461 (49.2)	77,990 (50.2)	
Left	2538 (50.8)	77,509 (49.8)	
Treated arteries			**<.001**
1	2411 (43.2)	91,063 (51.7)	
2	1655 (29.7)	53,717 (30.5)	
3-4	1514 (27.1)	31,438 (17.8)	
No. of treated arteries	1.95 ± 1.01	1.71 ± 0.89	**<.001**
Fluoroscopy time, minutes	25 ± 20	19 ± 21	**<.001**
Anticoagulant during the procedure			**<.001**
Heparin	5334 (97.9)	165,087 (96.1)	
Bivalirudin	63 (1.2)	1710 (1.0)	
Protamine	1240 (23.3)	45,594 (27.7)	**<.001**
Treatment artery			**<.001**
Femoropopliteal	2550 (45.8)	67,212 (38.3)	
Multilevel	2114 (38.0)	45,962 (26.2)	
Aortoiliac	579 (10.4)	36,962 (21.1)	
Tibial	325 (5.8)	25,303 (14.4)	
TASC			**<.001**
A	582 (14.2)	29,209 (22.1)	
B	852 (20.8)	32,716 (24.8)	
C	1132 (27.7)	30,982 (23.4)	
D	1521 (37.2)	39,264 (29.7)	
Treatment type			**<.001**
Balloon angioplasty	1185 (21.2)	67,262 (38.2)	
Stenting	3101 (55.6)	72,629 (41.2)	
Atherectomy	410 (7.3)	24,766 (14.1)	
Atherectomy and stenting	884 (15.8)	11,561 (6.6)	
Bailout stenting[b]	1673 (30.0)	2772 (1.6)	**<.001**
Total length treated, cm	20 ± 22	16 ± 21	**<.001**
Total occlusion length, cm	8 ± 16	7 ± 16	**<.001**

CLI, Critical limb ischemia; *CLTI*, chronic limb-threatening ischemia; *TASC*, Trans-Atlantic Inter-Society Consensus.
Data are presented as number (%) or mean ± standard deviation.
Boldface *P* values indicate statistical significance ($P < .05$).
Numbers are lower for long-term follow-up because of missing values in the database.
[a]Pearson χ^2 test; Welch two-sample *t*-test.
[b]Bailout stenting as a proportion of overall stenting.

The self-reported incidence of AD in this study was far lower than the reported incidence of dissection in previous prospective studies, which showed the incidence of AD to be 47.4% with drug-coated balloon angioplasty and 73.5% with percutaneous transluminal plain balloon angioplasty in the PACIFIER trial, 79.7% in the AcoArt II trial cohort, and 84% in a study by Fujihara et al.[1,8,12,13] This was mainly because the present study included all patients who had undergone PVI regardless of which artery treated and the type of treatment being used. In

Table III. Outcomes

Outcomes	Dissection (n = 2636)	No dissection (n = 117,396)	*P* value[a]
Periprocedural outcomes			
Technical result, successful	2405 (92.6)	107,709 (94.1)	**.001**
Post-procedural complications			
Cardiac	57 (2.2)	1393 (1.2)	**<.001**
Myocardial infarction	14 (0.5)	484 (0.4)	.4
Pulmonary	25 (0.9)	553 (0.5)	**<.001**
Renal	26 (1.0)	878 (0.8)	.2
Access site complication	118 (4.5)	2876 (2.5)	**<.001**
Hospital LOS, days	2.9 ± 6.7	3.6 ± 21.2	**<.001**
30-day mortality	34 (1.3)	1945 (1.7)	.13
Long-term outcomes			
Primary patency	1200 (86.6)	50,899 (89.9)	**<.001**
Reintervention	370 (20.4)	11,869 (15.8)	**<.001**
Major amputation	126 (7.5)	5915 (8.6)	.13
Mortality	453 (17.2)	19,425 (16.7)	.5
Follow-up time, days	832 ± 512	761 ± 514	**<.001**

LOS, Length of stay.
Data are presented as number (%) or mean ± standard deviation.
Boldface *P* values indicate statistical significance ($P < .05$).
[a]Pearson χ^2 test; Welch two-sample *t*-test.

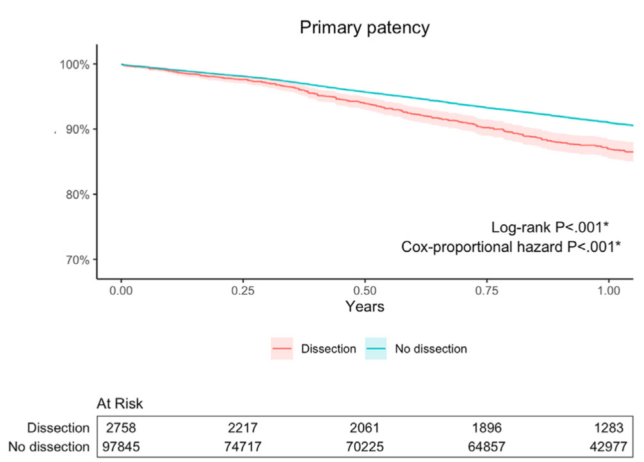

Fig 2. Kaplan-Meier curve of primary patency rates between patients with arterial dissection (AD) and no AD.

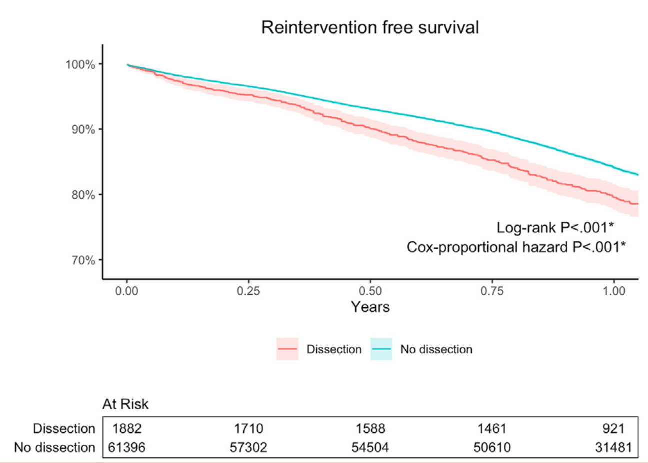

Fig 3. Kaplan-Meier curve of reintervention-free survival between patients with arterial dissection (AD) and no AD.

contrast, the previous reports only specified patients with a particular type of treatment and were limited to the femoropopliteal artery. In addition, there was a core lab reviewing the images and calling the dissections in the previous study. Although subgroup analysis was performed in this study, the overall incidence of AD over the study period was just 2%. The difference between these results may likely come from a lower proportion of patients with severe lesions, as the previous study reported mean total lesion length of 14.7 to 15.2 cm, whereas this present study had a mean total lesion length of 10.7 cm.[8,13] Higher proportions of TASC class C/D were also found in the previous studies (46.5%-69.4%) compared with this present study (31.5%).[5,8] The reporting in the VQI is subject to bias by the operator, depends on the extent of completion angiography performed, and is likely underreported.

The numbers of AD during PVI have increased over the study period, particularly with an uptick after 2019. These periods are when the COVID-19 outbreaks occurred, which heavily affected vascular surgical practice in a

Table IV. Factors associated with arterial dissection (AD) on multivariable regression for any first artery treated

Characteristic	OR	95% CI	*P* value
Female sex	1.41	1.31-1.51	**<.001**
Race			.5
White	—	—	
Black	1.06	0.96-1.16	
Other	1.00	0.87-1.14	
History of smoking	1.05	0.96-1.14	.3
COPD	0.97	0.89-1.05	.4
Coronary artery disease	0.87	0.81-0.94	**<.001**
Dialysis	0.97	0.85-1.09	.6
Aspirin	1.12	1.03-1.21	**.006**
Anticoagulant use	0.87	0.79-0.95	**.002**
Indication			**<.001**
Claudication	—	—	
Acute limb ischemia	0.60	0.48-0.74	
CLTI	1.07	1.00-1.16	
Urgency	0.90	0.69-1.19	.4
No. treated arteries	1.20	1.15-1.25	**<.001**
TASC II			**<.001**
A	—	—	
B	1.18	1.04-1.32	
C	1.62	1.45-1.82	
D	1.70	1.52-1.91	
Treatment type			**<.001**
Balloon angioplasty	—	—	
Stenting	2.69	2.47-2.93	
Atherectomy	0.74	0.64-0.85	
Atherectomy and stenting	3.44	3.07-3.85	

CI, Confidence interval; *CLTI*, chronic limb-threatening ischemia; COPD, chronic obstructive pulmonary disease; *OR*, odds ratio; *TASC*, Trans-Atlantic Inter-Society Consensus.
Boldface *P* values indicate statistical significance ($P < .05$).

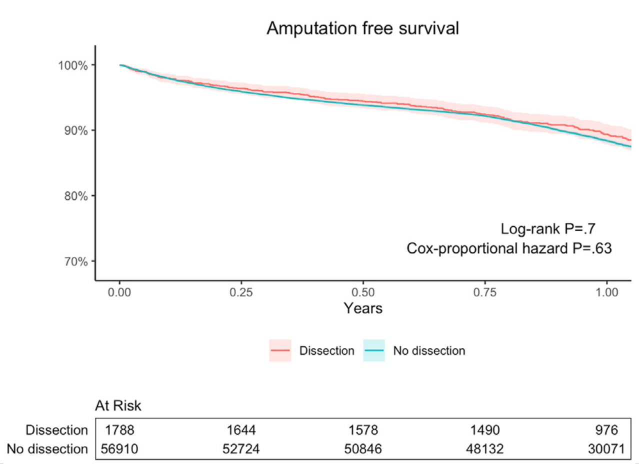

Fig 4. Kaplan-Meier curve of amputation-free survival between patients with arterial dissection (AD) and no AD.

multitude of aspects.[14,15] Although no direct relationship between COVID-19 infection and the tendency to develop AD following PVI procedures has been shown, this may likely be due to an increase in endovascular procedures during the pandemic.[16]

The characteristics of the treated lesions play a major role in the development of AD. Severe lesions characterized by a high TASC category were found to predict the development of AD during PVI. This result was consistent with the previous studies that evaluated AD in patients who underwent femoropopliteal intervention using balloon angioplasty.[6,17] Kobayashi et al, in their study, also found TASC class C and D were associated with more severe dissection.[3] On multivariate analyses of femoropopliteal intervention, occlusion length was predictive of the development of AD. Other studies demonstrated similar results showing longer lesion length and total occlusion were predictive of AD.[3,5,6,17-19]

The mechanical nature of balloon and stent expansion in endovascular intervention forces stenosed vessels to be distended and can result in atherosclerotic plaque fracture, intimal splitting, and localized dissection.[8,20] Certain patient and procedural conditions may predispose to the development of dissection despite the diameter of the balloon or stent used. This study demonstrated that the proportion of female patients was higher in the AD group. This is likely due to smaller vessel diameter among female patients, as previous studies also showed significantly less reference vessel diameter in the dissection group.[13,21,22] Higher proportions of preexisting comorbidities such as chronic obstructive pulmonary disease and history of smoking that are directly associated with plaque formation were also found in the AD group.[23-25] However, the morphology and the degree of vascular calcification may be different compared with patients with ESRD and on dialysis.[26] This study found that significantly lower proportions of kidney transplant recipients and patients on dialysis were found in the AD group. This was consistent with the previous studies that showed a protective effect of ESRD on AD.[5,8] Although the exact mechanism of this relationship remains unclear, diffuse concentric calcium deposition on the arterial lumen prevents dissection, as it distributes the forces of the expanded stent more diffusely as opposed to local eccentric calcium deposition, which was also reported to be associated with dissection.[5,26,27]

The damaged vessel walls from dissection in this study significantly impacted the long-term outcomes. Primary patency and reintervention-free survival were significantly lower in the overall AD group. No significant difference was found in the results within the femoropopliteal and balloon angioplasty subgroup. Previous studies showed the difference in primary patency was only found between severe dissection and mild or no dissection.[3,8] The AcoArt I trial showed a difference in primary patency was only in the percutaneous transluminal plain balloon angioplasty group but not in the drug-coated balloon group.[13] The VQI does not capture the severity of the dissection, and it is possible that analysis including only severe dissections could have impacted patency of the treated femoropopliteal segment.

Interestingly, the results of this study demonstrated significant differences in which ADs were more likely to occur in elective cases, less likely on protamine reversal, and had shorter length of stay. Contemporary published reports on iatrogenic dissection following angioplasty of the peripheral and coronary arteries did not include these variables in the analyses.[5,17,28] The exact explanation for these discrepancies is unclear. A previous VQI study that examined the outcomes of elective PVI cases in different settings (ie, hospital outpatient department, ambulatory surgical center, and office-based laboratory) demonstrated high variabilities in access-site complications and protamine use.[29] This may indicate that AD is more likely to occur in an outpatient setting, which also tends to have a shorter length of stay. However, the previous study did not include dissection as the definition of complications. Given the obscure granular reasons and the lack of the reported variables of interest, these results beg for further studies to examine the consistency of these findings.

This study has limitations of a retrospective registry-based study related to selection bias, as dissection was self-reported by vascular specialists across centers without actual review of imaging. Misclassification bias may also occur then the AD was non-flow limiting and thus treated as negligible rather than categorized as non-intervention requiring AD. The difference in imaging equipment to assess the presence of dissection may also impact its reporting. Although data on IVUS use has been reported in this study, many data were missing, which may indicate an underreporting. Procedures performed with a portable fluoroscopy machine may not be as good as a fixed imaging unit in a hybrid operating room, and thus the detection of subtle dissections are more likely to be missed. We did not have information regarding the degree of dissection severity, which may affect the long-term results as reported in the previous studies. We did not include the pressure of the balloon and the inflation time, which was found to influence the occurrence of AD, as they are not available in the database.[17]

CONCLUSIONS

The reported incidence of AD in the VQI is low but increasing. AD is more common in women and patients with more advanced disease. Even though most can be treated with endovascular means, AD is associated with decreased primary patency and increased reintervention.

AUTHOR CONTRIBUTIONS

Conception and design: FD, MS, JC, BT, RG, COC
Analysis and interpretation: FD, DA, MS, COC
Data collection: FD
Writing the article: FD, DA, COC
Critical revision of the article: FD, MS, JC, BT, RG, COC
Final approval of the article: FD, DA, MS, JC, BT, RG, COC
Statistical analysis: FD, MS, COC
Obtained funding: Not applicable
Overall responsibility: FD

DISCLOSURES

None.

REFERENCES

1. Armstrong EJ, Brodmann M, Deaton DH, et al. Dissections after infrainguinal percutaneous transluminal angioplasty: a systematic

review and current state of clinical evidence. *J Endovasc Ther.* 2019;26:479–489.
2. Abd El-Mabood ESA, Elkashef OA, Hosny AS, Zaghloul H. Bailout procedures during percutaneous transluminal angioplasty of superficial femoral artery occlusive disease. *Egypt J Radiol Nucl Med.* 2020;51:1–13.
3. Kobayashi N, Hirano K, Yamawaki M, et al. Simple classification and clinical outcomes of angiographic dissection after balloon angioplasty for femoropopliteal disease. *J Vasc Surg.* 2018;67:1151–1158.
4. Spiliopoulos S, Karamitros A, Reppas L, Brountzos E. Novel balloon technologies to minimize dissection of peripheral angioplasty. *Expert Rev Med Devices.* 2019;16:581–588.
5. Hong H, Park UJ, Roh YN, Kim HT. Predictive factors of severe dissection after balloon angioplasty for femoropopliteal artery disease. *Ann Vasc Surg.* 2021;77:109–115.
6. Horie K, Tanaka A, Taguri M, Inoue N. Impact of scoring balloons on percutaneous transluminal angioplasty outcomes in femoropopliteal lesions. *J Endovasc Ther.* 2020;27:481–491.
7. Isner JM, Rosenfield K, Losordo DW, et al. Percutaneous intravascular US as adjunct to catheter-based interventions: preliminary experience in patients with peripheral vascular disease. *Radiology.* 1990;175:61–70.
8. Fujihara M, Takahara M, Sasaki S, et al. Angiographic dissection patterns and patency outcomes after balloon angioplasty for superficial femoral artery disease. *J Endovasc Ther.* 2017;24:367–375.
9. Cronenwett JL, Kraiss LW, Cambria RP. The Society for Vascular Surgery vascular quality initiative. *J Vasc Surg.* 2012;55:1529–1537.
10. Brooke BS, Beck AW, Kraiss LW, et al. Association of quality improvement registry participation with appropriate follow-up after vascular procedures. *JAMA Surg.* 2018;153:216.
11. Bensley RP, Beck AW. Using the Vascular Quality Initiative to improve quality of care and patient outcomes for vascular surgery patients. *Semin Vasc Surg.* 2015;28:97–102.
12. Werk M, Albrecht T, Meyer DR, et al. Paclitaxel-coated balloons reduce restenosis after femoro-popliteal angioplasty: evidence from the randomized PACIFIER trial. *Circ Cardiovasc Interv.* 2012;5:831–840.
13. Ren H, Liu J, Zhang J, et al. Association between post-balloon angioplasty dissection and primary patency in complex femoropopliteal artery disease: 2-year clinical outcomes of the AcoArt I trial. *J Int Med Res.* 2021;49:030006052110065.
14. Ho VT, Eberhard AV, Asch SM, et al. US National trends in vascular surgical practice during the COVID-19 pandemic. *JAMA Surg.* 2021;156:681.
15. Björses K, Blomgren L, Holsti M, Jonsson M, Smidfelt K, Mani K. Editor's choice - the impact of covid-19 on vascular procedures in Sweden 2020. *Eur J Vasc Endovasc Surg.* 2021;62:136–137.
16. Duarte A, Gouveia E Melo R, Lopes A, Rato JP, Valente J, Pedro LM. Lessons learned from the impact of the COVID-19 pandemic in a vascular surgery department and preparation for future outbreaks. *Ann Vasc Surg.* 2021;73:97–106.
17. Horie K, Tanaka A, Taguri M, Kato S, Inoue N. Impact of prolonged inflation times during plain balloon angioplasty on angiographic dissection in femoropopliteal lesions. *J Endovasc Ther.* 2018;25:683–691.
18. Schmidt A, Piorkowski M, Görner H, et al. Drug-coated balloons for complex femoropopliteal lesions. *JACC Cardiovasc Interv.* 2016;9:715–724.
19. Jang SJ, Hsieh CA, Huang HL, et al. Feasibility and clinical outcomes of peripheral drug-coated balloon in high-risk patients with femoropopliteal disease. Taniyama Y, editor. *PLoS One.* 2015;10:e0143658.
20. Castaneda-Zuniga WR, Formanek A, Tadavarthy M, et al. The mechanism of balloon angioplasty. *Radiology.* 1980;135:565–571.
21. Schramm K, Rochon P. Gender differences in peripheral vascular disease. *Semin Interv Radiol.* 2018;35:009–16.
22. Choi KH, Park TK, Kim J, et al. Sex differences in outcomes following endovascular treatment for symptomatic peripheral artery disease: an analysis from the K-VIS ELLA registry. *J Am Heart Assoc.* 2019;8:e010849.
23. Soden PA, Zettervall SL, Deery SE, et al. Black patients present with more severe vascular disease and a greater burden of risk factors than white patients at time of major vascular intervention. *J Vasc Surg.* 2018;67:549–556.e3.
24. Thiruvoipati T. Peripheral artery disease in patients with diabetes: epidemiology, mechanisms, and outcomes. *World J Diabetes.* 2015;6:961.
25. Blum A, Simsolo C, Sirchan R. Vascular responsiveness in patients with chronic obstructive pulmonary disease (COPD). *Eur J Intern Med.* 2014;25:370–373.
26. Johnson RC, Leopold JA, Loscalzo J. Vascular calcification: pathobiological mechanisms and clinical implications. *Circ Res.* 2006;99:1044–1059.
27. Fitzgerald PJ, Ports TA, Yock PG. Contribution of localized calcium deposits to dissection after angioplasty. An observational study using intravascular ultrasound. *Circulation.* 1992;86:64–70.
28. Hui L, Shin ES, Jun EJ, et al. Impact of dissection after drug-coated balloon treatment of De novo coronary lesions: angiographic and clinical outcomes. *Yonsei Med J.* 2020;61:1004.
29. Chow CY, Mathlouthi A, Zarrintan S, Swafford EP, Siracuse JJ, Malas MB. Outcomes of elective peripheral endovascular interventions for peripheral arterial disease performed in hospital outpatient departments, ambulatory surgical centers and office-based labs. *J Vasc Surg.* 2023;77:1732–1740.

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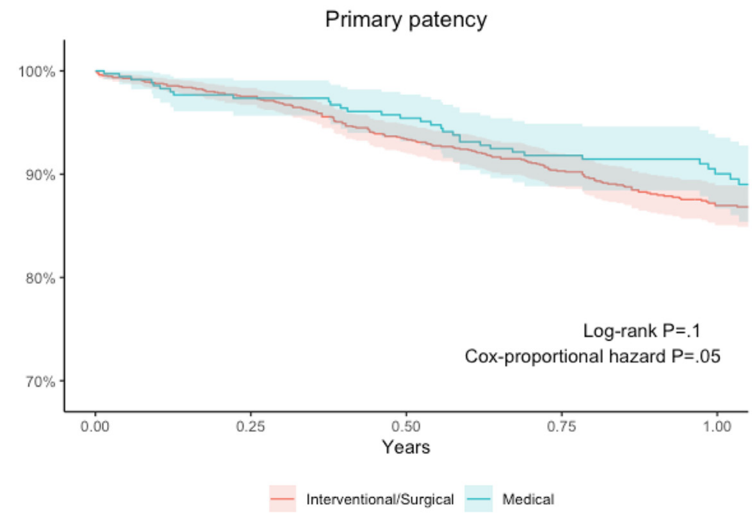
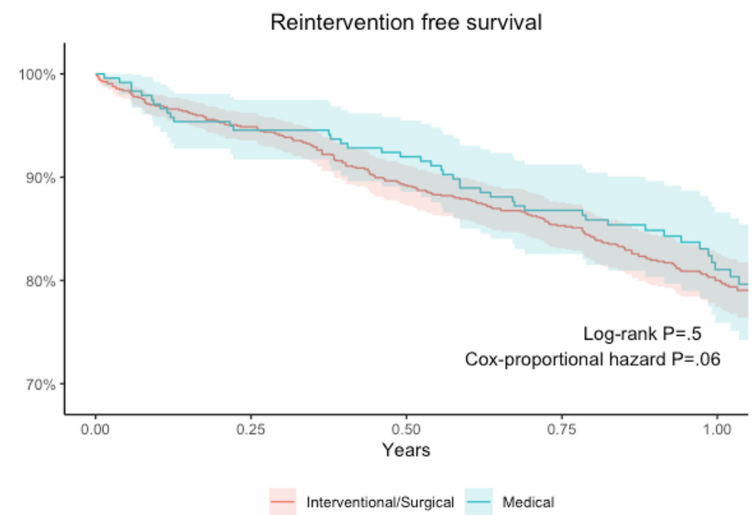


At Risk

Interventional/Surgical	1553	1208	1127	1055	723
Medical	365	307	292	273	180

Supplementary Fig 1 (online only). Kaplan-Meier curve of primary patency between patients with interventional or surgically required arterial dissection (AD) and AD that does not require further treatment.



At Risk

Interventional/Surgical	1055	934	868	815	520
Medical	240	222	214	197	118

Supplementary Fig 2 (online only). Kaplan-Meier curve of reintervention-free survival between patients with interventional or surgically required arterial dissection (AD) and AD that does not require further treatment.

Supplementary Table I (online only). Baseline characteristics of patients with arterial dissection (AD) requiring interventions or surgical procedures and non-requiring procedures

Characteristic	Interventional/surgical (n = 4571)	Medical (n = 777)	*P* value[a]
Patients' characteristics			
Age, years	68 ± 11	70 ± 11	**.002**
Female sex	2153 (47.1)	380 (48.9)	.4
Race			.12
White	3406 (74.6)	593 (76.3)	
African American	849 (18.6)	123 (15.8)	
Other	309 (6.8)	61 (7.9)	
Hypertension	4059 (89.8)	689 (89.2)	.6
Diabetes	2594 (56.8)	451 (58.0)	.5
History of smoking	3668 (80.3)	594 (76.4)	**.015**
COPD	1292 (28.3)	206 (26.5)	.3
Coronary artery disease	1452 (31.8)	295 (38.0)	**<.001**
Congestive heart failure	935 (20.5)	189 (24.3)	**.015**
CABG/PCI	1596 (35.8)	308 (40.1)	**.024**
ESRD			.2
Normal kidney	4179 (91.4)	696 (89.6)	
Kidney transplant	30 (0.7)	7 (0.9)	
Dialysis	362 (7.9)	74 (9.5)	
Prior amputation	802 (17.6)	141 (18.1)	.7
Prior carotid intervention	365 (8.2)	73 (9.5)	.2
Ambulatory status			.095
Ambulatory	3090 (68.1)	509 (65.8)	
Ambulatory with assistance	1103 (24.3)	194 (25.1)	
Wheelchair	327 (7.2)	62 (8.0)	
Bedridden	18 (0.4)	8 (1.0)	
ASA	3323 (72.7)	585 (75.4)	.12
P2Y12 inhibitor	2071 (45.3)	340 (43.8)	.4
Statin	3770 (82.5)	646 (83.2)	.6
Anticoagulation	3459 (75.7)	591 (76.2)	.8
Procedural characteristics			
Indication			.6
CLTI	2329 (57.3)	413 (59.2)	
Claudication	1599 (39.3)	263 (37.7)	
Acute limb ischemia	137 (3.4)	22 (3.2)	
Urgency			>9
Elective	3883 (85.0)	659 (84.9)	
Urgent/emergent	685 (15.0)	117 (15.1)	
Laterality			.050
Right	1985 (48.6)	368 (52.6)	
Left	2096 (51.4)	331 (47.4)	
Treated arteries			>.9
1	1945 (42.6)	337 (43.4)	
2	1369 (29.9)	231 (29.7)	
3-4	1257 (27.5)	209 (26.9)	
No. treated arteries	1.96 ± 1.02	1.92 ± 0.99	.3
Fluoroscopy time, minutes	25 ± 20	22 ± 17	**<.001**

(Continued on next page)

Supplementary Table I (online only). Continued.

Characteristic	Interventional/surgical (n = 4571)	Medical (n = 777)	*P* value[a]
Anticoagulant during the procedure			.2
Heparin	4365 (98.0)	745 (97.1)	
Bivalirudin	37 (0.8)	7 (0.9)	
Protamine	1007 (23.1)	190 (25.5)	.15
Treatment artery			**<.001**
Femoropopliteal	2064 (45.2)	346 (44.8)	
Multilevel	1754 (38.4)	290 (37.5)	
Aortoiliac	501 (11.0)	66 (8.5)	
Tibial	244 (5.3)	71 (9.2)	
TASC			.6
A	488 (14.5)	87 (15.9)	
B	724 (21.5)	106 (19.4)	
C	942 (28.0)	149 (27.3)	
D	1214 (36.0)	204 (37.4)	
Treatment type			**<.001**
Stenting	2799 (61.2)	164 (21.1)	
Balloon angioplasty	714 (15.6)	443 (57.0)	
Atherectomy	236 (5.2)	146 (18.8)	
Atherectomy and stenting	822 (18.0)	24 (3.1)	
Bailout stenting[b]	1591 (34.8)	11 (1.4)	**<.001**
IVUS	444 (9.8)	37 (4.8)	**<.001**
Total length treated, cm	20 ± 21	17 ± 27	**<.001**
Total occlusion length, cm	8 ± 15	7 ± 22	.2

ASA, Aspirin; *CABG/PCI*, coronary artery bypass graft/percutaneous coronary intervention; *CLI*, critical limb ischemia; *CLTI*, chronic limb-threatening ischemia; *COPD*, chronic obstructive pulmonary disease; *ESRD*, end-stage renal disease; *IVUS*, intravascular ultrasound; *TASC*, Trans-Atlantic Inter-Society Consensus.
Data are presented as number (%) or mean ± standard deviation.
Boldface *P* values indicate statistical significance ($P < .05$).
[a]Pearson χ^2 test; Welch two-sample *t*-test.
[b]Bailout stenting as a proportion of overall stenting.

Supplementary Table II (online only). Baseline characteristics of patients with femoropopliteal artery as the first artery treated and using balloon angioplasty

Characteristic	Dissection (n = 549)	No dissection (n = 26,901)	*P* value[a]
Age, years	69 ± 11	69 ± 11	.9
Female sex	292 (53.2)	12,065 (44.8)	**<.001**
Race			.4
White	415 (75.6)	20,095 (74.7)	
African American	87 (15.8)	4776 (17.8)	
Other	47 (8.6)	2019 (7.5)	
Hypertension	496 (90.7)	24,219 (90.4)	.9
Diabetes	312 (56.8)	15,346 (57.1)	>.9
Smoking	446 (81.2)	21,207 (78.9)	.2
COPD	143 (26.0)	7476 (27.8)	.4
Coronary artery disease	176 (32.1)	9936 (37.0)	**.018**
Congestive heart failure	104 (18.9)	5802 (21.6)	.14
CABG/PCI	185 (34.4)	10,092 (38.2)	.071
ESRD			.086
Normal kidney function	513 (93.4)	24,408 (90.7)	
Kidney transplant	3 (0.5)	272 (1.0)	
Dialysis	33 (6.0)	2221 (8.3)	
Prior major amputation	80 (14.6)	4868 (18.1)	**.033**
Prior carotid intervention	50 (9.3)	2255 (8.5)	.5
Ambulatory status			.6
Ambulatory	378 (69.2)	17,941 (68.1)	
Ambulatory with assistance	125 (22.9)	6533 (24.8)	
Wheelchair	40 (7.3)	1758 (6.7)	
Bedridden	3 (0.5)	110 (0.4)	
ASA	426 (77.6)	19,755 (73.5)	**.030**
P2Y12 inhibitor	243 (44.3)	12,790 (47.6)	.13
Statin	409 (74.5)	20,739 (77.1)	.15
Anticoagulation	88 (16.0)	5525 (20.5)	**.009**

ASA, Aspirin; *CABG/PCI*, coronary artery bypass graft/percutaneous coronary intervention; *COPD*, chronic obstructive pulmonary disease; *ESRD*, end-stage renal disease.
Data are presented as number (%) or mean ± standard deviation.
Boldface *P* values indicate statistical significance ($P < .05$).
[a]Pearson χ^2 test; Welch two-sample *t*-test; Fisher exact test.

Supplementary Table III (online only). Procedural characteristics of patients with femoropopliteal artery as the first artery treated and using balloon angioplasty

Characteristic	Dissection (n = 549)	No dissection (n = 26,901)	*P* value[a]
Indication			.5
CLTI	260 (48.3)	13,461 (50.8)	
Claudication	266 (49.4)	12,451 (47.0)	
Acute limb ischemia	12 (2.2)	577 (2.2)	
Urgency			.6
Elective	466 (84.9)	22,618 (84.1)	
Urgent/emergent	83 (15.1)	4264 (15.9)	
Laterality			.5
Right	279 (51.6)	13,323 (50.0)	
Left	262 (48.4)	13,338 (50.0)	
Treated arteries			**.010**
1	462 (84.2)	23,209 (86.3)	
2	73 (13.3)	3379 (12.6)	
3-4	14 (2.6)	313 (1.2)	
No. treated arteries	1.19 ± 0.46	1.15 ± 0.39	.070
Fluoroscopy time, minutes	18 ± 15	15 ± 29	**<.001**
Anticoagulant during the procedure			**.035**
Heparin	527 (98.0)	25,146 (95.5)	
Bivalirudin	4 (0.7)	261 (1.0)	
Protamine	109 (20.7)	6306 (25.1)	**.020**
TASC			**<.001**
A	97 (24.1)	6127 (30.7)	
B	107 (26.6)	5978 (30.0)	
C	120 (29.8)	4732 (23.7)	
D	79 (19.6)	3098 (15.5)	
Total length treated, cm	14 ± 16	11 ± 14	**<.001**
Total occlusion length, cm	7 ± 15	5 ± 11	**<.001**

CLI, Critical limb ischemia; *CLTI*, chronic limb-threatening ischemia; *TASC*, Trans-Atlantic Inter-Society Consensus.
Data are presented as number (%) or mean ± standard deviation.
Boldface *P* values indicate statistical significance ($P < .05$).
Numbers are lower for long-term follow-up because of missing values in the database.
[a]Pearson χ^2 test; Welch two-sample *t*-test; Fisher exact test.

Supplementary Table IV (online only). Surgical outcomes of patients with femoropopliteal artery as the first artery treated and using balloon angioplasty

Characteristic	Dissection (n = 300)	No Dissection (n = 17,739)	*P* value[a]
Periprocedural outcomes			
Technical result	267 (89.9)	16,160 (92.2)	.13
Post-procedural complications			
Cardiac	5 (1.7)	178 (1.0)	.2
Myocardial infarction	0 (0.0)	57 (0.3)	>.9
Pulmonary	4 (1.3)	68 (0.4)	**.032**
Renal	0 (0.0)	94 (0.5)	.4
Access site complications	19 (6.3)	431 (2.4)	**<.001**
Hospital LOS, days	2 ± 5	3 ± 26	**.004**
30-day mortality	3 (1.0)	267 (1.5)	.6
Long-term outcomes			
Primary patency	129 (89.6)	8294 (91.4)	.4
Reintervention	38 (18.8)	2041 (17.2)	.5
Major amputation	16 (7.5)	804 (6.5)	.5
Mortality	43 (14.3)	2952 (16.6)	.3
Follow-up time, days	798 ± 513	793 ± 518	.9

LOS, Length of stay.
Data are presented as number (%) or mean ± standard deviation.
Boldface *P* values indicate statistical significance ($P < .05$).
[a]Pearson χ^2 test; Welch two-sample *t*-test; Fisher exact test.

Supplementary Table V (online only). Factors associated with arterial dissection (AD) on multivariable regression for femoropopliteal artery as the first artery treated and using balloon angioplasty

Characteristic	OR	95% CI	*P* value
Female, sex	1.31	1.07-1.60	**.009**
Coronary artery disease	0.74	0.59-0.92	**.006**
Aspirin	1.23	0.96-1.58	.10
Anticoagulant use	0.79	0.59-1.03	.088
No. of treated arteries	1.19	0.94-1.48	.14
TASC II			**.011**
A	—	—	
B	1.03	0.78-1.37	
C	1.45	1.10-1.92	
D	1.42	1.04-1.94	

CI, Confidence interval; *OR*, odds ratio; *TASC*, Trans-Atlantic Inter-Society Consensus.
Boldface *P* values indicate statistical significance ($P < .05$).

Supplementary Table VI (online only). Cox proportional hazard model for long-term outcomes in patients with and without arterial dissection (AD)

Long-term outcomes	Adjusted HR[a]	95% CI	*P* value
Primary patency	0.78	0.67-0.92	**.002**
Reintervention-free survival	0.81	0.71-0.93	**.002**
Amputation-free survival	0.99	0.83-1.18	.92

CI, Confidence interval; *HR*, hazard ratio.
Boldface *P* values indicate statistical significance ($P < .05$).
[a]Adjusted for sex, race, smoking history, chronic obstructive pulmonary disease, coronary artery disease, dialysis, preoperative aspirin, preoperative anticoagulation, indication, urgency, treated artery, heparin use, Trans-Atlantic Inter-Society Consensus, and treatment modalities.