Late outcomes of Viabahn self-expandable covered stents for the elective treatment of popliteal artery aneurysms

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ABSTRACT

Objective: In the present study, we aimed to evaluate in detail the late outcomes of the overall endovascular cohort of the PARADE study, with a focus on factors that could influence such outcomes as these may provide useful insights for patients and clinicians alike.

Methods: Between January 2010 and December 2023 patients with nonacute elective popliteal artery aneurysms undergoing endovascular exclusion with the Viabahn stent graft were included in a multicenter retrospective cohort study (40 sites from 10 countries). A cut-off of 15 procedures was used to define a participating center as high volume (>15) or low volume (<15).

Results: During the 14-year studied period, 326 patients were treated who met inclusion criteria for the present study. Patients were predominantly male (304, 93.3%) with a mean age of 74.6 ± 9.2 years. Most patients were asymptomatic (221 [67.8%]); 56 (17.2%) had intermittent claudication and 49 (15%) chronic limb-threatening ischemia. Acute technical success was not obtained in two cases (0.6%), owing to residual type Ia endoleak (one case), and residual type Ib endoleak (one case). Of these, one patient underwent an open conversion, whereas the other one was followed up because unfit for any type of reintervention. At 30 days, two patients died with an overall 30-day mortality rate of 0.6%. Both were not cardiovascular deaths related to interventions. In addition, 30-day rates of major adverse cardiovascular events, graft occlusion, and procedure-related reinterventions were 1.2%, 3.7%, and 5.2%, respectively. No patient underwent early major amputation. The 5-year Kaplan-Meier estimates of primary patency, secondary patency, freedom from reinterventions(s), and amputation-free survival were 65.8% (95% confidence interval [CI], 61.7%-71.9%), 84.9% (95% CI, 78.7%-89.1%), 70.5% (95% CI, 66.2%-74.8%), and 98.2% (95% CI, 96.4%-99.6%), respectively. Amputation-free survival was adversely affected by active smoking ($P = .011$), chronic kidney disease ($P < .001$), poor run-off status ($P = .042$), and low number of cases for each center (<15) ($P = .011$). Multivariate analysis reported an approaching significance for active smoking (hazard ratio, 3.460; 95% CI, 2.6-6.1; $P = .051$), and confirmed the association with chronic kidney disease (hazard ratio, 7.413; 95% CI, 5.4-9.3; $P = .006$).

Conclusions: The findings from this study show that endovascular repair using the Viabahn stent graft may provide a feasible technical option for elective treatment of popliteal artery aneurysm. Some patient-related and procedure-related factors were identified, including chronic kidney disease, that were associated with higher rates of long-term complications. (J Vasc Surg 2025;82:1658-68.)

Keywords: Popliteal artery aneurysm; Endovascular treatment; Covered stent; Viabahn

Current clinical practice guidelines recommend performing elective surgical treatment in patients with an asymptomatic popliteal artery aneurysm (PAA) measuring at least 20 mm in diameter.[1] With the expansion and refinement of endovascular techniques, two main options are currently available for treatment of PAA, namely open surgical repair (either via a medial or posterior approach) or minimally invasive endovascular repair with covered stents.

To date, no randomized controlled trials exist in this field, and several factors play a role in the decision-making, including PAA morphology, patients' clinical conditions (including age and comorbidities), patients' choice, and surgeons' discretion.[2] The Viabahn self-expanding covered stent was the most largely

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used device in this setting owing to some unique characteristics that include flexibility, a heparin-bonded internal surface, and availability in a wide range of lengths and diameters.[2,3] However, the long-term outcomes and their determinants remain relatively unexplored as most prior studies have reported only relatively small single-center retrospective series.[4]

The recent PARADE study demonstrated how open surgical repair via a posterior approach and endovascular exclusion with covered stents were associated with comparable outcomes in terms of overall patency and amputation-free survival for PAA with a length of less than 60 mm in a nonacute (elective) setting.[5] Therefore, in the present study, we aimed to evaluate in detail the late outcomes of the overall endovascular cohort of the PARADE study, with a focus on factors that could influence such outcomes as these may provide useful insights for patients and clinicians alike.

ARTICLE HIGHLIGHTS

- **Study design:** Retrospective multicenter observational study
- **Key findings:** The findings from this study show that endovascular repair using the Viabahn stent graft may provide a feasible technical option for elective treatment of popliteal artery aneurysm, with durable results up to 5 years.
- **Take Home Message:** Some patient-related and procedure-related factors were identified, including the number of cases performed, that were associated with higher rates of long-term complications. These factors could be incorporated into the decision-making process, as well as help to identify subset of patients that may benefit from stricter follow-up regimes with intensified antithrombotic therapy.

METHODS

Study population. Between January 2010 and December 2023, patients with nonacute elective PAAs undergoing open repair via a posterior approach or endovascular exclusion with covered stenting were included in a multicenter retrospective cohort study[5] under the auspices of the Research Collaborative in Peripheral Arterial Disease,[6] a pan-European scientific collaboration of vascular specialists.[6] A total of 40 departments from 10 different countries enrolled all PAA patients with preoperative duplex ultrasound (DUS) examination, and computed tomography angiography (CTA). Each of the participating centers had its own study in which patient data were collected at the time of surgery and were later added to the PARADE Study. Each center adhered to internal pathways for obtaining ethical approval for retrospective research.

Treatment selection was based on the treating clinicians' and local multidisciplinary team's preferences. Given the pragmatic nature of this study, all departments applied their local/regional standardized protocols for perioperative medication, and follow-up examinations and/or imaging. The follow-up protocol included at least a physical examination combined with a DUS or CTA one month after the index procedure, at 6 months and yearly thereafter. All patients provided written consent for the procedure and to the fully anonymized processing of data.

During the 14-year studied period, 971 consecutive patients with a PAA were treated. In the first manuscript about the PARADE study,[5] data from one center were not included for a misunderstanding; for this reason, the overall number of patients increased from 956 to 971. In addition, in the first manuscript[5] the only criterion to compare open surgery with posterior approach and endovascular exclusion was the PAA length (>60 mm) to compare two homogeneous groups, feasible with both options; for this reason, 165 lesions were selected for that analysis.

For the purposes of the present analysis, only patients who underwent endovascular treatment with Viabahn (Gore Medical) self-expandable covered stent were included (n = 326) independently from the PAA length. Therefore, patients who underwent open surgical repair (n = 640), and patients endovascularly treated with another covered stent (n = 5) were excluded. Fig 1 summarizes the study population.

Preoperative and intraoperative data. All patients underwent preoperative evaluation including clinical examination, DUS examination, and CTA, to identify the length and diameter of the aneurysmal lesion, and the diameters of the popliteal artery 1 cm above and 1 cm below the aneurysmal sac. After stent implantation, flexed knee view angiography was performed in all cases to minimize technical graft failure.

Definitions. A cut-off of 15 procedures was used to define a participating center as high volume (>15) or low volume (<15). Chronic limb-threatening ischemia was defined as the presence of peripheral artery disease in combination with rest pain, gangrene, or a lower limb ulceration of 2 weeks or more in duration. Run-off status was defined by the number of patent tibial arteries based on imaging (diagnostic angiogram) obtained during the index procedure and preoperative DUS examination and CTA. Run-off status was considered poor in case of 0 patent below-the-knee vessels or one patent vessel with indirect flow.

Outcome measures and statistical analysis. All data concerning the procedures were collected retrospectively

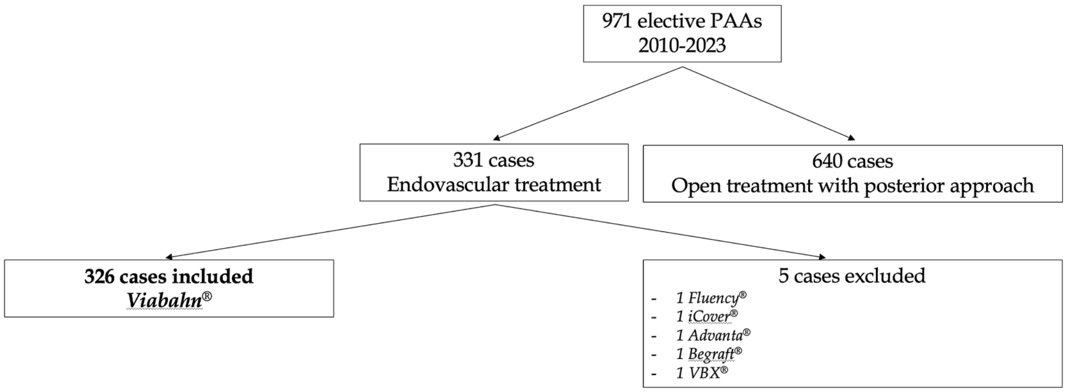


Fig 1. Study population.

in a dedicated online database. This included demographics, preoperative risk factors, clinical and diagnostic preoperative assessments, intraoperative features, 30-day data, and follow-up data.

Early (30-day) outcomes were assessed in terms of mortality, major adverse cardiovascular events, graft occlusion, procedure-related reintervention(s), and major (above-the-ankle) amputations were recorded. At follow-up, the evaluated outcome measures were survival, primary patency, secondary patency, freedom from reintervention(s), and amputation-free survival. Estimated 5-year outcomes were obtained using Kaplan-Meier curves. Estimates were given with the 95% confidence intervals (CI).

Univariate analysis with log-rank test was performed to identify perioperative predictive factors affecting primary patency, secondary patency, freedom from reintervention(s), and amputation-free survival. Variables with a *P* value of less than .10 were included and analyzed in the Cox regression multivariate analysis. Continuous data were expressed as the mean ± standard deviation or median with interquartile range values when necessary. Categorical data were expressed as percentages. Statistical significance was defined at a *P* value of less than .05 level. Statistical analysis was performed using SPSS software (version 24.0 for Apple; IBM Corporation).

RESULTS

Demographics and morphological data. Patients were predominantly male (304 [93.3%]) with a mean age of 74.6 ± 9.2 years (Table I). Most patients were asymptomatic (221 [67.8%]), whereas 56 (17.2%) had intermittent claudication and 49 (15%) had chronic limb-threatening ischemia. Overall, in seven cases (2.1%) a previous vascular intervention was performed in the index limb (five saphenectomy, one superficial femoral artery angioplasty, and one above-the-knee femoropopliteal prosthetic bypass). In 183 patients (56.1%), at least another aneurysm was found. The abdominal aorta and the contralateral popliteal artery were the most

Table I. Demographic data and preoperative risk factors

Demographics	
Males	304 (93.3%)
Mean age, years	74.6
>80 years	110 (33.7%)
Risk factors	
Active smoking	79 (24.2%)
Former smoking	141 (43.3%)
Hypertension	260 (79.8%)
Hypercholesterolemia	200 (61.3%)
Diabetes mellitus	63 (19.3%)
Coronary artery disease	111 (34%)
Chronic kidney disease[a]	26 (8%)
Dialysis treatment	1 (0.3%)

[a]Glomerular filtration rate <30 mL/min.

represented locations of other aneurysmal disease in the whole study population (Table II).

The proportion of patients operated basing on CTA was 321 of 326 cases (98.5%). In the remaining five cases (1.5%), magnetic resonance imaging was used. Table III summarizes the preoperative morphological data. Nine centers out of the 40 (22.5%) enrolled more than 15 patients in the present analysis and they could be considered as high-volume centers.

Intraprocedural details. Access site was percutaneous antegrade femoral in 251 cases (77%), percutaneous contralateral femoral approach in 49 cases (15%), surgical antegrade femoral in 24 cases (7.4%), percutaneous brachial approach in 1 case (0.3%), and percutaneous retrograde tibial approach in 1 case (0.3%). The total number of stents for each patient was 1 in 140 cases (42.9%), 2 in 132 cases (40.5%), 3 in 49 cases (15%), and 4 in 5 cases (1.6%). The mean stent maximum diameter was 8.8 ± 1.7 mm. In 63 patients (19.3%), the maximum diameter of the stents used was 6 or 7 mm. The mean length of the covered stents used was 186.9 ± 72.6 mm.

Table II. Other aneurysmal disease (n – 183)

Disease	No. (%)
AAA	59 (32.2)
AAA, cerebral aneurysm	1 (0.5)
AAA, common femoral aneurysm	4 (2.2)
AAA, contralateral PAA	28 (15.4)
AAA, contralateral PAA, common femoral aneurysm	3 (1.6)
Ascending aorta, contralateral PAA	1 (0.5)
Common femoral aneurysm	4 (2.2)
Contralateral PAA	64 (35)
Iliac aneurysm	6 (3.3)
Iliac aneurysm, contralateral PAA	4 (2.2)
TAA	4 (2.2)
TAA, contralateral PAA	2 (1.1)
TAAA type IV	2 (1.1)
TAAA type V, contralateral PAA	1 (0.5)

AAA, Abdominal aortic aneurysm; *PAA,* popliteal artery aneurysm; *TA,* thoracic aortic aneurysm; *TAAA,* thoraco-abdominal aortic aneurysm.

Table III. Morphological data (N = 326)

Characteristic	Mean ± SD or No. (%)
Aneurysmal sac maximum diameter, mm	31.7 ± 12.2
Diameter >30 mm	129 (39.6)
Lesion length, mm	78.9 ± 44.9
Length >60 mm	237 (72.7)
1 cm above aneurysm diameter, mm	7.9 ± 1.5
Diameter ≥9 mm	111 (34)
1-cm below aneurysm diameter, mm	7.3 ± 1.5
Diameter ≥9 mm	65 (19.9)
Patent tibial vessels, mean	2.3 ± 0.7
Poor run-off status (0-1 BTK vessels)	42 (12.9)

BTK, Below-the-knee vessels.

In 88 cases (27% of the whole population study), an adjunctive procedure was performed, including 30 procedures (34.1%) of angioplasty/stenting of the superficial femoral artery to improve the inflow, and 42 procedures (47.7%) of angioplasty/thrombolysis/thrombectomy of tibial vessels. The remaining adjunctive procedures were: common femoral artery reconstruction (endarterectomy/tube graft) in seven cases (8%), endovascular abdominal aortic aneurysm repair in four cases (4.5%), popliteal saccotomy in three cases (3.4%), and embolization of genicular arteries in two cases (2.3%).

Acute technical success was not obtained in two cases (0.6%), owing to residual type Ia endoleak (one case), and residual type Ib endoleak (one case). Of these, one patient received an open conversion, whereas the other one was followed because the patient was deemed unfit for any type of reintervention.

Outcomes at 30 days. The mean hospital stay was 4.9 ± 4.3 days, and at discharge the rate of overall patency was 100%. Postoperative medical therapy consisted of single antiplatelet therapy in 78 cases (24%), dual antiplatelet therapy in 199 cases (61%), single antiplatelet therapy and oral anticoagulation in 23 cases (7%), and dual pathway inhibition (acetylsalicylic acid and low-dose rivaroxaban) in 26 cases (8%). Postoperative statin was administered in 195 patients (59.8%).

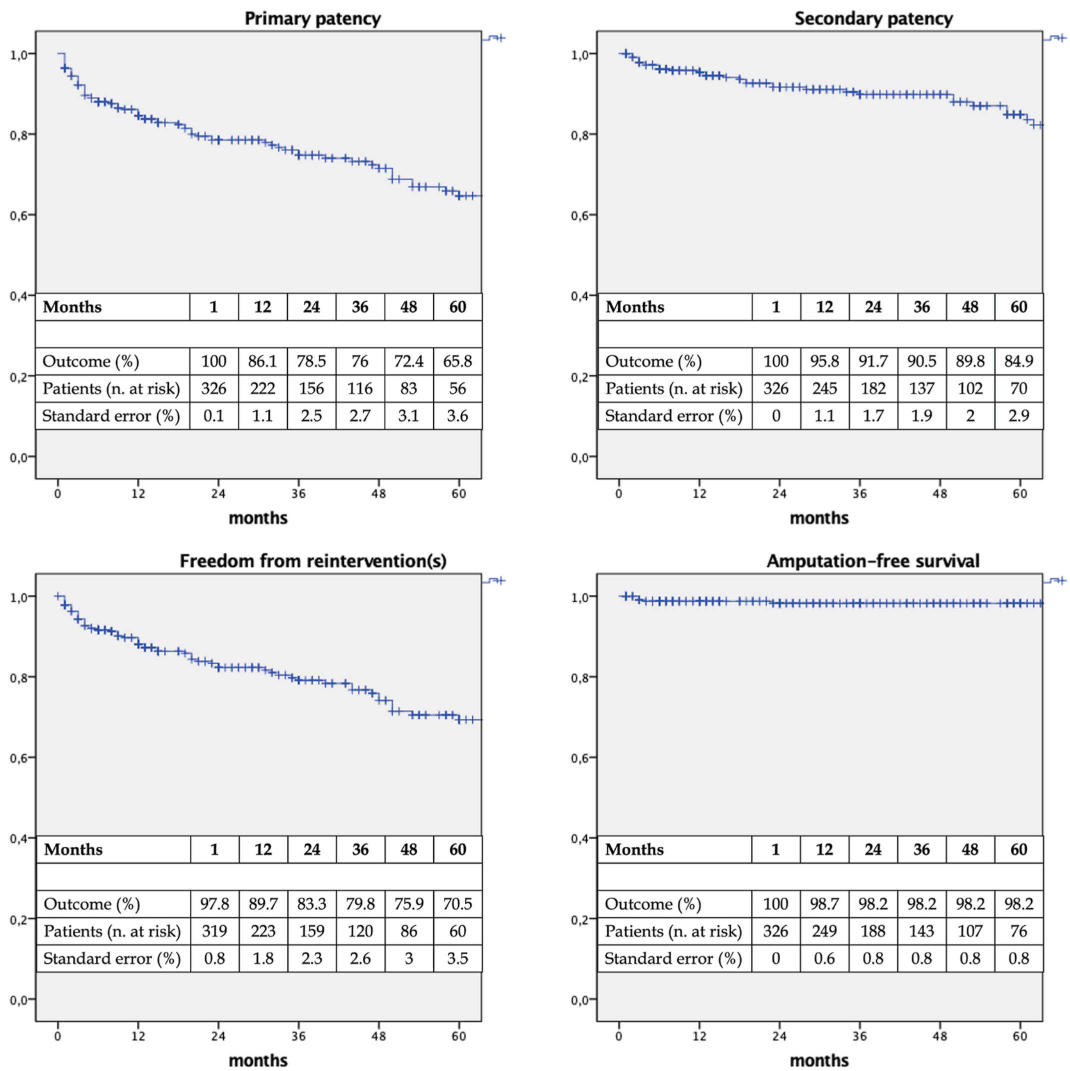
At 30 days, two patients died with an overall 30-day mortality rate of 0.6%. Both were not cardiovascular deaths related to interventions. In addition, 30-day rates of major adverse cardiovascular event, graft occlusion, and procedure-related reinterventions were 1.2% (4 cases), 3.7% (12 cases), and 5.2% (17 cases), respectively. No patient underwent early major amputation. At 30 days, 6 patients (1.8%) underwent surgical revision for an access site bleeding, and 11 patients (3.4%) underwent reintervention for graft occlusion (6 surgical thrombectomy, 4 thromboaspiration and stenting, 1 fibrinolysis, and stenting).

Follow-up outcomes. Follow-up was available for all patients with a median follow-up period of 29 months (interquartile range, 12-59 months). During the final follow-up period, another 51 deaths occurred. The cause of death was unknown in 13 cases (25.5%), malignancy related in 7 cases (13.7%), acute myocardial infarction in 8 cases (15.7%), chronic heart failure in 6 cases (11.7%), COVID-19 infection in 4 cases (7.7%), sepsis and multiorgan failure in 3 cases (5.9%), pneumonia in 3 cases (5.9%), ruptured abdominal aortic aneurysm in 3 cases (5.9%), acute mesenteric ischemia in 1 case (2%), liver cirrhosis in 1 case (2%), peritonitis in 1 case (2%), and intracerebral hemorrhage in 1 case (2%).

The estimated 5-year survival rate was 82.7% (95% CI, 77.4%-87.9%). In addition, during follow-up 66 further reinterventions occurred, including 11 surgical bypass, 11 surgical thrombectomy, 8 relining with covered stents to manage type Ia/Ib endoleak or stent fracture, 30 endovascular procedure to restore flow after graft occlusion, 5 endovascular procedures to improve the outflow, and 1 abscess drainage in the groin. Finally, six major amputations were recorded.

The 5-year Kaplan-Meier estimates of primary patency, secondary patency, freedom from reinterventions(s), and amputation-free survival were 65.8% (95% CI, 61.7%-71.9%), 84.9% (95% CI, 78.7%%-89.1%), 70.5% (95% CI, 66.2%%-74.8%), and 98.2% (95% CI, 96.4%%-99.6%), respectively (Fig 2).

Tables IV and V show the univariate analysis at 5 years. None of the perioperative factors analyzed including medical therapy adversely affected primary patency, secondary, and freedom from reintervention(s).



Primary patency

Months	1	12	24	36	48	60
Outcome (%)	100	86.1	78.5	76	72.4	65.8
Patients (n. at risk)	326	222	156	116	83	56
Standard error (%)	0.1	1.1	2.5	2.7	3.1	3.6

Secondary patency

Months	1	12	24	36	48	60
Outcome (%)	100	95.8	91.7	90.5	89.8	84.9
Patients (n. at risk)	326	245	182	137	102	70
Standard error (%)	0	1.1	1.7	1.9	2	2.9

Freedom from reintervention(s)

Months	1	12	24	36	48	60
Outcome (%)	97.8	89.7	83.3	79.8	75.9	70.5
Patients (n. at risk)	319	223	159	120	86	60
Standard error (%)	0.8	1.8	2.3	2.6	3	3.5

Amputation-free survival

Months	1	12	24	36	48	60
Outcome (%)	100	98.7	98.2	98.2	98.2	98.2
Patients (n. at risk)	326	249	188	143	107	76
Standard error (%)	0	0.6	0.8	0.8	0.8	0.8

Fig 2. Estimated 5-year primary patency, secondary patency, freedom from reintervention(s), and amputation-free survival (Kaplan-Meyer curves with number of patients at risk and standard error values).

Amputation-free survival was adversely affected by active smoking (P = .011), chronic kidney disease ($P < .001$), poor run-off status ($P = .042$), and low number of cases for each center (<15) (P = .011). Multivariate analysis reported an approaching significance for active smoking (hazard ratio, 3.460; 95% CI, 2.6 to 6.1; $P = .051$), and confirmed the association with chronic kidney disease (hazard ratio, 7.413; 95% CI, 5.4 to 9.3; $P = .006$).

DISCUSSION

In this large, multicentric, contemporary study focusing on long-term outcomes after endovascular exclusion of PAA using the Viabahn stent graft, we showed that despite a gradual decrease in primary patency over time, the secondary patency and amputation-free survival rates remained satisfactory during extended follow-up. In fact, the first publication from the PARADE study showed that open surgical repair via a posterior approach and endovascular exclusion with covered stents are associated with comparable outcomes in terms of overall patency and amputation-free survival in the long term after intervention for PAA with a length of less than 60 mm in a nonacute (elective) setting.[5] This report further substantiates these findings, by adding knowledge on factors that could be independently associated with worse outcomes. Indeed, loss of patency during long-term follow-up, with subsequent need for additional interventions, remain the most critical concern for endovascular treatment of PAA. Therefore, the identification of factors that could play a role in this respect (something that was not evaluated in the first registry report) would provide much valuable clinical information, because it could aid with the identification of patients who may not be offered endovascular treatment or may benefit from stricter follow-up protocols if treated endovascularly.

Table IV. Univariate analysis of preoperative and intraoperative factors affecting primary patency, and secondary patency rates at 5 years

Characteristic	Primary patency	*P* value	Log-rank	Secondary patency	*P* value	Log-rank
Sex		.640	.219		.126	2.345
Male	65.5			85.8		
Female	74.1			73.9		
Age, years		.930	.008		.236	1.406
<80	63.2			83.2		
>80	71.2			85.5		
Clinical presentation		.361	2.035		.526	1.284
Asymptomatic	66.9			83.1		
Intermittent claudication	74.6			90.4		
CLTI	49.0			89.8		
Active smoking		.931	.007		.820	.052
Yes	68.7			87.2		
No	64.9			84.1		
Chronic kidney disease		.649	.207		.384	.757
Yes	67.3			88.0		
No	66.0			85.0		
Diameter >30 mm		.847	.037		.415	.663
Yes	70.0			85.4		
No	67.2			84.5		
Lesion length >60 mm		.522	.410		.737	.113
Yes	67.1			83.8		
No	62.4			87.4		
Run-off BTK vessels		.232	1.426		.933	.007
0-1	51.3			87.2		
2-3	68.0			84.6		
No. of stents		.885	.021		.684	.165
1-2	64.7			84.3		
3-4	70.9			88.4		
Stent graft diameter, mm		.399	.711		.218	1.519
6 or 7	58.8			76.5		
≥8	67.9			87.0		
No. of cases for each center		.171	1.870		.838	.042
<15	61.1			86.3		
>15	67.4			84.4		

BTK, Below-the-knee vessels; *CLTI,* chronic limb-threatening ischemia; *PAA,* popliteal artery aneurysm.
Values are percent unless otherwise noted.

Notably, we were unable to identify independent associations with most morphological parameters (with the exception of poor run-off status), although chronic kidney disease, active smoking (approaching significance), and surgeon volume seemed to influence the long-term results. These observations may play a critical role as they will help with the decision-making process, allowing to address modifiable risk factors such as smoking and identify subsets of patients in whom stricter follow-up may be beneficial.

Overall, the favorable outcomes are in line with those reported in the literature, even though with a much larger cohort than most previously available studies. For instance, in a prior meta-analysis by Patel et al[6] (14 studies reporting outcomes for 514 PAA), the pooled primary and secondary patency rates were 69% and 77%, respectively, at 5 years.[7] These figures seem largely comparable with those from the present analysis, thereby increasing the generalizability of our results. In fact, our study with its 326 cases, would (virtually) amount to

Table V. Univariate analysis of preoperative and intraoperative factors affecting freedom from reintervention(s), and amputation-free survival rates at 5 years

	Freedom from reintervention(s)	*P*	Log-rank	Amputation-free survival	*P*	Log-rank
Sex		.252	1.315		.285	1.144
Male	68.7			98.4		
Female	89.1			95.2		
Age, years		.707	.141		.295	1.098
<80	66.8			97.1		
>80	75.6			98.8		
Clinical presentation		.451	1.594		.260	2.693
Asymptomatic	70.7			98.3		
Intermittent claudication	77.7			100		
CLTI	51.5			95.7		
Active smoking		.435	.610		**.011**	**6.473**
Yes	76.0			95.9		
No	67.6			98.9		
Chronic kidney disease		.892	.018		**<.001**	**19.306**
Yes	73.5			88.0		
No	69.5			99.1		
Diameter >30 mm		.493	.471		.153	2.040
Yes	67.9			97.6		
No	70.6			98.6		
Lesion length >60 mm		.542	.372		.525	.404
Yes	70.8			97.9		
No	65.7			98.9		
Run-off BTK vessels		.825	.049		**.042**	**4.133**
0-1	60.3			94.8		
2-3	70.7			98.7		
No. of stents		.901	.015		.287	1.132
1-2	69.6			98.0		
3-4	69.6			98.3		
Stent graft diameter, mm		.840	.041		.450	0.570
6 or 7	58.8			95.2		
≥8	67.5			98.8		
No. of cases for each center		.303	1.063		**.011**	**6.397**
<15	65.0			94.0		
>15	72.2			99.6		

BTK, Below-the-knee vessels; *CLTI,* chronic limb-threatening ischemia; *PAA,* popliteal artery aneurysm.
Values are percent unless otherwise noted.
Bolded *P* values indicate statistical significance ($P < .05$).

63% of the entire meta-analysis sample. Most notably, because durability remains a key concern for the endovascular repair of aneurysms, in the above-mentioned meta-analysis the authors failed to identify predictors of stent graft complications owing to the small sample sizes of existing studies. Therefore, this study adds incremental knowledge substantiated by a large cohort that may reduce risk for residual type 2 error in comparison with prior publications. Also, the multicentric nature of the study further contributes to its generalizability, by providing evidence beyond that from single-center reports.

The surgical solution is still considered the gold standard for treatment of PAA and in published experiences endovascular options are suggested only as a solution for the older and frailer patients.[8,9] In the decision-making process, the superiority of endovascular technique in avoiding the risk of nerve injury and reducing the length of hospitalisation should, however, be considered in selected patients, although these potential advantages may be offset by the higher rate of reinterventions required to maintain graft patency and limb preservation.

Accurate evaluation of the risk-benefit balance is mandatory to achieve satisfactory results with both treatments, and endovascular PAA repair should be considered selectively in patients with suitable anatomy on an individual basis (particularly in patients at high surgical risk, including the elderly or obese, patients with poor cardiorespiratory fitness, patients with poor availability of autogenous bypass conduit, or those well informed patients who desire to proceed with stent graft repair). Our results seem to demonstrate satisfactory outcomes of endovascular procedures without a clear learning curve effect, as for other vascular pathologies subject to endoluminal treatment.[10,11]

Although these findings need careful interpretation, it should be underlined that all participating institutions were high-volume centers for peripheral endovascular arterial surgery; thereby, it is reasonable to assume that skills and knowledge developed in the treatment of other districts/pathologies may be safely translated to different scenarios in the hands of highly experienced operators. In our series, we recorded very few instances of 30-day graft thrombosis (which are usually thought to underpin anatomical or procedural issues including patient selection, case planning, and treatment execution), although late occlusions occurred in approximately one-third of the cases. Nonetheless, the secondary patency and limb salvage rates were very high, thereby signaling that, with careful monitoring and appropriate reinterventions, clinical success may be maintained in the long run after endovascular treatment.

Interestingly, the multivariate analyses did not show any independent associations between morphological and/or procedural factors traditionally thought to be linked to patency loss (and higher risk for reinterventions) and observed outcomes. Although the exact reasons beyond these observations may not be causally proven, some key points in the planning and execution of endovascular treatment are worth mentioning in the authors' opinion. First, the durability after stent graft placement in the setting of PAA may be influenced by the number of runoff vessels. Although this seems intuitive, in our series, the occurrence of graft occlusion was not related to the number of patent runoff vessels. Among anatomical features, the discrepancy between the diameters of the proximal and distal landing zone was also reported as possible risk factors for graft failure. To overcome such a discrepancy, a greater number of stent grafts may be required to avoid an excessive oversizing, but the use of multiple stent grafts can itself be a predictor of complications. In our experience, the number of stent grafts was not associated with worse outcomes, possibly signaling that with meticulous technique the need for multiple devices should not be seen as an absolute contraindication to proceed with endovascular repair.

Finding associations (although not necessarily causal ones, given the retrospective nature of the study) may not only lead to better decision-making, but also identify those patients in whom more aggressive follow-up protocols may be needed. For instance, we observed that chronic kidney disease was independently associated with higher risk for reinterventions and amputations during follow-up. This finding is in line with prior research that has consistently shown worse outcomes in patients with impaired renal function after endovascular treatment for aortic pathology and peripheral disease.[12,13] However, a patient with chronic kidney disease may be a poor surgical candidate and thereby offered endovascular treatment instead of open surgery to prevent PAA-related complications. Still, knowing that his or her baseline kidney function impairment may be associated with higher risks for patency loss, could prompt to more aggressive antithrombotic regimens and/or intensified imaging algorithms during follow-up.

Last, we were unable to show any independent association between antiplatelet or anticoagulant drugs and the incidence of graft failure. Therefore, according to our findings, there is no evidence suggesting oral anticoagulation for all patients treated for PAA by endovascular means. The choice of antithrombotic drugs should be carefully sought on a case-by-case basis by taking into consideration several factors including the hemorrhagic risk profile of the patient, the anatomy of runoff vessels, and the complexity of the repair. In our opinion, most patients who are not on chronic anticoagulation before surgery may benefit from a variable period of dual antiplatelet therapy and could then be switched to lifelong single antiplatelet therapy, possibly in combination with low-dose rivaroxaban twice daily.[14] However, this remains a matter for future studies that may accordingly inform the development of clinical practice guidelines.[15]

Study limitations. The present study has several limitations, mostly inherent to its design that must be considered. First, it was a retrospective collection of data, which could potentially lead to selection bias. Also, although we tried to account for known confounders with robust regression analyses, it is possible that some unmeasured confounders may have remained. Last, we were unable to ascertain the reasons why surgeons elected to perform endovascular over open repair, because this remains beyond the scope of the present study.

CONCLUSIONS

This study comprehensively evaluated the performance of the Viabahn endoprosthesis for PAA management. The findings from this study show that endovascular repair using the Viabahn stent graft may provide a durable technical option for elective treatment of PAA. Some patient-related and procedure-related factors were identified, including chronic kidney disease, that were associated with higher rates of long-term complications. These factors could be incorporated into decision-making processes and help to identify the subset of patients that may benefit from stricter follow-up regimes with intensified antithrombotic therapy.

AUTHOR CONTRIBUTIONS

Conception and design: NT, GB, SL, RB, GB, MDO
Analysis and interpretation: NT, GB, SL, RB, GB, MDO
Data collection: NT, GB, GB, MDO
Writing the article: NT, GB, MDO
Critical revision of the article: NT, GB, SL, RB, GB, MDO
Final approval of the article: NT, GB, SL, RB, GB, MDO
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Overall responsibility: MDO
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APPENDIX

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