Femoral artery transposition is a safe and durable option for the treatment of popliteal artery aneurysms

Gaël Bounkong, MD, Jean-Michel Davaine, MD, PhD, Philippe Tresson, MD, Lucie Derycke, MD, Nicolas Kagan, MD, Thibault Couture, MD, James Lawton, MD, Mahine Kashi, MD, Julien Gaudric, MD, Laurent Chiche, MD, PhD, *and* Fabien Koskas, MD, PhD, *Paris, France*

ABSTRACT

Objective: A suitable ipsilateral great saphenous vein (GSV) autograft is widely considered the best material for arterial reconstruction of a popliteal artery aneurysm (PAA). There are, however, cases in which such a GSV is absent, diseased, or of too small diameter for this use. Alternatives to GSV are synthetic conduits, but with a reduced long-term patency, in particular for infragenicular bypass; other venous autografts of marginal use; and stent grafts still in the first stages of their evaluation. However, a sufficiently long segment of the ipsilateral superficial femoral artery (SFA) is often preserved in patients with a PAA. Such a segment may be used as an autograft for popliteal reconstruction. Moreover, the morphometric characteristics of the SFA often optimally match those of the distal native popliteal bifurcation. SFA autografts (SFAAs) have therefore become our choice when the ipsilateral GSV is not suitable. We herein present the long-term results of SFAA for the treatment of PAA in the absence of a suitable GSV.

Methods: Within this single-center study, all cases during the last 26 years were retrospectively reviewed. Demographics, risk factors, comorbidities, morphometrics of the PAA, and preoperative and follow-up data were intentionally sought.

Results: From 1997 to 2017, there were 67 PAAs treated with an SFAA. The mean age of the patients was 67.67 ± 12 years, and 98% were male. Symptoms included intermittent claudication in 25% (17), critical limb ischemia in 7% (5), and acute ischemia in 10% (7) of the patients; 51% (34) of the patients were asymptomatic. The mean aneurysm diameter of the treated PAA was 29 ± 11 mm (12-61 mm). The mean operative time was 254.8 ± 65.6 minutes (140-480 minutes), with a mean cross-clamp time of 64.5 ± 39 minutes (19-240 minutes). The median length of stay was 9 ± 6.4 days (5-42 days). There were no early amputations or deaths in the series. During a mean follow-up of 47.91 ± 48.23 months, there were 2 anastomotic stenoses, 11 thromboses, 1 infection, and 1 aneurysmal degeneration of the graft; 6 patients died of unrelated causes. The 1-, 3-, 5-, and 10-year primary and secondary patency rates were 93% and 96%, 85% and 90%, 78% and 87%, and 56% and 87%, respectively.

Conclusions: These data suggest that SFAA use to treat PAA is a safe and durable option. A prospective and comparative work is necessary to confirm these results and to determine the interest of this technique as a first-line strategy. (J Vasc Surg 2018;■:1-8.)

Popliteal artery aneurysm (PAA) does not exceed 1% in prevalence.[1-3] It affects mainly men between 65 and 80 years of age and is associated with aortic aneurysms in up to 40% of the cases.[1-4] Growth of the aneurysmal sac leads to complications such as distal emboli, aneurysm thrombosis, compression of surrounding structures, and rupture.[3] The risk of limb loss has been found to be as high as 67%, depending on the initial clinical presentation.[1,5] It is therefore permitted to operate on symptomatic PAA as well as asymptomatic PAA of >2 cm in diameter.[5] Exclusion of the aneurysm combined with arterial reconstruction using an ipsilateral great saphenous vein (GSV) autograft is considered the "gold standard" treatment.[6] There are, however, cases in which such a GSV is absent, diseased, or of too small diameter for this use. Alternatives to GSV are synthetic conduits, but with a reduced long-term patency rate, in particular for infragenicular bypass; other venous autografts of marginal use; and stent grafts still in the first stages of their evaluation.[6-9] However, a sufficiently long segment of the ipsilateral superficial femoral artery (SFA) is often preserved in patients with a PAA. Such a segment may be used as an autograft for the popliteal reconstruction. Moreover, the morphometric characteristics of the SFA often optimally match those of the distal outflow. Its mechanical behavior is perfectly adapted to such a mobile articular region as the knee. SFA autografts (SFAAs) have therefore become our choice when the ipsilateral SFA is not suitable. After it is harvested, the SFAA is replaced by a synthetic conduit but at a thigh level much less exposed to mechanical positional strain than the popliteal. Previous studies have reported encouraging results.[10-12] We herein report our single-center experience with a larger number of patients and with a longer follow-up.

From the Vascular Surgery Department, University Hospital of La Pitié-Salpêtrière.

Author conflict of interest: none.

Correspondence: Jean-Michel Davaine, MD, PhD, Vascular Surgery Department, University Hospital of La Pitié-Salpêtrière, 47-83 Boulevard de l'Hôpital, 75013 Paris, France (e-mail: davainej@yahoo.fr).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

0741-5214

https://doi.org/10.1016/j.jvs.2017.12.049

METHODS

All PAAs treated in our center using an SFAA between April 1991 and April 2017 were included and retrospectively studied. Inclusion criteria were a PAA recognized as an indication for surgical treatment with no suitable GSV and an available healthy segment of the ipsilateral SFA. If the contralateral GSV was available, it was preferred to the ipsilateral SFA, unless its use was anticipated for the contralateral limb in the foreseeable future. Demographics, risk factors, clinical presentation, preoperative data, characteristics of the PAA, outflow, and intraoperative and postoperative data were intentionally sought. All patients agreed to the protocol and gave informed consent. Institutional Review Board approval was not required for this study. A total of 17 surgeons were involved in these procedures (3 senior surgeons and 14 fellows).

Surgical technique. Under general anesthesia, the PAA was approached through a single anteromedial incision including division of sartorius, gracilis, and semitendinosus muscles in most cases and the medial head of the gastrocnemius muscle in some (Fig 1, *A*). All divided muscles were systematically repaired at the end of the procedure. During this approach, great care was taken to preserve the saphenous nerve. Once the medial aspect of the aneurysm was exposed, the distance between its proximal and distal necks was measured while the knee was extended. After systemic heparinization, a slightly longer segment of the ipsilateral SFA was then harvested (Fig 1, *B*), generally from the femoral bifurcation to the femoropopliteal junction, and immediately replaced by a synthetic conduit of polyester, polytetrafluoroethylene, or hybrid (Fig 1, *C*). All the collaterals of the graft were closed with ligatures or small titanium clips. The aneurysm was then neutralized either by resection for short lesions or by a *mise-à-plat* with endoaneurysmorrhaphy of collaterals for longer lesions. The SFAA was then anastomosed end to end to the distal neck with a running suture of monofilament 5 or 6-0 polypropylene. The proximal end of the graft was then anastomosed in the same fashion, either to the prosthetic conduit or to the healthy femoropopliteal artery to which the conduit had been anastomosed (Fig 1, *D*). Among young arteriomegalic patients, a synthetic sleeve was implanted around the transposed SFA to prevent further aneurysmal degeneration of the graft. The sleeve was indeed a prosthesis of a diameter 2 or 3 mm over that of the SFAA. Holes of 5 mm every 25 mm were tailored to the sleeve to prevent any collection of blood between the SFAA and the sleeve. Completion angiography was systematic. Patients were prescribed lifelong antiplatelets and followed up by clinical examination and duplex ultrasound at 1 month, 6 months, and 12 months and yearly thereafter. In case of clinical or hemodynamic abnormal findings, computed tomography (CT) angiography was performed. Patency data were reported considering the synthetic portion and the transposed SFA portion as a single reconstruction. As a result, thrombosis of the bypass was considered when one or the other portion was occluded.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective cohort study
- **Take Home Message:** Surgical treatment of popliteal artery aneurysms using ipsilateral superficial femoral artery in 67 patients resulted in primary and secondary patency rates of 93% and 96%, 78% and 87%, and 56% and 87% at 1 year, 5 years, and 10 years, respectively.
- **Recommendation:** This study suggests that the ipsilateral superficial femoral artery is an acceptable conduit for repair of a popliteal artery aneurysm.

Statistical analysis. Continuous variables were presented as mean and standard deviation or median and interquartile range. Categorical variables were presented as count and percentage. Survival and patency rates were calculated according to the Kaplan-Meier method. For patients who died before the final follow-up examination or for patients lost to follow-up, the status of the last follow-up examination was recorded. A P value $<.05$ was considered statistically significant. Data were analyzed using the Statistical Package for the Social Sciences software (SPSS Inc, Chicago, Ill).

RESULTS

Patients and lesions. From April 1991 to April 2017, there were 67 PAAs treated in 59 patients using an SFAA. Demographics, risk factors, and characteristics of the lesions are detailed in Table I. A majority were men (58 [98%]), with a mean age of 67.7 ± 12 years (22-89 years); 39 (66%) were hypertensive and 42 (71%) were smokers. The mean American Society of Anesthesiologists score was 2.1 ± 0.7. Sixty-seven concomitant aneurysms were noted: 21 (31%) abdominal aortic aneurysms, 25 (42%) contralateral PAAs, 13 (22%) iliac artery aneurysms, and 8 (14%) common femoral artery aneurysms (Table I). Initial clinical presentation was asymptomatic in 34 (51%) patients. Seventeen (25%) patients presented with intermittent claudication. In three (4%) patients, rest pain was present at the time of diagnosis; two (3%) patients presented with ulcers. Seven (40%) patients were treated for acute ischemia secondary to thrombosis of the PAA. No case of rupture was recorded. The mean diameter of the treated aneurysm was 29 ± 11 mm (12-61 mm). There was one patent leg vessel in 6 (9%) patients, two in 14 (21%) patients, and three in 41 (61%) patients. The mean distal outflow score was 2.6 ± 0.7. Preoperative workup consisted of duplex ultrasound in 47 (70%), CT angiography

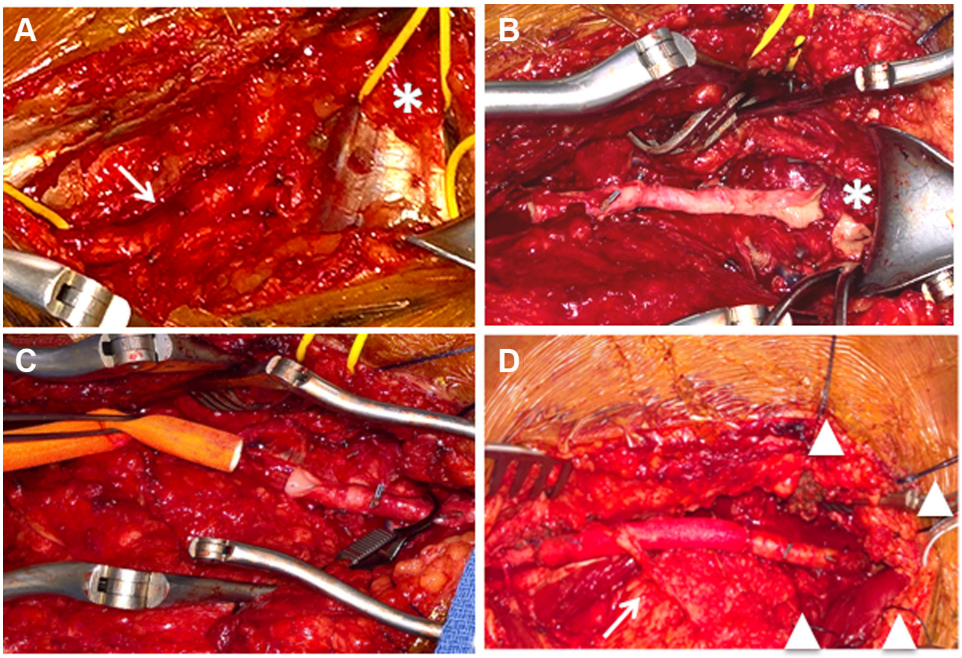


Fig 1. A, The popliteal artery aneurysm (PAA) was approached through a single anteromedial incision of the thigh. The proximal popliteal artery (*arrow*) was exposed. Division of the sartorius, gracilis, and semitendinosus muscles and in some cases of the medial head of the gastrocnemius muscle (*asterisk*) was performed to thoroughly expose the aneurysm. **B** and **C,** A segment of the ipsilateral superficial femoral artery (SFA) was then harvested and transposed between the distal popliteal artery (*asterisk*) and the synthetic graft. Note the beveled aspect of the anastomoses. **D,** Final aspect. Great care was taken to not injure the saphenous nerve (*arrow*). Muscles were repaired at the end of the procedure with large Vicryl sutures (*arrowheads*).

in 40 (60%), and angiography in 45 (67%) performed in addition to a CT scan in 23 cases (Table II).

Surgery. In three cases, preoperative fibrinolysis was performed because of an acute thrombosis of the PAA during the 24 to 48 hours preceding surgery (Table II). The mean operative time was 254.8 ± 65.6 minutes (140-480 minutes), with a mean cross-clamp time of 64.5 ± 39 (19-240 minutes; Table III). In six cases, a thrombectomy was necessary to remove thrombi from leg vessels. Four of the six patients initially presented with acute ischemia secondary to PAA thrombosis. The two other patients suffered from rapidly worsening claudication. The SFAA was replaced by a polyester graft in 49 cases (73%), a polytetrafluoroethylene graft in 9 cases (13%), and a bilayer prosthetic graft (Fusion; Maquet Cardiovascular, Wayne, NJ) in 8 cases (12%). The mean diameter of the vascular graft was 8.7 ± 1.1 mm (7-12 mm). In 16 cases (24%), an outer prosthetic sleeve was used to reinforce the SFAA as explained before. In one complex case combining an aortouni-iliac endograft and a crossed femoral bypass to treat a concomitant abdominal aortic aneurysm, completion angiography revealed thrombosis of the bypass. A thrombectomy was performed.

Postoperative period. In the 30 days after surgery or before discharge, no death or amputation was noted. The median length of stay was 9 ± 6.4 days (5-42 days). The patient who had an intraoperative thrombosis of his bypass was discharged at 42 days. Ten complications were noted. One patient had a bypass thrombosis resulting in acute ischemia the day after surgery. He fully recovered after a successful emergency thrombectomy. One patient who had prolonged (90-minute) cross-clamping of the popliteal artery developed an acute compartment syndrome of the leg requiring an aponeurotomy. In two cases, surgical evacuation of a hematoma was necessary. Four patients presented with wound dehiscence and skin necrosis. One patient developed ipsilateral deep venous thrombosis, and one patient developed a urinary tract infection. All patients underwent duplex ultrasound examination in the month after surgery. No thrombosis was noted then, and the mean outflow score was 2.4 ± 0.8 (Table IV).

Follow-up. The mean follow-up was 47.9 ± 48.2 months. No amputation was noted during this follow-up. The 1-, 3-, 5-, and 10-year primary and secondary patency rates were 93% to 96%, 85% to 90%, 78% to 87%, and 56% to 87%, respectively (Fig 2).

Patients who had one-tibial vessel runoff had 1-, 3-, and 5-year primary and secondary patency of 100% and 100%, 80% and 80%, and 80% and 80%, respectively. Patients who had two-tibial vessel runoff had 1-, 3-, and 5-year primary and secondary patency of 92% and 100%, 79% and 86%, and 63% and 69%, respectively.

Table I. Demographics, cardiovascular risk factors, and clinical characteristics

Variable	No. or mean ± SD (maximum-minimum)	%
Total	59	100
Bilateral	8	13.6
Age, years	67.7 ± 12 (22-89)	
Sex		
Men	58	98.3
Women	1	1.7
Hypertension	39	66.1
Diabetes	9	15.3
Type 1	2	3.4
Type 2	7	11.9
Dyslipidemia	35	59.3
Obesity	36	
BMI	28.4 ± 3.2 (25.2-40.9)	61
BMI	26 ± 4.3 (17.6-24.9)	
Tobacco	42	71.2
Coronary artery disease	22	37.3
Cerebrovascular disease	5	8.5
Other vascular disease	12	20.3
Other aneurysms		
AAA	21	35.6
IAA	13	22
FAA	8	13.6
cPAA	25	42.4

AAA, Abdominal aortic aneurysm; *BMI,* body mass index; *cPAA,* contralateral popliteal artery aneurysm; *FAA,* femoral artery aneurysm; *IAA,* iliac artery aneurysm; *SD,* standard deviation.

Table II. Preoperative data

Variable	No. or mean ± SD (maximum-minimum)	%
Total	67	100
ASA score	2.1 ± 0.7 (1-3)	
No symptoms	34	50.8
Symptoms	29	43.3
Claudication	17	25.4
Rest pain	3	4.5
Ulcer	2	3
Acute ischemia	7	10.5
Rupture	0	0
Mean diameter, mm	29 ± 11 (12-61)	
Thrombosis	13	19.4
Patent tibial vessel		
One	6	9
Two	14	20.9
Three	41	61.2
Mean distal outflow	2.6 ± 0.7	
Imaging		
CT angiography	40	59.7
Arteriography	45	67.2
Doppler ultrasound	47	70.2
Fibrinolysis	3	4.5

ASA, American Society of Anesthesiologists; *CT,* computed tomography; *SD,* standard deviation.

Patients who had three-tibial vessel runoff had 1-, 3-, and 5-year primary and secondary patency of 91% and 94%, 87% and 94%, and 82% and 94%, respectively. For comparison purposes, a total of 104 patients have been operated on using GSV during the same period (1991-2017) in our institution. The 1-, 3-, and 5-year primary patency rates were 96%, 92%, and 90%, respectively.

Two anastomotic stenoses were identified, all of which were surgically treated at 12 and 24 months. The patient treated after 12 months had a new thrombosis at 36 months of follow-up. Since he was free from symptoms, he was treated medically. There was one aneurysmal degeneration of the transposed SFA graft 7 years after surgery. Prosthetic replacement of the transposed SFA was performed. The early postoperative period had been marked by early thrombosis, which was treated by successful thrombectomy. One case of graft infection was treated by removal of the synthetic graft and bypass using an arterial allograft. The bypass was found to be occluded on the 1-month Doppler ultrasound examination. No surgery was performed. A total of 11 thromboses were observed. Five occurred during the first year after surgery. Four were operated on. Two were successfully treated by performing a saphenous bypass; one underwent a failed attempt at thromboaspiration; one was the case of graft infection; and the last patient was treated medically. Six other thromboses occurred (26, 27, 36, 86, 96, and 120 months of follow-up). One was successfully treated by thrombectomy; one underwent a failed attempt at thrombectomy; one had a femoropopliteal bypass with a contralateral GSV; one was the stenotic case at 12 months; one was the aneurysmal degeneration of the transposed SFA; and the sixth was medically treated because of the absence of symptoms. Six patients died during follow-up: two of a pulmonary embolism at 12 and 174 months; one of an abdominal aortic aneurysm rupture at 49 months; one of cancer at 120 months; and two of an undetermined cause at 8 months and 143 months. The mean runoff score was 2.5 ± 0.8 after 48 months of follow-up.

DISCUSSION

Our data show that SFAAs are suitable, safe, and durable arterial substitutes for the treatment of PAA, thus confirming the data of previous reports.[10-12]

PAA is a limb-threatening condition through thromboembolic complications.[2,5,13] Its treatment necessitates a popliteal reconstruction using a conduit with good resistance to thrombosis in this area of articular strain. The

Journal of Vascular Surgery
Volume ■, Number ■

Table III. Intraoperative data

Variable	No. or mean ± SD (maximum-minimum)	%
Total	67	100
Operative time, minutes	254.8 ± 65.6 (140-480)	
Mean cross-clamping time, minutes	64.5 ± 39 (19-240)	
Thrombectomy	6	9
Arteriography	51	76.1
Outflow	2.4 ± 0.8	
Graft		
PET (Dacron)	49	73.1
PTFE	9	13.4
ePTFE/PET (Fusion)	8	11.9
Diameter, mm	8.7 ± 1.1 (7-12)	
7 mm	4	6
8 mm	38	56.7
9 mm	5	7.5
10 mm	16	23.9
11 mm	2	3
12 mm	1	1.5
Prosthetic sleeve	16	23.9
Complication	1	1.5
Thrombosis	1	1.5

ePTFE, Expanded polytetrafluoroethylene; *PET,* polyethylene terephthalate; *PTFE,* polytetrafluoroethylene; *SD,* standard deviation.

Table IV. Postoperative period data

Variable	No. or mean ± SD (maximum-minimum)	%
Total	67	100
Length of stay, days	9 ± 6.4 (5-42)	
ICU, days	0	0
Imaging	62	100
Doppler ultrasound	62	100
Arteriography	1	1.5
CT angiography	2	3
Patency	62	92.5
Outflow	2.4 ± 0.8	
Complications	10	14.9
Thrombosis	1	1.5
Acute compartment syndrome of the leg	1	1.5
Hematoma	2	3
Wound (dehiscence and skin necrosis)	4	6
Phlebitis	1	1.5
Urinary infection	1	1.5
Amputation	0	0
Death	0	0

CT, Computed tomography; *ICU,* intensive care unit; *SD,* standard deviation.

ipsilateral GSV has gained the status of gold standard for this purpose[6] but is not available in up to 23% of the cases.[14]

In the absence of a suitable GSV, prosthetic grafts can be used with satisfying results, provided extension of the aneurysm is limited to the proximal part of the popliteal artery. Patency of prosthetic bypasses in this setting has been shown to be better with a posterior approach than with a medial approach.[15] In contrast, in going farther down to the mid or distal popliteal artery, synthetic conduits yield lower patency rates ranging from 29% to 69% at 5 years.[3,9]

Stent grafts are less invasive, are associated with lower morbidity and mortality, and have reduced hospital stay. Since the first report in 1994 by Marin et al,[16] publication on that matter has steadily increased, paralleling the rise of endovascular surgery from 12% in 2005 to 24% in 2007 in the United States.[8]

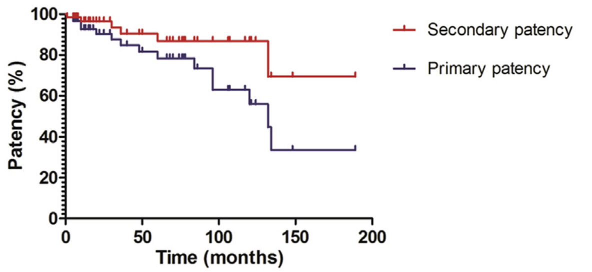
Several reviews and meta-analyses comparing stent grafting and open repair of PAA suggest that the stent graft has lower patency rates with more thromboses, amputations, and deaths.[7,8] Despite their methodologic limits, these studies suggest that endovascular treatment of PAA should be reserved for high-risk surgical patients.[16] As an alternative to the gold standard, SFAAs therefore have a place but have been scarcely reported in the literature to date (Table V).[10-12]

To our knowledge, our series of PAAs treated with use of an SFAA is the largest, with the longest follow-up. Demographics and risk factors of our series are similar to those of previous reports on PAA.[10,12,17,18]

Patients with aneurysmal disease are less susceptible to occlusive disease of the SFA than typical atherosclerotic patients. This explains the likely availability of a suitable SFAA in patients with a PAA. This is further confirmed by the high number of patients with more than one aneurysmal site in our series: 36% of abdominal aortic aneurysms, 42% of contralateral PAAs.[1-3]

In one case, an abdominal aortic aneurysm was treated during the same surgical procedure. An intraoperative thrombosis of popliteal bypass occurred, probably because of a prolonged duration of arterial exclusion.

The use of SFAA has several genuine advantages. The main advantage is that the diameter (6-12 mm) and texture of the graft ideally match those of the distal neck of the PAA. Such a match is far from constant with the GSV. In this population, the SFA diameter ranges frequently between 6 and 12 mm in PAA patients; the three anastomoses necessary for our procedure (proximal, distal, and intermediary between the prosthesis and the SFAA) may therefore be carried out with minimal mismatch.[19] Such harmony is less than constant with a GSV, which often has a smaller diameter than its matching artery for both proximal and distal anastomoses. This mismatch between artery and vein is decreased



		1 month	12 months	36 months	60 months	120 months
Primary patency	N	67	46	31	25	9
	%	99	93	85	78	56
Secondary patency	N	67	467	31	25	9
	%	98	96	90	87	87

Fig 2. At 1 year, primary and secondary patency rates were 93% and 96%, respectively; at 3 years, 85% and 90%; at 5 years, 78% and 87%; and at 10 years, 56% and 87%.

than a synthetic graft or stent in this setting. Moreover, these reasons could advocate for the use of an SFAA as a first choice in treating a PAA, with the obvious advantages of sparing the GSV and a more direct approach to the PAA. Of course, the volume of our study does not allow changing the gold standard. However, our short- and long-term patency rates (at 1 year, primary and secondary patency were 93% and 96%, respectively; at 3 years, 85% and 90%; at 5 years, 78% and 87%; and at 10 years, 56% and 87%) compare favorably with those reported in the literature using the GSV.[6,9-12] For example, Huang et al[6] analyzed patency in a series of 289 patients with 242 PAAs treated with GSV bypass. The 5-year primary and secondary patency rates were 85% and 94%, respectively (Table V). Beseth and Moore[27] reported their experience of 30 PAAs treated through the posterior approach and using a synthetic graft. The 2-year primary and secondary patency rates were 92% and 96%, respectively.

Table V. Primary and secondary patency in different studies

Lead author (year)	No.	Material	Follow-up, months	1 year	2 years	3 years	5 years	10 years
Bounkong (2017)	67	SFA	47.9	92/96		84/90	78/86	55/86
Reix[11] (2000)	18	SFA	22		91/100			
Paraskevas[10] (2008)	37	SFA	36			86/96		
Lemonnier[12] (2009)	29	SFA	39.2	100/NS		92/NC		
Huang[6] (2007)	94	Prosthesis	50.4				50/63	
	242	GSV					85/94	
Dawson[9] (1991)	42	GSV	60					NC/84
Dorigo[17] (2015)	49	GSV	62				65/75	58/69
	181	Prothesis						
Lamoca[35] (2010)	99	GSV	49	94/100	94/100		78/90	76/88
	40	Prothesis		83/93	79/80		54/61	44/46
	32	Stent graft		79/89	79/88			

GSV, Great saphenous vein; *NS*, not specified; *SFA*, superficial femoral artery.

if the GSV is used devalvulated but at the price of trauma to its fragile venous endothelium. The mismatch is of course maximal if the GSV is used reversed. Arterial autografts are now acknowledged to be the best arterial substitutes in critical domains of arterial repair, like coronary disease, for which mammary autografts are considered the gold standard, or visceral arterial disease.[20-24]

The theoretical reason for such success is that arterial autografts become resistant to thrombosis because of a genuine autologous endothelium and resistance to external strain, like flexion or external compression, because of a smooth muscular media. Indeed, several studies have explored the mechanical stress (axial shortening or elongation, bending and twisting) of the femoropopliteal segment.[25,26] The popliteal artery is more susceptible to shortening and torsion than the femoral artery, but similar deformations to the SFA are observed. As a result, one can hypothesize that the SFA is a conduit better fit to sustain mechanical strain

In this study, all PAAs were treated using the *mise-à-plat* with endoaneurysmorrhaphy technique, offering a total guarantee against any further aneurysmal growth as in up to 8% of cases of bipolar exclusion-bypass.[28] There is, however, a concern that some SFAAs might degenerate, resulting in a new aneurysm. We observed this complication in one case and preferred to prevent it in 18 cases using a prosthetic sleeve around the SFAA. Such an aneurysmal degeneration has also been described with the GSV.[29,30]

Another drawback of SFAAs is that their harvest necessitates doubling of the length of the incision. Moreover, the incision is deeper than that for harvesting of a GSV, with a definite risk of harming the saphenous nerve and the need to sever all small arterial branches of the SFA with a collateral potential. There is also a theoretical higher risk of postoperative wound hematoma. We indeed did not observe a higher rate of postoperative hematoma (3%) or saphenous nerve injuries. We acknowledge a longer incision than with the use of a GSV only if the segment of the GSV harvested is the genicular. In our experience, this segment is not always suitable, prompting an extension to the crural segment. Moreover, the saphenous bed is not always exactly in line with the arterial, with therefore a shift during the approach, a source of wound hematoma or cutaneous necrosis. With the use of an SFAA, the approach is straightforward and spares the GSV for any further use. There are some situations in which sparing of the collateral potential is mandatory and section of all branches of the SFA is a concern. In those cases, we take special care to maintain good flow through the profunda femoris by proper reconstruction and to spare the re-entry segment of the femoropopliteal junction. This junction is often spared by aneurysmal disease and bears important collaterals. Such a junction may be inserted into the circuit with a proximal anastomosis to the prosthesis and a distal anastomosis to the SFAA. Of course, this adds one anastomosis to the procedure and can be advocated only when it is thought to be unavoidable, for example, when the preoperative angiogram shows that some important leg artery is fed through the spared collaterals.

The use of a synthetic prosthesis is definitely the major theoretical drawback of our technique. Indeed, this use carries the risks of infection in the short term and thrombosis in the long term. Infection of the prosthetic segment occurred in only one of our cases and was treated using an arterial allograft.[31]

Long-term thrombosis of the graft also occurred in 11 (16%) of our cases and could have been promoted at the prosthetic level of the bypass. However, the patency rates of our series compare with those obtained using a GSV. This might be explained by the shortness of the prosthesis used, which never surpassed the level of the knee joint in this series.[32,33]

During follow-up, aside from the 11 thromboses, there were 2 stenoses, all at the level of the intermediary anastomosis and not the distal one. This fact stresses a potential role of the elastic mismatch between a rigid prosthesis and a compliant SFAA. All of these stenoses were repaired through open surgery, given the poor long-term results of stenting for anastomotic disease.[34] These anastomotic stenoses must be prevented through a beveled technique to smooth the transition between different materials.

CONCLUSIONS

Despite its retrospective nature and the absence of a control group but with a span of 26 years, this work represents the largest report of SFAA for PAA. It demonstrates that this option is safe, efficient, and durable whenever a GSV is not available. Our data suggest that it might be equivalent to the use of a GSV even when such a GSV is available and suitable. This hypothesis would, however, have to be confirmed by a prospective randomized trial.

AUTHOR CONTRIBUTIONS

Conception and design: JD, NK, JG, LC, FK
Analysis and interpretation: GB, JD, PT, FK
Data collection: GB, JD, LD, TC, JL, MK, FK
Writing the article: GB, JD, PT, LD, FK
Critical revision of the article: GB, JD, PT, LD, NK, TC, JL, MK, JG, LC, FK
Final approval of the article: GB, JD, PT, LD, NK, TC, JL, MK, JG, LC, FK
Statistical analysis: GB, JD
Obtained funding: Not applicable
Overall responsibility: JD
GB and JD contributed equally to this article and share first authorship.

REFERENCES

1. Dawson I, Sie RB, van Bockel JH. Atherosclerotic popliteal aneurysm. Br J Surg 1997;84:293-9.
2. Trickett JP, Scott RA, Tilney HS. Screening and management of asymptomatic popliteal aneurysms. J Med Screen 2002;9:92-3.
3. Galland RB. Popliteal aneurysms: from John Hunter to the 21st century. Ann R Coll Surg Engl 2007;89:466-71.
4. Lawrence PF, Lorenzo-Rivero S, Lyon JL. The incidence of iliac, femoral, and popliteal artery aneurysms in hospitalized patients. J Vasc Surg 1995;22:409-15; discussion: 415-6.
5. Hamish M, Lockwood A, Cosgrove C, Walker AJ, Wilkins D, Ashley S. Management of popliteal artery aneurysms. ANZ J Surg 2006;76:912-5.
6. Huang Y, Gloviczki P, Noel AA, Sullivan TM, Kalra M, Gullerud RE, et al. Early complications and long-term outcome after open surgical treatment of popliteal artery aneurysms: is exclusion with saphenous vein bypass still the gold standard? J Vasc Surg 2007;45:706-13; discussion: 713-5.
7. Ying H, Gloviczki P. Popliteal artery aneurysms: rationale, technique, and results of endovascular treatment. Perspect Vasc Surg Endovasc Ther 2008;20:201-13.
8. Huang Y, Gloviczki P, Oderich GS, Duncan AA, Kalra M, Fleming MD, et al. Outcomes of endovascular and contemporary open surgical repairs of popliteal artery aneurysm. J Vasc Surg 2014;60:631-8.e2.
9. Dawson I, van Bockel JH, Brand R, Terpstra JL. Popliteal artery aneurysms. Long-term follow-up of aneurysmal disease and results of surgical treatment. J Vasc Surg 1991;13:398-407.
10. Paraskevas N, Castier Y, Fukui S, Soury P, Thabut G, Leseche G, et al. Superficial femoral artery autograft reconstruction in the treatment of popliteal artery aneurysm: long-term outcome. J Vasc Surg 2008;48:311-6.
11. Reix T, Rudelli-Szychta P, Mery B, Sevestre-Pietri MA, Pietri J. Treatment of popliteal arterial aneurysm using a superficial femoral artery autograft. Ann Vasc Surg 2000;14:594-601.
12. Lemonnier T, Feugier P, Ricco JB, de Ravignan D, Chevalier JM. Treatment of popliteal aneurysms by femoral artery transposition: long-term evaluation. Ann Vasc Surg 2009;23:753-7.
13. Michaels JA, Galland RB. Management of asymptomatic popliteal aneurysms: the use of a Markov decision tree to

determine the criteria for a conservative approach. Eur J Vasc Surg 1993;7:136-43.
14. Varga ZA, Locke-Edmunds JC, Baird RN. A multicenter study of popliteal aneurysms. Joint Vascular Research Group. J Vasc Surg 1994;20:171-7.
15. Ravn H, Wanhainen A, Bjorck M. Surgical technique and long-term results after popliteal artery aneurysm repair: results from 717 legs. J Vasc Surg 2007;46:236-43.
16. Marin ML, Veith FJ, Panetta TF, Cynamon J, Bakal CW, Suggs WD, et al. Transfemoral endoluminal stented graft repair of a popliteal artery aneurysm. J Vasc Surg 1994;19:754-7.
17. Dorigo W, Pulli R, Alessi Innocenti A, Azas L, Fargion A, Chiti E, et al. A 33-year experience with surgical management of popliteal artery aneurysms. J Vasc Surg 2015;62:1176-82.
18. Johnson ON 3rd, Slidell MB, Macsata RA, Faler BJ, Amdur RL, Sidawy AN. Outcomes of surgical management for popliteal artery aneurysms: an analysis of 583 cases. J Vasc Surg 2008;48:845-51.
19. Jacobowitz G, Cayne NS. Lower extremity aneurysms. Chapter 139. Peripheral and visceral aneurysms. Section 23. In: Cronenwett JL, Johnston KW, editors. Rutherford's vascular surgery. 8th edition. Philadelphia: Elsevier Saunders; 2014. p. 2190-205.
20. Stoney RJ, Olofsson PA. Aortorenal arterial autografts: the last two decades. Ann Vasc Surg 1988;2:169-73.
21. Wylie EJ. Vascular replacement with arterial autografts. Surgery 1965;57:14-21.
22. van Bockel JH, van Schilfgaarde R, van Brummelen P, Terpstra JL. Long-term results of renal artery reconstruction with autogenous artery in patients with renovascular hypertension. Eur J Vasc Surg 1989;3:515-21.
23. Novick AC, Stewart BH, Straffon RA. Autogenous arterial grafts in the treatment of renal artery stenosis. J Urol 1977;118:919-22.
24. Nicolini F, Agostinelli A, Spaggiari I, Vezzani A, Benassi F, Maestri F, et al. Current trends in surgical revascularization of multivessel coronary artery disease with arterial grafts. Int Heart J 2014;55:381-5.
25. Ansari F, Pack LK, Brooks SS, Morrison TM. Design considerations for studies of the biomechanical environment of the femoropopliteal arteries. J Vasc Surg 2013;58:804-13.
26. Klein AJ, Chen SJ, Messenger JC, Hansgen AR, Plomondon ME, Carroll JD, et al. Quantitative assessment of the conformational change in the femoropopliteal artery with leg movement. Catheter Cardiovasc Interv 2009;74:787-98.
27. Beseth BD, Moore WS. The posterior approach for repair of popliteal artery aneurysms. J Vasc Surg 2006;43:940-4; discussion: 944-5.
28. Bellosta R, Sarcina A, Luzzani L, Carugati C, Cossu L. Fate of popliteal artery aneurysms after exclusion and bypass. Ann Vasc Surg 2010;24:885-9.
29. Lopez MT, Dorgham AS, Rosas FC, de Loma JG. Aneurysmal degeneration of a saphenous vein graft following the repair of a popliteal aneurysm: case report and literature review. Vascular 2012;20:294-8.
30. Sharples A, Kay M, Sykes T, Fox A, Houghton A. Vein graft aneurysms following popliteal aneurysm repair are more common than we think. Vascular 2015;23:494-7.
31. Kieffer E, Gomes D, Chiche L, Fleron MH, Koskas F, Bahnini A. Allograft replacement for infrarenal aortic graft infection: early and late results in 179 patients. J Vasc Surg 2004;39:1009-17.
32. Sala F, Hassen-Khodja R, Lecis A, Bouillanne PJ, Declemy S, Batt M. Long-term outcome of femoral above-knee popliteal artery bypass using autologous saphenous vein versus expanded polytetrafluoroethylene grafts. Ann Vasc Surg 2003;17:401-7.
33. Klinkert P, Post PN, Breslau PJ, van Bockel JH. Saphenous vein versus PTFE for above-knee femoropopliteal bypass. A review of the literature. Eur J Vasc Endovasc Surg 2004;27:357-62.
34. van Oostenbrugge TJ, de Vries JP, Berger P, Vos JA, Vonken EP, Moll FL, et al. Outcome of endovascular reintervention for significant stenosis at infrainguinal bypass anastomoses. J Vasc Surg 2014;60:696-701.
35. Lamoca LM, Alerany MB, Hernando LL. Endovascular therapy for a ruptured popliteal aneurysm. Catheter Cardiovasc Interv 2010;75:427-9.

Submitted Jul 1, 2017; accepted Dec 15, 2017.