J CARDIOVASC SURG 2007;48:267-74

Endovascular treatment of asymptomatic popliteal aneurysms: 8-year concurrent comparison with open repair

M. ANTONELLO, P. FRIGATTI, P. BATTOCCHIO, S. LEPIDI, A. DALL'ANTONIA, G. P. DERIU, F. GREGO

Vascular and Endovascular Section
Department of Cardiac, Thoracic and Vascular Sciences
University of Padua, Padua, Italy

Aim. **The aim of this prospective comparative study was to compare the results of 8-years experience of endovascular treatment (ET) of popliteal aneurysms (PAs) using the Hemobahn/Viabahn endograft with those achieved with open repair (OR). Endpoints were primary and secondary patency rate.**

Methods. **The study was a prospective randomized clinical trial from January 1999 to December 2003 and a prospective comparative study from January 2004 to December 2006. Patients with an asymptomatic aneurismal lesion in the popliteal artery 2 cm at angio-computed tomography were included in the study. Indication for ET was PA (proximal and distal neck length >1 cm); contraindications were: 1) age <50 years; 2) poor distal run-off; 3) contraindication to antiplatelet, anticoagulant or thrombolytic therapy.**

Results. **Between January 1999 and December 2006, of a total of 42 patients with 48 PA, 27 were treated with OR (group A) and 21 with ET (group B). The primary patency rate was 100% in group A and 80.9% in group B at 12 months and 71.4% and 88.1%, respectively, at 72 months; the secondary patency rate at 72 months was 88.15% and 85.9% in groups A and B, respectively. No statistical differences were observed at the log-rank test. During the entire study period, 3 (14.3%) patients in group B required conversion to open surgery because of endograft occlusion.**

Conclusion. **Within the power limitations of this study, ET for asymptomatic PA in patients with suitable anatomy can be considered safe, with long-term results comparable with those of OR.**

KEY WORDS: Popliteal artery - Aneurysms - Endovascular surgical procedures.

Popliteal aneurysms (PA), the most frequent type of peripheral artery aneurysms,[1-5] are strongly associated with an aneurysm at another site, especially with abdominal aortic aneurysm in 1/3 of cases; about 50% are bilateral. PA are confined to the popliteal artery in almost 50% of cases; they frequently involve the origin of the anterior tibial artery and the tibioperoneal trunk; 10% are associated with an enlargement of the superficial femoral artery. PA occur more frequently in men during the 6th decade of life.[6-9] The aetiology of the disease is still unclear. It is believed that a combination of factors (haemodynamic, genetic and risk factors for atherosclerosis) may lead to the accumulation of inflammatory cells within the artery wall, which release inflammatory mediators responsible for medial degradation and aneurismal dilatation of the artery.[10] When asymptomatic, PA are often discovered incidentally; when symptomatic, patients present with limb-threatening ischaemia due to acute thrombosis or distal embolization. It is estimated that about 14-24% of asymptomatic PA become symptomatic every year. Rupture is an uncommon complication (2-4%).[6-9] Patients with an asymptomatic or symptomatic aneurysm >2 cm in diameter are considered candidates for elective surgery.[4] Limb salvage is low in patients with symptomatic PA, particularly in those with acute ischemia, but higher in asymptomatic patients.[11-15]

PA are treatable by endovascular procedures. Less invasive than conventional surgery, the endovascular exclusion of PA offers distinct advantages: less blood loss, quicker recovery and shorter hospital stay. Moreover, it permits deployment of the endograft through a percutaneous access. Good early results with endovascular repair for PA have been variously

Address reprint requests to: M. Antonello, Department of Cardiac, Thoracic and Vascular Sciences, University of Padua, School of Medicine, Via Giustiniani 2 35125 Padua, Italy. E-mail: michele.antonello.1@unipd.it

described.[16-19] Results of a previous prospective randomized study at our department showed that endovascular treatment for PA is safe and has early and mid-term results comparable to those with open surgery.[20]

The aim of this prospective comparative study was to compare the results of 8-years experience of endovascular treatment (ET) of PA using the Hemobahn/Viabahn endograft (W.L. Gore & Assoc, Flagstaff, AZ) versus open repair (OR). Endpoints were primary and secondary patency rate.

Materials and methods

The study was a prospective randomized clinical trial from January 1999 to December 2003 and a prospective comparative study from January 2004 to December 2006. During the entire study period, patients with a diagnosis of asymptomatic PA at duplex scanning underwent angio-CT and digital subtraction angiography (DSA) to define aneurysm extension and diameter, proximal and distal necks and distal out-flow. Patients with an aneurismal lesion in the popliteal artery >2 cm at angio-CT were included in the study.

As previous reported,[20] indications for ET were: 1) aneurismal lesion in the popliteal artery with a diameter >2 cm at angio-CT scan; 2) proximal and distal neck of the aneurysm length >1 cm to provide a secure fixation site for the stent-graft.

Exclusion criteria for ET were: 1) age <50 years; 2) poor distal run-off defined as a run-off score >8 according to the recommendations of the JC-JVS/ISCVS, in which a score of 1 denotes optimal run-off and a score of 10 denotes no run-off;[21] 3) contraindication to antiplatelet, anticoagulant or thrombolytic therapy; 4) symptoms of nerve and vein compression.

Patients with symptomatic PA or with a run-off score <8 were excluded from the study.

Patients

A total of 57 patients with a diagnosis of asymptomatic PA at duplex ultrasonography between January 1999 and December 2006 were considered for inclusion. Of these, 15 (26.3%) were excluded: 7 had poor distal run-off; 6 had a proximal or distal neck length <1 cm; 2 had symptoms of nerve and vein compression. The remaining 42 patients (48 PA) were included in the study: 27 PA (56.2%) were treated with open repair (OR; group A) and 21 (43.8%) with endovascular treatment (ET; group B). Patient demographics and the preoperative risk factors for the 2 groups are reported in Table I. Mean aneurysm diameter and length in group A was 36.3±13.1 and 11.1±2.3, respectively, and 37.3±14.9 and 10.1±2.3, respetively, in group B; the PA were saccular in 29 (60.4%) cases (16 in group A, 13 in group B) and fusiform in 19 (39.6%) cases (9 in group A, 10 in group B).

TABLE I.—*Demographic and clinical data.*

	Group A (OR)	Group B (ET)	P
Male/Female	21/2	17/4	NS
Mean Age (range)	62.8 (51-83)	65.7 (51-85)	NS
Smoking	14 (60.8%)	15 (71.4%)	NS
Diabetes mellitus	4 (17.4%)	4 (19.1%)	NS
Hypertension°	11 (47.8%)	15 (71.4%)	NS
CAD#	7 (33.3%)	7 (33.3%)	NS
Hypercholesterolemia	9 (30.4%)	8 (38.1%)	NS
COPD§	4 (17.3%)	5 (23.8%)	NS

°History of hypertension; patient taking at least one antihypertensive medication.

#History of myocardial infarction, angina or electrocardiographic sign of myocardial ischemia.

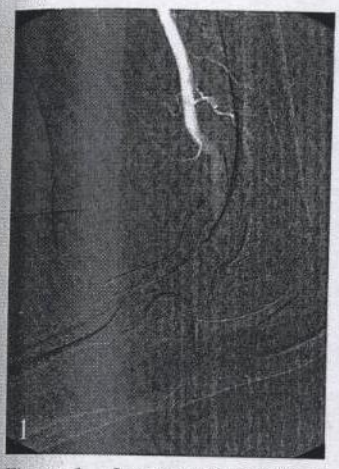
§Chronic obstructive pulmonary disease defines as forced expiratory volume1 (FEV_1)<1 or FEV_1/FVC (forced vital capacity)<75.

Stent graft design

The Hemobahn/Viabahn (Gore, Falstaff, Arizona, USA) endoprosthesis was used for PA treatment. The endoprosthesis is a self-expanding nitinol stent, internally covered with an ultrathin polytetrafluoroethylene (PTFE) graft. Thanks to the special nitinol stent design, the number of net junctions is reduced, allowing the combination of flexibility and radial stiffness; risk of kinking is minimized. Two clear linear radiopaque markers along the graft allow easy and exact deployment in the target vessels.

Endovascular technique

In order to permit conversion to OR in case of ET failure, the endovascular procedure was performed in an operating room equipped with a 12-inch digital C-arm fluoroscopy unit (Series Eurocolumbus). The endograft was inserted via anterograde percutaneous transfemoral access. The final choice of stent length was confirmed by intraoperative angiography. When choos-



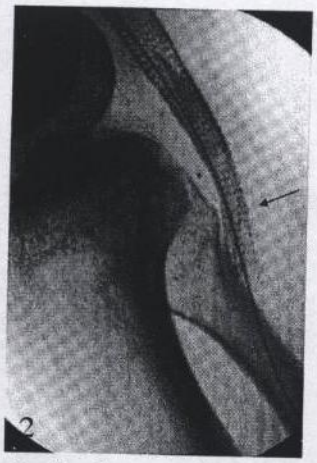


Figure 1.—Intraoperative DSA showing the absence of endograft kinking during forced leg flexion. Figure 2.—Intraoperative plain radiogram of the knee showing a fold (arrow) on the distal part of the endograft caused by oversizing >20%.

ing graft length, an important point is that the stent extremity should not be positioned in the knee joint region or very proximal to it (2-3 cm). Since in this anatomical area the popliteal artery displays maximal flexibility, the endograft is always placed 2-3 cm above the knee joint region. If multiple stent-grafts were required to seal the PA the endografts were overlapped by at least 1 cm.[22]

ET was defined as successful when the PA was completely excluded without signs of endoleaks at intraoperative DSA. To verify endograft flexibility during knee joint movement, intraoperative control DSA in lateral projection with a knee flexion >120° was performed (Figure 1). Endograft kinking with a stenosis >50% was considered a criterion of ET failure.

Immediately after the procedure, antiplatelet therapy was started (single intravenous dose of 125 mg ASA). Double antiplatelet therapy (ASA 100 mg daily + ticlopidin 250 mg twice a day) was started from the first postoperative day and continued for 1 month; antiplatelet therapy was continued thereafter with ASA 100 mg daily *sine die*.

Open surgical technique

Direct endoaneurysmorraphy and bypass through a medial approach was the preferred method of repair. Aneurysm excision as an alternative method was used for treating a small PA.

The bypass was performed with an end to side anastomosis preferably from the above to the below knee popliteal artery. When these arteries were intraoperatively deemed by the surgeon unsuitable to receive a vascular anastomosis, because of a macroscopic aspect suggestive of dysplastic degeneration and therefore increasing the risk of an anastomotic pseudoaneurysm, the superficial first or the common femoral artery were chosen as the inflow artery and the tibioperoneal trunk as the outflow artery.

A reversed great saphenous vein (GSV) was the conduit of choice; when the GSV was unavailable or unsuitable for a bypass, preference was given to a 7 mm PTFE graft. The bypass pathway was always anatomical. Antiplatelet therapy (ASA 100 mg daily *sine die*) was started at discharge.

Postoperative assessment and clinical data follow-up examination

The follow-up protocol consisted of duplex ultrasound scan the day before discharge to evaluate graft patency, PA exclusion and the value of the ankle-brachial index (ABI) during forced leg flexion in group B patients. A reduction of ABI ?20% from rest to leg flexion was considered a sign of endograft kinking and ET failure.

Long-term follow-up was based on clinical evaluation at 1, 3 and every 6 months thereafter with duplex ultrasonography and ABI measured as previously described. DSA was performed when the duplex ultrasound scan revealed signs of restenosis >50%. A restenosis >50% was considered a failure of the procedure. A plain radiogram of the knee joint even during forced leg-flexion (>120°) was performed in group B patients at 6 and 12 month and then yearly to assess stent skeleton integrity and signs of endograft kinking.

Statistical analysis

Statistical analysis was performed using the χ^2 and Fisher's exact test for discontinuous variables, Student t-test for continuous variables and the log-rank test for Kaplan-Meier analysis.

Results

Between January 1999 and December 2006, a total of 48 PA (27 OR group A, 21 ET group B) were performed in 42 patients (6 with bilateral PAA). In the

TABLE II.—*Early procedural results.*

	Group A (OR)	Group B (ET)	P
Graft/Endograft occlusion	0	2 (9.5%)	NS
Primary patency rate	100%	90.5%	NS
Secondar patency rate	-	95.2%	NS
Conversion to OR	-	1 (4.7%)	
Limb salvage rate	100%	100%	NS
Endoleaks	-	0	NS
Number of Endograft implanted	-	37	

same period, 26 patients underwent 29 PA correction with OR out of the study. Eleven PA were symptomatic (8 had acute ischemia associated with a thrombosed PA; 3 had critical leg ischemia with a patent fusiform PA); 7 were asymptomatic but with poor distal run-off; 6 patients were excluded because of aneurysm neck length <1 cm, 5 because aged <50 years. The mean PA diameter of these patients was 3.3±0.6 cm.

The study patients accounted for 61.7% of the whole population that underwent PA surgery at the Department of Vascular Surgery, University of Padua.

There were no statistical differences between the demographic and clinical data in the 2 groups (Table I).

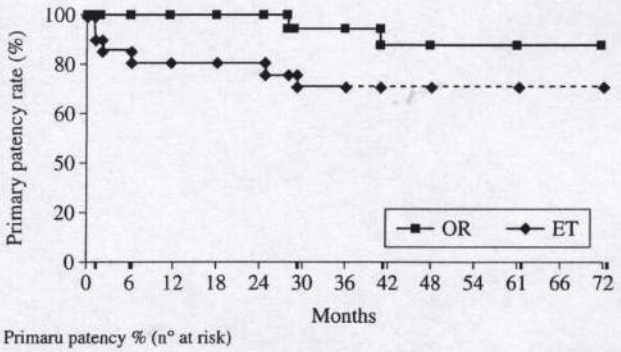
Open repair

Bypass and exclusion of PA with direct endoaneurysmorraphy was the preferred method of repair; aneurysm excision was performed in 4 (14.8%) cases. All patients had their aneurysms repaired through a medial approach. OR was performed under locoregional anaesthesia in 18 (66.7%) cases and general anesthesia in 9 (33.3%).

Reversed GSV was the conduit of choice; in 10 (37.1%) patients a prosthetic bypass using ePTFE graft was performed because of an unsuitable saphenous vein. Inflow arteries varied among the study patients; the common femoral artery was used in 4 (14.8%), the superficial femoral artery in 10 (37.1%), the above-knee popliteal artery in 13 (48.1%). The infrageniculate popliteal artery served as the outflow artery in most cases; 7 (25.9%) bypasses required distal anastomosis on the tibioperoneal trunk. No perioperative graft failures were observed in the early postoperative period (Table II).

Endovascular treatment

ET for PA was performed under locoregional anaesthesia.



Primaru patency % (n° at risk)

OR 100 (27) 100 (27)	94.4 (18)	88.1 (15)	88.1 (12)	88.1 (10)
ET 85.7 (19) 80.9 (18)	71.4 (16)	71.4 (13)	71.4 (9)	71.4 (7)

Figure 3.—Kaplan-Meier curve shows primary patency-rate in group A (OR) and group B (ET) at 6-month intervals. Standard error is >10% after 36 months for ET (——).

In all, 37 stent-grafts were placed in 21 PA: single devices were used in 13 (61.9%) aneurysms; 6 (28.6%) required 2 stent-grafts and 2 (9.5%) needed 3. The mean diameter and length of the implanted endografts was 8.14 ± 0.7 mm and 11.4 ± 3.6 cm, respectively.

Between January 1999 and December 2003, a collateral artery originating from the aneurismal sac was embolized in 2 cases to prevent a type II endoleak; in 2 other cases, this procedure was not performed because of technical difficulties and no signs of type II endoleak were detectable during the follow-up period (18 and 20 months, respectively).

Aneurismal exclusion was successful in all cases, none required conversion to open surgery, no signs of endoleak and no endograft kinking during leg flexion were observed at intraoperative DSA (Figure 1).

Endograft thrombosis occurred in 2 (9.5%) cases the day after the procedure. In one it was related to intraoperative difficulty during release of the distal part of the endograft. This patient underwent successful intra-arterial thrombolytic therapy followed by an additional endovascular procedure; dilatation of the distal part of the endograft, permitted re-establishment of stent-graft patency. In the other case, an endograft oversized by about 20% was used to seal the PA; this caused incomplete disclosure of the distal part of the endograft, resulting in stent folding (Figure 2). This was successfully treated with intraoperative percutaneous transluminal angioplasty and stenting; but 72 h later the endograft occluded, requiring conversion to OR (Table II).

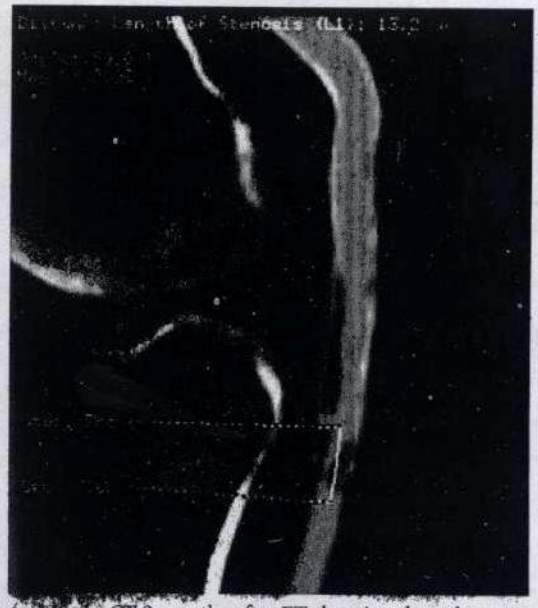


Figure 4.—Angio-CT 2 months after ET showing thrombus apposition inside the endograft in a patient with minor thrombophilic disease.

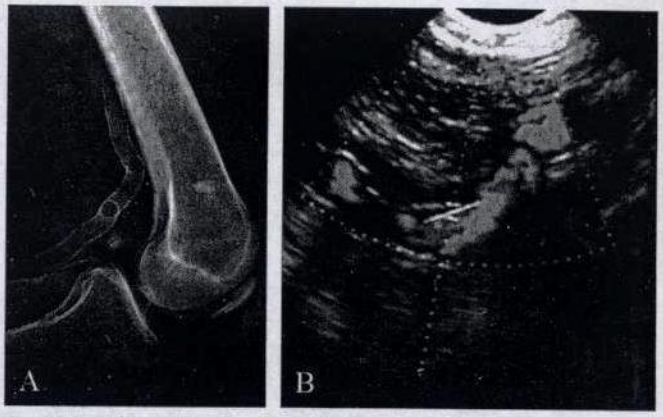


Figure 5.—Plain radiogram of the knee (A) and duplex ultrasound scan (B) 48 months after the procedure showing flexibility and integrity of the Hemobahn stent graft during knee flexion (>120°).

Follow-up

The mean follow-up period was 46.7 months (range 10-97) in group A and 47.8 months (range 11-97) in group B.

In 2 patients in group A, thrombosis of an ePTFE femoropopliteal above knee bypass and of a GSV femorotibioperoneal trunk bypass developed at 28 and 41 months. These patients were not considered for redo surgery because they presented lower limb claudication >500 m at the treadmill test after the acute event. The Kaplan-Meier analysis showed a primary patency rate of 100% at 12 months, 94.4% at 36 months and 88.15% at 72 months (Figure 3). Clinical examination and duplex ultrasonography demonstrated that the remaining bypasses were patent.

Duplex ultrasound scan at 6 and 24 months revealed in 2 patients in group B an asymptomatic restenosis >60% in the distal part of the endograft and was confirmed at DSA. These patients underwent a secondary endovascular procedure of dilatation and placement of a covered stent. An endograft occlusion occurred 6 months after the secondary endovascular procedure, with acute lower-limb ischemia, requiring conversion to OR. In this case, the below knee-popliteal artery was about 4 mm in diameter at preoperative angio-CT. A Viabhan (5 mm diameter) was used to seal the distal part of the PA. In this case, the 25% oversize of the endograft could explain the early distal restenosis and the late occlusion.

In one patient with minor thrombophilic disease (heterozygous for factor V Leyden), conversion to OR was performed 2 months after ET. In this case, angio-CT performed 2 months later showed a thrombus apposition inside the endograft (Figure 4); 24 h after the examination the endograft occluded. The patient underwent unsuccessful local thrombolytic therapy and conversion to OR was required.

No signs of endoleak, aneurismal sac increase (37.8±13.9 cm of diameter at preoperative angio-CT; 36.2±13.3 at angio-CT 12 months after the procedure) or endograft kinking during leg flexion were observed on the plain radiogram (Figure 5).

No significant variations in ABI were observed between the rest position and during forced leg flexion (Figure 5).

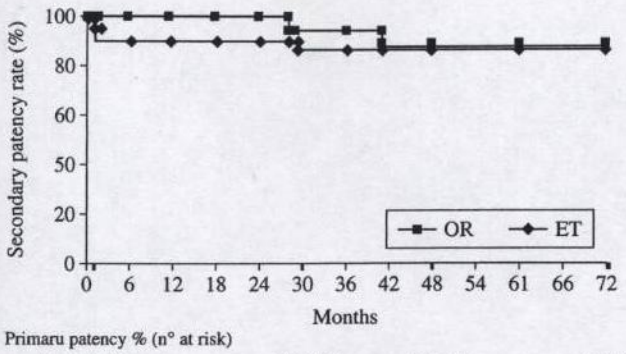
Primary patency rate was 80.9% at 12 months and 71.4% at 72 months; secondary patency rate was 90.5% and 85.9%, respectively (Figure 3, 6).

At the log-rank test no statistical differences between the 2 groups were observed in primary patency rate at 36 months and in secondary patency at 72 months.

No deaths occurred.

Discussion and conclusions

Surgical treatment is indicated for symptomatic or complicated PA; however, controversy surrounds opti-



Primaru patency % (n° at risk)			
OR 100 (27)	94.4 (18)	88.1 (13)	88.1 (10)
ET 90.5 (20)	85.7 (18)	85.7 (14)	85.7 (10)

Figure 6.—Kaplan-Meier analysis of the secondary patency rate in group A (OR) and group B (ET) at 6-month intervals.

mal management of asymptomatic PA and indications for surgical treatment for asymptomatic PA vary. Lowell *et al.* reported aneurysm diameter 2 cm, presence of thrombus and poor run-off as risk factors for complications in a group of 67 aneurysms treated conservatively.[4]

A body of evidence supports surgical management of asymptomatic PA since graft patency and limb salvage rate are consistently better than in symptomatic PA.[11-15] After surgical repair, 5-year patency rate >90% is reported for asymptomatic and >75% in symptomatic aneurysms.[11-15] Surgical mortality is low (0-1%) in asymptomatic patients and 2.1% in acute patients.[23] However, morbidity rates as high as 30-40% have been reported, usually associated with wound complications.[24-26]

Endovascular surgery has become a valid alternative to OR and particularly significant advances have been made in the endovascular treatment of arterial aneurysms. PA are potentially treatable by an endovascular approach. Moreover, compared with conventional surgical treatment, percutaneous endoluminal exclusion of lower extremity aneurysms as a minimally invasive procedure offers distinct advantages: less blood loss, quicker recovery, and shorter hospital stay.[27-29] So far, experience with endoluminal grafting for PA exclusion has been limited. Endovascular repair of a popliteal aneurysm was first described in 1994 by Marin *et al.*, who used a homemade stent-graft consisting of a PTFE graft and 2 Palmaz stents to seal the ends of the graft to the vessel wall.[30] In others reports, a variety of stents (Palmaz, Cragg, Wallstent or Gianturco) covered with PTFE, polyester, polyurethane or autologous vein were used.[31-38] Tielliu *et al.* reported the largest prospective series using the Hemobahn/Viabahn endograft, with good early outcomes in 57 PA, and a cumulative secondary patency rate at 24 months of 87%.[16] Mohan *et al.* reported on a series of 25 patients with 30 PA that underwent ET, with a secondary patency rate of 83.2% at 36 months.[19] To date, the only published randomized study is the one performed at our department, in which 30 PA were randomized into 2 treatment groups for either OR or ET using the Hemobahn/Viabahn endograft. No statistical differences between the two types of treatment were observed in the secondary patency rate at 36 months (90.9% OR vs. 100% ET).[20]

The Hemobhan/Viabhan endograft was chosen because of its technical characteristics: it is a self-expanding nitinol stent, internally covered with an ultrathin PTFE graft incorporating a special nitinol stent design that reduces the number of net junctions and allows the combination of flexibility and radial stiffness, thus reducing the risk of kinking during knee joint flexion.

In this comparative study with a longer follow-up period (72 months) than our first experience, no statistical difference in primary and secondary patency rates was found between the two treatments.

During the entire study period, 3 (14.3%) patients in group B required conversion to open surgery because of endograft occlusion. In 2 cases this was thought to be the results of excessive endograft oversizing; in both cases, oversizing was >20%. In one patient this caused uncompleted disclosure of the distal part of the endograft, resulting in a fold that was not treatable with an adjunctive endovascular procedure and the endograft occluded. In the second case, the endograft was deployed in a small below knee-popliteal artery (4 mm), resulting in tight restenosis 24 months after ET, which was first corrected with a secondary endovascular procedure that prolonged endograft patency for 6 months. Having learned from this experience, we now prefer an endograft oversize no greater than 15%. In the third case, endograft occlusion occurred in a patient with minor thrombophilic disease (heterozygous for factor V Leyden) that caused acute thrombosis of the endograft 2 months after ET. In this case, thrombolytic therapy failed and conversion to OR was required.

As estimated by Kaplan-Meier analysis, the primary patency rate at 72 months was 88.1% after OR and 71.4% after ET; the secondary patency rate at 72 months was 88.1% after OR and 85.7% after ET. The primary patency rate after OR is comparable to those

TABLE III.—*Personal recommendations for ET of PA.*

- Avoid oversizing >10-15%
- Distal landing zone below the knee-joint. It should leave a tract of popliteal artery useful for a popliteal bypass anastomosis.
- Areas of overlapping of multiple stents should avoid flexion critical points of popliteal artery
- Strict follow-up and sine-die antiplatelet therapy
- Contraindication:
  - Small BK popliteal artery (<0.4 mm)
  - Minor or major thrombophilic disease
  - Less than 2 tibial arteries patency
  - Distal neck <1 cm

reported by previous studies, while the primary and secondary patency rates after ET are slightly better than those of other studies that reported a primary patency rate at 1 year between 47% and 75%.[16-19] This difference may be the result of patient selection and postoperative therapy. In our study, only patients with optimal anatomical characteristics and a run-off score >8 according to the recommendations of the JC-JVS/ISCVS were selected for ET. Postoperative therapy (single intravenous dose of 125 mg ASA) immediately after the surgical procedure followed by double antiplatelet therapy (ASA 100 mg daily + ticlopidin 250 mg twice a day) continued for 1 month differed from other studies in which a single oral dose of ASA (100 mg daily) or anticoagulant therapy with low molecular weight heparin were used.

ET permits a quicker recovery and appears to be have greater potential advantage in young patients who need to resume normal activities quickly, and even in older patients in whom a prolonged hospital stays is detrimental.[20] Thus, for this reason and considering the results of the study, we did not still judge an age <50 years.

During the follow-up period, no signs of endoleak were observed; moreover, no evidence of type II endoleak was observed even in those patients in which the collateral vessels originating from the aneurismal sac were not embolized due to technical difficulties.

During the follow-up period, no significant variations in ABI were observed between the rest position and during forced leg flexion (>120°) in patients in group B. This is an important goal. In fact, the great mobility of the popliteal artery, along with the risk of device rotation, twisting and kinking, remains a problematic point in ET for PA. Recently, Diaz *et al.* showed that the popliteal artery has a point of maximal flexion that does not correspond to the same level were the knee bends.[39] This paper confirmed previous anatomo-radiologic studies that found that the distal part of the popliteal artery is relatively fixed between the origin of the anterior tibial artery and the origin of the descending genicular artery.[40-42] Knee flexion increases tortuosity of the supraarticular popliteal artery, while the middle and lower parts of the popliteal artery keep an even curve retracted from the posterior surface of the joint. Wensing *et al.* described different dynamic changes in the popliteal artery during leg flexion depending on patient age. They concluded that, in patients aged over 60 years, popliteal artery tortuosity is more pronounced than in younger patients and does not disappear during knee estension.[42] These findings are similar to what we observed at intraopertive DSA and plain radiogram of the knee with forced leg flexion, in which endograft tortuosity was more marked in the supragenicular segment of the artery.

Thanks to its structure, the Hemobahn/Viabahn endograft seems to be suitable for this procedure since it reduces the risk of kinking during knee joint movement. In our experience, no signs of deformity of endograft structural skeleton were seen on the plain radiogram of the knee during forced leg flexion (>120°). The endograft showed good compliance in the supragenicular region of the popliteal artery—the most critical region for tortuosity during knee flexion. Biomechanical stresses between the popliteal artery and the stent-graft during leg flexion could be responsible for stent fracture that seem to have relevant implications for graft patency.[19] In our study, no stent fractures were detectable on plain radiograms of the knee joint at 6 and 12 months and then yearly. This event seems to be unusual for the Hemobahn/Viabahn device. In the most recent papers describing the use of the endograft in ET for PA, a stent fracture was reported only in the study by Tielliu *et al.* (2/57 patients; 3.5%).[16]

Table III contains our recommendations that may be helpful for successful PA exclusion with use of the Hemobahn/Viabahn device. We believe that, in the near future, a tapered device needs to be developed to treat a PA with a single device and to deal with the smaller size of the belwo-knee popliteal artery in particular.

Given the power limitations of this study, ET for asymptomatic PA in patients with suitable anatomy is safe and has long-term results comparable with those of OR.

References

1. Lucke B, Rea MH. Studies on aneurysms. JAMA 1921;77:935-40.
2. Halliday AW, Wolfe JH, Taylor PR. The management of popliteal aneurysm: the importance of early surgical repair. Ann R Coll Surg 1991;73:253-7.
3. MacGowan GW, Saif MF, O'Neil G. Ultrasound examination in the diagnosis of popliteal artery aneurysms. Br J Surg 1985;72:528-9.
4. Lowell R, Gloviczki P, Hallett JW Jr, Naessens JM, Maus TP, Cherry KJ Jr *et al.* Popliteal artery aneurysms: the risk of nonoperative management. Ann Vasc Surg 1994;8:14-23.
5. Szilagyi DE, Schwartz RL, Reddy HD. Popliteal arterial aneurysms: their natural history and management. Arch Surg 1981;116:724-8.
6. Dawson I, Sie RB, van Bockel JH. Atherosclerotic popliteal aneurysm. Br J Surg 1997;84:293-9.
7. 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.
8. Duffy ST, Colgan MP, Sultan S, Moore DJ, Shanik GD. Popliteal aneurysms: a 10-year experience. Eur J Vasc Endovasc Surg 1998;16:218-22.
9. Galland RB, Magee TR. Management of popliteal aneurysm. Br J Surg 2002;89:1382-5.
10. Siauw R, Koh EH, Walker SR. Endovascular repair of popliteal artery aneurysm: techniques, current evidence and recent experience. ANZ J Surg 2006;76:505-11.
11. Aulivola B, Hamdan AD, Hile CN, Sheahan MG, Skillman JJ, Campbell DR *et al.* Popliteal artery aneurysms: a comparison of outcomes in elective versus emergent repair. J Vasc Surg 2004;39:1171-7.
12. Mahmood A, Salaman R, Sintler M, Smith SR, Simms MH, Vohra RK. Surgery of popliteal artery aneurysms: a 12-year experience. J Vasc Surg 2003;37:586-93.
13. Dawson I, Sie R, van Baalen JM, van Bockel JH. Asymptomatic popliteal aneurysm: elective operation versus conservative follow-up. Br J Surg 1994;81:1504-7.
14. Saracina A, Bellosta A, Luzzani L, Agrifoglio G. Surgical treatment of popliteal artery aneurysm: a 20 year experience. J Cardiovasc Surg 1997;38:347-54.
15. Pulli R, Dorigo W, Troisi N, Innocenti AA, Pratesi G, Azas L *et al.* Surgical management of popliteal artery aneurysms: which factors affect outcomes? J Vasc Surg 2006;43:481-7.
16. Tielliu IF, Verhoeven EL, Prins TR, Post WJ, Hulsebos RG, van den Dungen JJ. Treatment of popliteal artery aneurysms with the Hemobahn stent-graft. J Endovasc Ther 2003;10:111-6.
17. Gerasimidis T, Sfyroeras G, Papazoglou K, Trellopoulos G, Ntinas A, Karamanos D. Endovascular treatment of popliteal artery aneurysms. Eur J Vasc Endovasc Surg 2003;26:506-11.
18. Howell M, Krajcer Z, Diethrich EB, Motarjeme A, Bacharach M, Dolmatch B *et al.* Walgraft endoprosthesis for the percutaneous treatment of femoral and popliteal artery aneurysms. J Endovasc Ther 2002;9:76-81.
19. Mohan IV, Bray PJ, Harris JP, May J, Stephen MS, Bray AE *et al.* Endovascular popliteal aneurysm repair: are the results comparable to open surgery? Eur J Vasc Endovasc Surg 2006;32:149-54.
20. Antonello M, Frigatti P, Battocchio P, Lepidi S, Cognolato D, Dall'Antonia A *et al.* Open repair versus endovascular treatment for asymptomatic popliteal artery aneurysm: results of a prospective randomized study. J Vasc Surg 2005;42:185-93.
21. Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S *et al.* Recommended standards for reports dealing with lower extremity ischemia: revised version. J Vasc Surg 1997;26:517-38. Erratum in: J Vasc Surg 2001;33:805.
22. Deriu G, Frigatti P, Bonvini S, Lepidi S, Ragazzi R, Grego F. Endovascular treatment of popliteal aneurysms. In: Greenhalgh RM editor. Vascular and endovascular surgical techniques. 4th ed. Philadelphia: W.B. Saunders; 2001. p. 427-30.
23. Graham LM. Femoral and popliteal aneurysms. In: Rutherford RB editor. Vascular surgery. 5th ed. Philadelphia: W.B. Saunders; 2000.p.1345-56.
24. Inahara T, Toledo AC. Complications and treatment of popliteal aneurysms. Surgery 1978;84:775-83.
25. Wengrovitz M, Atnip RG, Gifford RR, Neumyer MM, Heitjan DF, Thiele BL. Wound complications of autogenous subcutaneous infrainguinal arterial bypass surgery: predisposing factors and management. J Vasc Surg 1990;11:156-63.
26. Schwartz ME, Harrington EB, Schanzer H. Wound complications after in situ bypass. J Vasc Surg 1988;7:802-7.
27. Nagarajan M, Chandrasekar P, Krishnan E, Muralidharan S. Repair of iliac artery aneurysms by endoluminal grafting. Tex Heart Inst J 2000;27:250-2.
28. Lacroix H, Stockx L, Wilms G, Nevelsteen A. Transfemoral treatment for iliac occlusive disease with endoluminal stent-grafts. Eur J Vasc Endovasc Surg 1997;14:204-7.
29. Diethrich EB. Endoluminal grafting in the treatment of iliac and superficial femoral artery disease. Tex Heart Inst J 1997;24:185-92.
30. 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.
31. Muller-Hulsbeck S, Link J, Schwarzenberg H, Walluscheck KP, Heller M. Percutaneous endoluminal stent and stentgraft placement for the treatment of femoropopliteal aneurysms: early experience. Cardiovasc Intervent Radiol 1999;22:96-102.
32. Puech-Leao P, Kauffman P, Wolosker N, Anacleto AM. Endovascular grafting of a popliteal aneurysm using the saphenous vein. J Endovasc Surg 1998;5:64-70.
33. van Sambeek MR, Gussenhoven EJ, van der Lugt A, Honkoop J, du Bois NA, van Urk H. Endovascular stent-grafts for aneurysms of the femoral and popliteal arteries. Ann Vasc Surg 1999;13:247-53.
34. Henry M, Amor M, Cragg A, Porte JM, Henry I, Amicabile C *et al.* Occlusive and aneurysmal peripheral arterial disease: assessment of a stent-graft system. Radiology 1996;201:717-24.
35. Krajcer Z, Diethrich EB. Successful endoluminal repair of arterial aneurysms by Wallstent prosthesis and PTFE graft: preliminary results with a new technique. J Endovasc Surg 1997;4:80-7.
36. Kudelko PE 2nd, Alfaro-Franco C, Diethrich EB, Krajcer Z. Successful endoluminal repair of a popliteal artery aneurysm using the Wallgraft endoprosthesis. J Endovasc Surg 1998;5:373-7.
37. Dorros G, Joseph G. Closure of a popliteal arteriovenous fistula using an autogenous vein covered Palmaz stent. J Endovasc Surg. 1995; 2:177-81.
38. Burger T, Meyer F, Tautenhahn J, Halloul Z, Fahlke J. Initial experiences with percutaneous endovascular repair of popliteal artery lesions using a new PTFE stent-graft. J Endovasc Surg 1998;5:365-72.
39. Diaz JA, Villegas M, Tamashiro G, Micelli MH, Enterrios D, Balestrini A. Flexion of the popliteal artery: dynamic angiography. J Invasive Cardiol 2004;16:712-5.
40. Shiomi J, Takahashi T, Imazato S, Yamamoto H. Flexion of the knee increases the distance between the popliteal artery and the proximal tibia: MRI measurements in 15 volunteers. Acta Orthop Scand 2001;72:626-8
41. Avisse C, Marcus C, Ouedraogo T, Delattre JF, Menanteau B, Flament JB. Anatomo-radiological study of the popliteal artery during knee flexion. Surg Radiol Anat 1995;17:255-62.
42. Wensing PJ, Scholten FG, Buijs PC, Hartkamp MJ, Mali WP, Hillen B. Arterial tortuosity in the femoropopliteal region during knee flexion: a magnetic resonance angiographic study. J Anat 1995;187 (Pt 1):133-9.