



## POPLITEAL ARTERY ANEURYSMS: OUTCOME FOLLOWING OPEN VERSUS ENDOVASCULAR REPAIR.

### Surgery

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### KEYWORDS

#### Introduction

Popliteal artery aneurysms (PAA) are the most common true peripheral arterial aneurysm<sup>1</sup>. They have a prevalence rate of about 1%<sup>2</sup>, and occur in men aged 65 to 80 years<sup>3</sup>. Due to the relative rarity of the disease, the natural history and long-term outcomes of PAA have been difficult to study.

The majority of PAA are symptomatic at the time of presentation<sup>4</sup>. If left untreated, PAA can have potentially dangerous complications<sup>5</sup>. Acute thrombosis and distal embolisation occur in up to one third of popliteal artery aneurysms<sup>6</sup>. Subsequent acute limb ischaemia and major amputation occur in 30% of symptomatic PAA<sup>7</sup>. Prompt diagnosis and appropriate surgical intervention can effectively prevent these potentially devastating complications.

Rupture of a PAA occurs in less than 5% of patients, while saccular aneurysms have a higher risk of rupture than fusiform aneurysms<sup>10</sup>. Therefore, a secondary objective of management is to prevent aneurysm expansion and rupture<sup>8</sup>.

The optimal management of PAA remains a topic of debate in vascular surgery. It is uncertain whether surgical intervention is necessary for small and asymptomatic PAA<sup>11</sup>. Currently there are two indications for repair of PAA. Symptomatic PAA that present with acute limb ischaemia, regardless of size, must be repaired to minimise the risk of limb loss<sup>12</sup>. Popliteal aneurysms  $\geq 2$ cm in diameter, especially those with significant thrombus load or with chronic distal tibial artery embolic occlusion, are also repaired. These patients have a 30-40% risk of developing complications of acute ischaemia and subsequent limb loss.

Another issue in the treatment of PAA is whether to perform the procedure as open or endovascular. In many centres, open surgical repair (OSR) remains the gold standard<sup>13</sup>. Concerning OSR, different operative techniques and approaches are described in the literature<sup>14</sup>. An open approach has provided satisfactory results in many studies with high rates of graft patency and freedom from amputation reported in the follow-up period.

In recent years, PAA exclusion with stent graft has been emerging as a possible alternative to open surgery. High-risk patients, such as those with advanced age or shorter life expectancy, and patients without a suitable autologous vein may benefit from a stent graft. Other

advantages of endovascular repair (ER) are shorter recovery time and hospital stay<sup>9</sup>.

We reviewed our experience with PAA to improve our understanding of outcomes following open versus surgical repair.

#### Objectives

We aim to compare the patency of the popliteal artery graft following OSR and ER of PAA and to identify risk factors associated with graft failure. The primary endpoint was amputation free survival following popliteal revascularization surgery. Secondary endpoints included:

- Technical success
- Haemodynamic success
- Clinical success
- Patency rates
- Risk factors contributing to graft failure
- Freedom from secondary intervention

#### Methods

##### *Patients Included in this Study*

All patients who underwent PAA repair interventions at our tertiary vascular centre from 2005 to 2016 were reviewed. Any patient who underwent open or endovascular surgical repair of PAA was included in the study.

##### *Data Collection*

Clinical, operative and radiological data was collected from patients' hospital charts and a prospectively collated database (Vascubase™, Version 5.2, Consensus Medical Systems Inc., Richmond, BC, Canada). Laboratory results were gathered from our institutional Patient Administration System. Imaging details were collected from our Picture Archiving and Communication System.

The Society of Vascular Surgery (SVS) does not currently have reporting standards pertaining solely to PAA. Therefore, the SVS reporting standards for Endovascular Aortic Aneurysm Repair were used as a guideline in the assessment of patient demographics, risk factors and clinical presentation<sup>20</sup>. The demographic factors analysed were age and sex. The risk factors analysed were smoking, hypertension, hyperlipidaemia, diabetes and hyperfibrinogenemia. The clinical presentation was analysed in terms of mode of admission, symptomatic status, preoperative ankle brachial index (ABI) and whether the aneurysm was thrombosed or patent.

### Procedure

Surgical repair of PAA was performed on all symptomatic aneurysms that presented with acute limb ischaemia and on all patent popliteal aneurysms  $\geq 2$  cm in diameter.

OSR involved surgical bypass of the aneurysmal segment with ligation of the popliteal artery proximal and distal to the area of aneurysmal degeneration. All OSR were performed with a medial approach. The great saphenous vein from the contralateral limb was the preferred conduit. Alternatively, veins from the ipsilateral limb or the arm were harvested.

ER involves deployment of a stent graft. The stent types used were Gore Viabahn Endoprosthesis (W.L. Gore & Associates, Flagstaff, Arizona, USA) and Hemobahn Endoprosthesis (W.L. Gore & Associates, Flagstaff, Arizona, USA), both were supported with smart stent inside the covered stent graft.

### Follow-Up

Post-operatively, all OSR patients were managed with dual antiplatelet therapy; aspirin and clopidogrel; indefinitely and NOACH with Clopidogrel in all cases of ER. Patients were followed with a Duplex Ultrasound (DUS) post-operatively at day 1, 6 weeks and at 6 monthly intervals thereafter.

### Outcome Variables

The primary outcome of this analysis was amputation free survival. Only major amputations (above the ankle) were considered. The secondary outcomes of this analysis are technical, haemodynamic, and clinical success, the incidence of binary restenosis following popliteal revascularisation surgery, risk factors contributing to restenosis, and freedom from reintervention. Technical success was defined according to the SVS reporting standards as freedom from any adverse events from the initiation of the procedure to the first 24 hours postoperatively<sup>20</sup>. Haemodynamic success was defined as a  $\geq 0.15$  increase in ankle brachial index (ABI) postoperatively<sup>21</sup>. This was only analysed in patients who presented with ischaemic symptoms or those with an ABI of  $\leq 0.7$ . Clinical success was defined as an improvement in symptoms to a Rutherford category score of  $\leq 3$ <sup>21</sup>. Binary restenosis was diagnosed on DUS as a peak systolic velocity ratio  $\geq 2.4$ , which corresponds to a  $\geq 50\%$  decrease in popliteal artery diameter<sup>22</sup>.

### Statistical Analysis

Data was analysed using IBM Statistical Package for the Social Sciences Statistics Version 22 (IBM corp., Armonk, NY, USA). The statistical tests used to analyse continuous data were independent sample t-tests or Mann-Whitney U test where appropriate. Chi-square or Fischer's exact analysis was used to assess continuous data. A risk ratio was performed where suitable. Multivariate regression analysis was conducted for those risk factors with significant p values ( $< 0.05$ ) from univariate analysis. The times to event endpoints (graft failure, reintervention and amputation) over a 5-year follow-up period were calculated using Kaplan-Meier survival estimates with significance assessed by a log rank test. A hazard ratio with 95% confidence intervals was obtained by performing a cox proportional analysis.

### Results

From 2005 to 2016, 32 PAA repair interventions were performed on 23 patients at our tertiary vascular centre. There were 16 OSR procedures and 16 ER procedures. Bilateral PAAs were identified in 6 patients (26.1%). There were 4 patients (17.4%) with coexistent abdominal aortic aneurysms.

### Patient Characteristics

Patients managed by ER were significantly older than those managed by OSR (69.75 $\pm$ 8.22 years vs. 61.06 $\pm$ 11.71 years,  $p=0.021$ ). Hyperlipidemia was significantly more common in the ER group compared to the OSR group (93.8% vs. 56.3%,  $p=0.037$ ). The remaining demographics and risk factors between both groups were comparable (Table 1). The SVS combined comorbidity score for the OSR group was 5.8 with the ER group having a score of 4.7.

The clinical presentation of patients undergoing OSR versus ER was compared (Table 2). The mean hospital stay was 1.72 $\pm$ 1.14 days. Of the 32 PAA, 2 (6.25%) were treated emergently and 30 (93.75%) were elective procedures. Significantly more patients in the OSR group were symptomatic compared to the ER group (87.5% vs. 50%,  $p=0.022$ ). The mean diameter of the treated lesion was 3.26  $\pm$  1.32 cm in the OSR group and 2.61 $\pm$ 1.03 cm in the ER group ( $p=0.133$ ).

### Surgical Technique

All open repairs were performed via the medial approach. Conduits for bypass included 14 great saphenous veins (87.5%), 1 arm vein (6.25%) and 1 popliteal pseudoaneurysm that was repaired with a vein patch (6.25%). ER was performed through a femoral approach in all 16 cases.

### Follow-Up

Follow-up information over a 5-year period was available for 31 interventions. One patient was lost to follow-up at our centre, as they did not reside in the country postoperatively. Mean follow-up time was 34.20 $\pm$ 35.33 months.

### Outcomes

The 5-year amputation free survival was 100% in the OSR group and 93.8% in the ER group (log rank  $p=0.254$ ). Four years after initial procedure, 1 patient who underwent ER required an above knee amputation after developing symptoms of acute limb ischaemia due to complete occlusion of the graft. This patient had refused taking any antiplatelet or anti-coagulations.

Technical success was 100% in all OSR and ER patients. Haemodynamic success was analysed in patients with an ABI of  $\leq 0.7$ . There were only two patients in each group with an ABI of  $\leq 0.7$ . All 4 patients achieved haemodynamic success with an increase of  $\geq 0.15$  in their ankle brachial index post operatively. Clinical success was achieved in 100% of OSR and ER patients.

Postoperative complications within 30 days following OSR and ER were compared (Table 3). 12.5% of patients managed with OSR and 6.3% of patients managed with ER had blood loss of  $>200$ ml, respectively ( $p=1.000$ ). A hematoma at the access site developed in none of the patients in the OSR group and 6.3% in the ER group, respectively ( $p=1.000$ ). An infection at the access site was observed in none of the patients in the OSR group and 12.5% of patients in the ER group, respectively ( $p=0.484$ ).

Within 30-days of the procedure, primary patency was 100% in the OSR and 86.7% in the ER group ( $p=0.226$ ).

In the OSR group, the primary, assisted primary and secondary patency rates at 1 year were 100%, 0% and 0% ( $p=0.101$ ). In the ER group, the primary, assisted primary and secondary patency rates at 1 year were 80%, 0% and 20% ( $p=0.101$ ).

In the OSR group, the primary, assisted primary and secondary patency rates at 5 years were 87.5%, 6.3% and 6.3% ( $p=0.134$ ). In the ER group, the primary, assisted primary and secondary patency rates at 5 years were 68.8%, 0.0% and 31.3% ( $p=0.134$ ).

Performing a multivariate analysis, patient demographics, vascular-related risk factors and clinical presentation were not found to be independent predictors of graft failure.

The 5-year survival from reintervention was 93.8% in the OSR group and 87.5% in the ER group (log rank  $p=0.317$ ) (Figure 1). Two patients who underwent ER developed acute limb ischaemia 10 days and 30 days after initial surgery and underwent subsequent OSR, respectively. One patient who had OSR required angioplasty due to restenosis of the graft.

### Discussion

OSR with great saphenous vein bypass has been considered the gold standard treatment for PAA<sup>9</sup>. In recent years, an endovascular approach has emerged as an alternative to open repair.

A meta-analysis of all studies comparing outcomes following ER and OSR of PAA between 1994 and 2008 found no significant differences in primary patency rates<sup>23</sup>. However, the ER group had an 18-fold increased risk for reintervention and 5-fold increased risk for 30-day graft thrombosis<sup>23</sup>. The author's concluded that their results did not justify ER of PAA<sup>23</sup>. This contradicts our finding that there is no long term difference between OSR and ER. Since this meta-analysis, there has been a valuable increase in studies comparing OSR to ER in the treatment of PAA. An endovascular approach has been found to be safe and effective with primary and secondary patency rates comparable to those of OSR. There is still limited information on long-term outcomes following ER.

Our study allows us to gauge outcomes following management of PAA. Demographics of our cohort were typical of PAA patients, with the majority being elderly and male. Vascular-related risk factors and clinical presentation were similar for both groups with the exception of age and hyperlipidaemia. Follow up data was available for 97% of our patients. This compares well with previous reports.

The only prospective randomised control trial comparing OSR with ER showed similar 1-year primary patency rates between the two groups (100% vs. 87%)<sup>19</sup>. In other studies 1-year primary patency rates following ER ranged from 75% to 94%. The outcomes of our study showed the primary patency rates between OSR and ER of PAA to be comparable (87.5% vs. 80%).

Pulli et al reported 2-year secondary patency rates of 73% in OSR and 75% in ER<sup>20</sup>. Stone et al reported 3-year primary patency rates in OSR and 64% in ER<sup>28</sup>. At 5 years, our primary patency rates were 87.5% in OSR and 68.8% in ER.

Symptomatic PAAs, acute limb ischemia and runoff score <2 have been reported to be independent predictors of restenosis<sup>26</sup>. Our study did not identify any risk factors for restenosis on multivariate analysis. A reported advantage of ER is shorter hospital stay<sup>16</sup>. Although insignificant, patients who had ER had shorter mean hospital stay compared to the OSR group (1.50±0.97 versus 1.94±1.29, p=0.286).

Several studies found ER to be associated with higher reintervention rates compared to OSR. Pulli et al reported similar midterm reintervention rates between OSR and ER<sup>16</sup>. Both findings are inconsistent with our own cohort of patients where 5-year reintervention-free survival was 93.8% in the OSR group and 87.5% in the ER group. Two ER patients developed acute limb ischaemia after initial surgery and underwent subsequent OSR, respectively. One OSR patient required angioplasty due to restenosis of the graft.

Idelchik et al. found that patients who underwent OSR as an emergency were found to have prolonged intensive care unit and hospital stay as well as higher rates of early complications and reinterventions<sup>250</sup>. In our own study, emergency procedures resulted in significantly longer intensive care unit and hospital stays (p=0.040 and 0.040), respectively. There was no significant difference in postoperative complications between elective and emergency procedures.

**Conclusion**

OSR and ER resulted in similar rates of technical and clinical success in our study. No differences in rates of patency, amputation and reintervention were observed. We did not identify any factors to be independent predictors of binary restenosis.

**Table 1. Baseline Demographics and Risk Factors According to Procedure Type**

	OSR (n = 16)	ER (n = 16)	p
Age	61.06 ± 11.71	69.75 ± 8.22	0.021
Male	87.5% (n = 14)	87.5% (n = 14)	1.000
Smoking	12.5% (n = 2)	37.5% (n = 6)	0.220
Hypertension	75% (n = 12)	81.3% (n = 13)	1.000
Hyperlipidaemia	56.3% (n = 9)	93.8% (n = 15)	0.037
Diabetes	18.8% (n = 3)	37.5% (n = 6)	0.433
Cardiac Disease	37.5% (n = 6)	43.75% (n = 7)	1.000
Pulmonary Disease	12.6% (n = 2)	12.6% (n = 2)	1.000
Renal Insufficiency	6.3% (n = 1)	6.3% (n = 1)	1.000
Fibrinogen	4.25 ± 2.02	3.97 ± 0.78	0.642
Comorbidity Score	5.8	4.7	

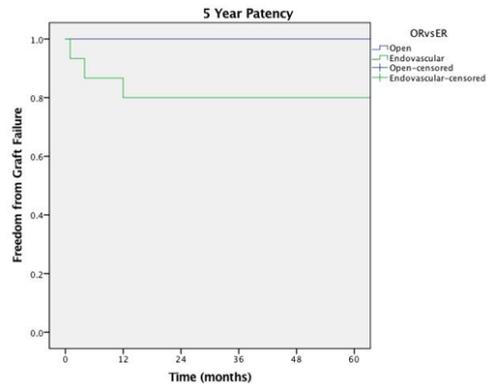
**Table 2. Clinical Presentation According to Procedure Type**

	OSR (n = 16)	ER (n = 16)	p
Emergency	12.5% (n = 2)	0% (n = 0)	0.484
Symptomatic	87.5% (n = 14)	50% (n = 8)	0.022
Thrombosed	31.3% (n = 5)	37.5% (n = 6)	0.710
Claudication	50% (n = 6)	35.7% (n = 5)	0.462
Rest pain	28.6% (n = 2)	60% (n = 3)	0.558
Ulcer	14.3% (n = 1)	66.7% (n = 2)	0.183
Gangrene	14.3% (n = 1)	0% (n = 0)	1.000
Affected Limb Pre ABI	0.96 ± 0.27	1.01 ± 0.29	0.641
Size of Aneurysm	3.26 ± 1.32	2.61 ± 1.03	0.133

**Table 3. Postoperative Complications According to Procedure Type**

	OSR (n = 16)	ER (n = 16)	P
Bleeding >200 mL	12.5% (n = 2)	6.3% (n = 1)	1.000
Access artery dissection or thrombosis	0% (n = 0)	6.3% (n = 1)	1.000
Access site haematoma	0% (n = 0)	6.3% (n = 1)	1.000
Access site infection	0% n = (0)	12.5% (n = 2)	0.484
Amputation	0% (n = 0)	6.3% (n = 1)	1.000
Reintervention	12.5% n = (2)	6.3% (n = 1)	1.000

**Figure 1**



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