Two Decades of Endovascular Repair of Popliteal Artery Aneurysm—A Meta-analysis

M. von Stumm a,*, H. Teufelsbauer b, H. Reichenspurner a, E.S. Debus c

a Department of Cardiovascular Surgery, University Heart Center, Martinistr. 52, 20246 Hamburg, Germany
b Department of Surgery, Division of Vascular Surgery, Medical University of Vienna, Währinger Gürtel 18-20, A-1090 Vienna, Austria
c Department of Vascular Medicine, University Heart Center, Martinistr. 52, 20246 Hamburg, Germany

WHAT THIS PAPER ADDS
The evidence on the comparison of endovascular repair with open surgical repair of popliteal artery aneurysms remains inconclusive. Here, findings from the largest meta-analysis on this topic to date, based on 652 cases, are reported. The results suggest that patient outcomes after endovascular repair may be equal to open surgical repair, and the endovascular technique appears to be a viable alternative to open surgery. Nevertheless, current evidence on endovascular repair is limited and further research is necessary.

Objective/Background: Over the last two decades endovascular repair (EVR) of popliteal artery aneurysms has emerged as a treatment alternative to conventional open surgical repair (OSR). The aim of this review was to evaluate the safety and efficiency of each repair method, comparing the following outcomes after EVR and OSR: (i) primary patency; (ii) operating time; (iii) length of hospital stay; (iv) peri-operative complications; (v) limb salvage; and (vi) patient survival.

Methods: The PubMed and Cochrane Central Register of Controlled Trials were searched for publications that compared outcomes after EVR and OSR (last search November 2014). Randomized controlled trials (RCTs), prospective and retrospective observational cohort studies were included. The quality of studies was evaluated using the Newcastle-Ottawa scale and the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system. Random effect models were employed to estimate odds ratios (ORs), mean differences, and hazard ratios (HRs).

Results: One RCT combined with a prospective cohort study and four retrospective cohort studies with an overall total of 652 cases (236 EVR, 416 OSR) were identified. GRADE quality of evidence was low or very low for all outcomes. After a median follow up of 33 months, patients who received EVR showed equal primary patency rates to patients who received OSR (HR 1.46, 95% confidence interval [CI] 0.92—2.33). Lengths of operation and hospitalization were significantly shorter following EVR; rates of 30 day graft thrombosis (OR 3.16, 95% CI 1.31—7.62) and 30 day re-intervention (OR 2.15, 95% CI 1.02—4.55) were significant higher for patients who received EVR compared with those who received OSR. There was no effect on mortality (OR 2.31, 95% CI 0.37—14.49) or limb loss (OR 0.59, 95% CI 0.16—2.15).

Conclusion: EVR of popliteal artery aneurysm showed mid-term results comparable to open surgery and appears to be a safe alternative to OSR. However, the existing empirical evidence base is too fragmentary to draw firm conclusions. Further research and the introduction of population based registries will be needed to allow reliable evaluation of EVR.

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Keywords: Endovascular repair, Meta-analysis, Popliteal artery aneurysm
INTRODUCTION

Popliteal artery aneurysm (PAA) accounts for 70% of all peripheral arterial aneurysms; its prevalence is estimated to be 1% in men aged 60–80 years.1,2 PAA affects women less frequently, with a male to female ratio of 20:1.3

The natural course of PAA includes a high incidence of acute and chronic thromboembolic complications. Owing to chronic thromboembolism, 50% of patients present with such symptoms as intermittent claudication, rest pain, blue toe syndrome, or acral necrosis.1 Approximately 30% of untreated patients with PAA experience acute thrombosis and distal embolization, with amputation rates of up to 20%.3–5 Another limb threatening complication of PAA is rupture, which occurs in approximately 2% of patients.1 In contrast, early elective treatment of PAA with open surgery is associated with limb salvage rates of 86–99% and primary patency rates of 66–86% over 5 years.3

Over the last 50 years, PAAs have commonly been repaired by proximal and distal ligation of the aneurysmal arterial segment combined with an autologous vein bypass.6 In 1994, Marin et al. described the first stent graft implantation into a PAA.7 Since then, endovascular repair (EVR) of PAAs has evolved as a new treatment alternative to conventional open surgical repair (OSR).

Previous studies assumed that EVR provides similar results to OSR.8–12 To determine if one treatment method is superior to the other, the mid-term outcomes after EVR and OSR were compared in this systematic review. To evaluate the safety and efficiency of each repair method, primary patency, limb salvage, peri-operative complications, and patient survival rates were analyzed.

MATERIALS AND METHODS

Eligibility criteria

Randomized controlled trials (RCTs), prospective and retrospective observational cohort studies that compared outcomes of EVR and OSR of PAA were considered for inclusion. Reports of patients of every age and sex with asymptomatic, symptomatic or acute ischemic PAA requiring an elective or emergency treatment were taken into account.

Surgical aneurysm repair techniques included endoaneurysmorrhaphy, proximal and distal ligation of the popliteal artery or exclusion of the aneurysm. For reconstruction, autologous venous or prosthetic graft material was used through a medial or posterior approach. In the endovascular group, all stent graft designs and all stent graft manufactures were accepted.

Outcomes of interest

The primary outcome was the primary patency rate after aneurysm repair. Primary patency was defined as uninterrupted patency following initial graft deployment.13

Secondary outcomes were all cause mortality, limb loss, procedure duration, length of hospitalization, and peri-operative complications (30 day graft thrombosis and 30 day re-intervention). The end point limb loss implied below and above knee amputations. Peri-operative complications were classified as treatment complications arising in the first 30 days after intervention.

Search strategy and study selection

A systematic literature search of PubMed and the Cochrane Central Register of Controlled Trials was performed, using the search term “popliteal aneurysm” in the title or abstract. To identify additional reviews the reference lists of the articles obtained were manually examined. The search was restricted to studies published between January 1994 and November 2014, and to the English and German language.

After screening the title and abstracts, and deleting duplicates, matching full text references were retrieved. Two authors (MVS and HT) independently assessed the reports for inclusion.

Data extraction

Two authors (MVS and HT) independently extracted the study data. Data for mortality, graft patency, and limb loss were collected over the peri-operative and follow up period. Peri-operative variables, including operation time, length of hospitalization, 30 day graft thrombosis, and 30 day re-intervention, were also noted. Technical success rates following EVR and stent graft complications (migration, kinking, and endoleak) were extracted. Additionally, individual patient characteristics were extracted, including total number of patients, mean or median age, sex, symptomatic presentation, and comorbidities. Medication with antiplatelet and anticoagulant drugs was also noted.

Assessment of study quality and evidence rating

The quality of studies was assessed independently by two authors (MVS and HT) using the Newcastle—Ottawa Scale (NOS).14 The NOS evaluates studies by patient selection methods, comparability of study groups, and assessment of outcome. Studies with a score of more than six stars from a maximum of nine were considered to be of higher quality.

The quality of evidence was assessed independently by two authors (MVS and HT) using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system, as recommended by the Cochrane collaboration.15 Study quality was evaluated by risk of bias, indirectness of evidence, heterogeneity, imprecision of results, and publication bias. The presence of one or more serious limitations resulted in a very low grade of evidence. Cohort studies usually have a low quality of evidence.

Statistical analysis

For this meta-analysis, the recommendations of the Cochrane Collaboration for reporting systematic reviews and meta-analyses (Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA]) were followed.16 Statistical analyses were carried out using RevMan version 5.1.6. (Cochrane Collaboration, Oxford, UK).
For each end point, study results were statistically pooled with a summary statistic and compared in a meta-analysis with a 95% confidence interval (CI). The patients’ baseline characteristics and peri-operative details given as dichotomous or continuous data were combined with an odds ratio (OR) or mean difference (MD). Analyzing the outcomes of mortality, limb loss, and primary patency in different time intervals, variables were extracted either from the published text or given Kaplan—Meier curves. Missing data for desired time intervals were calculated on the recommendations of Tierney et al. for time to event data. A Mantel—Haenszel chi-square method in a random effects model was used to combine the ORs of each end point. An OR > 1 meant that an event was more likely to follow OSR. Additionally, primary patency rates were analyzed as hazard ratios (HRs), as described by Tierney et al. Subsequently, the HRs were compared with the generic inverse variance method of RevMan. At present, the HR is considered to be the most appropriate statistical method to analyze time to event data by reflecting the general censorship of patients during the observation period.

Owing to the low number of identified studies (see “Results”), meta-regression and sensitivity analysis could not be conducted in a reasonable statistical manner.

RESULTS

Study selection and study characteristics

The literature search identified 11 studies comparing the outcomes of OSR and EVR of PAAAs. Three articles were excluded: the first only published the results of primary patency after 30 days and after 1 year—no Kaplan—Meier curve or any secondary outcome parameter was published; in the second study, the study population was inhomogeneous—136 OSR patients and only 3 EVR patients were examined; the third study did not report on endovascular stent graft implantation into the popliteal artery, but rather about a different endovascular aneurysm repair technique with aneurysm coiling and in situ venous bypass, and was therefore also excluded.

The literature search identified three articles providing an update on previously published studies comparing EVR and OSR. In 2005, Antonello et al. published a RCT with data from 1999 to 2003. Two years later they combined this RCT with a prospective cohort study and published data from 1999 to 2006. Similarly, in 2012, Pulli et al. published a study of EVR and OSR of PAAAs, which contained data from 2005 to 2010. One year later, in 2013, they released a new study with patient data from 2000 to 2011. Stone et al. also published two studies, one in 2005 and one in 2013. The first dealt with patient records from 1995 to 2004, and the second with data from 2001 to 2011. The first series of studies was excluded, only the most recent studies with the lengthiest follow up data were selected for this analysis.

Overall, five studies were included, containing a total of 652 PAA repairs (236 EVR, 416 OSR; Table 1). The five studies varied in study design: one was a RCT combined with a prospective comparative study; the other four were retrospective cohort studies containing the data of symptomatic and asymptomatic patients. Only one cohort study separated outcome measurements of elective and emergency cases.

The indications for PAA treatment were identical in all studies. Patients with asymptomatic aneurysms with a diameter > 20 mm were treated; in symptomatic patients the indication for surgery was unrelated to the diameter of the aneurysm.

Different stent grafts were used in each study: in three studies, Hemobahn and Viabahn (Gore, Falstaff, AZ, USA) stent grafts were used; in the remaining two, only Viabahn (Gore) stent grafts were implanted into the popliteal artery. There were no differences in the operative strategy between the selected studies: the bypass material of choice was the autologous greater saphenous vein; only in rare cases were polytetrafluorethylene grafts used.

Patient characteristics differed significantly in all four cohort studies. Only Antonello et al. provided a study population without significant differences between baseline characteristics.

There were four low quality articles (NOS score = 5) and one moderate quality article (NOS score = 7) (Table 2).

GRADE assessment of all outcomes was “low” or “very low” (Table 2).

Patient characteristics

In total, 597 patients with a mean age of 71 years (range 51–83 years) were treated for 652 popliteal aneurysms (236 EVR, 416 OSR; Table 3). There were 560 men (94%; 204 EVR; 356 OSR) and 37 women (19 EVR; 18 OSR). Demographic data differed significantly between the OSR and EVR groups with regard to age and clinical status. Patients undergoing EVR were significantly older (75 ± 6 years vs. 68 ± 3 years; MD 6.95, 95% CI 4.04–9.86 [p < .001]) and had fewer symptoms than patients receiving OSR (OR 0.38, 95% CI 0.26–0.54; p < .001). However, the number of emergency patients and patients with poor vessel runoff did not differ statistically significant between the groups.

Comorbidities included hypertension (72%; n = 442), heart disease (32%; n = 197), hyperlipidemia (43%; n = 262), and diabetes mellitus (21%; n = 86). A history of tobacco abuse was noted in 65% (n = 423) of the patients. Nearly half of the patients presented with bilateral PAA (46%; n = 281), and in 29% (n = 176) PAA was associated with abdominal artery aneurysm.

All patients in all studies were treated post-operatively with double antiplatelet therapy (acetylsalicylic acid, clopidogrel) at least for 1 month, or with oral anticoagulation plus one antiplatelet medication.

Outcomes of EVR and OSR

After 30 days, graft occlusion rates (9% vs. 2%; OR 3.16, 95% CI 1.31–7.62 [p = .01]) and re-intervention rates (9% vs. 4%; OR 2.15, 95% CI 1.02–4.55 [p = .04]) were significantly
greater following EVR compared with OSR (Table 4). In both treatment groups, patients required second interventions for graft thrombosis, bleeding, and wound infections. The duration of the endovascular intervention (EVR 163 minutes vs. OSR 345 minutes; MD 182.00, 95% CI 220.90 to 143.10 [p < .001]) and length of hospitalization after EVR were significantly shorter than for OSR (EVR 3.5 days vs. OSR 7.3 days; MD 3.73, 95% CI 4.74 to 2.72 [p < .001]).

Stent graft complications following EVR were found in seven patients. One patient was described to have stent graft migration, combined with type I and III endoleaks. The patient required re-intervention with the deployment of an additional endograft. Overall, six endoleaks were found in the cumulative endovascular population: one patient (endoleak type I) required conversion surgery; two (endoleak type II) required late re-intervention; and the remaining three (endoleak type II) were treated conservatively.

There were no statistically significant differences between open and endovascular treatment in the categories of patient survival, limb loss, and primary patency when calculated as the HR in a random model (Figs. S1–S3; see Supplementary material).

After 4 years the cumulative primary patency rates lay between 63% and 88% after OSR and between 54% and 86% after EVR. Over the complete follow up of all five studies (mean length of follow up 33 months, range 1–156), the summary HR showed no statistically significant differences in the risk of graft thrombosis between the groups. The summary HR was 1.46 (95% CI 0.92–2.33; p = .11), indicating slightly reduced patency rates in the
<table>
<thead>
<tr>
<th>Study</th>
<th>Study design</th>
<th>No. of cases (EVR/OSR)</th>
<th>No. of emergency cases (EVR/OSR)</th>
<th>Mean (range) length of follow up (mo)</th>
<th>Operative strategy Approach: posterior/medial PAA: ligature/excision Graft: vein/prosthesis</th>
<th>Type of stent graft</th>
<th>Technical success of EVR (%)</th>
<th>Outcomes Score (max. 9)</th>
<th>Risk of bias (RCT)</th>
<th>Quality of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huang et al. (2014)18</td>
<td>Retrospective, single center</td>
<td>149 (42/107)</td>
<td>24 (10/14)</td>
<td>31 (1–78)</td>
<td>Yes Viabahn</td>
<td>98&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1, 4, 5, 8</td>
<td>5</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Pulli et al. (2013)19</td>
<td>Retrospective, multicenter</td>
<td>312 (134/178)</td>
<td>40 (10/30)</td>
<td>31 (1–156)</td>
<td>Yes Viabahn, Hemobahn</td>
<td>100</td>
<td>1, 2, 3, 5, 6, 7, 8</td>
<td>5</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Stone et al. (2013)17</td>
<td>Retrospective, single center</td>
<td>87 (24/63)</td>
<td>27 (7/20)</td>
<td>39 (2–122)</td>
<td>Yes Viabahn</td>
<td>100</td>
<td>1, 3, 5, 8</td>
<td>5</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Antonello et al. (2007)13</td>
<td>RCT plus prospective study, single center</td>
<td>48 (21/27)</td>
<td>None</td>
<td>47 (10–97)</td>
<td>Yes Viabahn, Hemobahn</td>
<td>100</td>
<td>1, 2, 3, 6, 7, 8</td>
<td>7</td>
<td>+/+/?/+/?/+/?/+/?/? Moderate</td>
<td></td>
</tr>
<tr>
<td>Curi et al. (2007)19</td>
<td>Retrospective, single center</td>
<td>56 (15/41)</td>
<td>5 (0/5)</td>
<td>17 (1–156)</td>
<td>Yes Viabahn</td>
<td>100</td>
<td>1, 2, 5, 8</td>
<td>5</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>652 (236/416)</td>
<td>96 (27/69)</td>
<td>33</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note.** Outcomes: 1 = primary patency; 2 = patient survival; 3 = limb salvage; 4 = operative time; 5 = length of hospital stay; 6 = 30 day re-intervention; 7 = 30 day thrombosis; 8 = 30 day mortality. “?” = unclear risk; “+” = low risk for the following (in order): random sequence generation (selection bias), allocation concealment (selection bias), blinding (performance bias), incomplete outcome data (attrition bias), selective reporting (reporting bias), other bias. EVR = endovascular repair; OSR = open surgical repair; RCT = randomized controlled trial; PAA = popliteal artery aneurysm.

<sup>a</sup> Viabahn and Hemobahn both manufactured by Gore (Falstaff, AZ, USA).

<sup>b</sup> Conversion to OSR in one case.

<sup>c</sup> NO Score for Newcastle Ottawa score.
endovascularly treated group compared with the open surgery group (Fig. 2).

DISCUSSION

This is the largest meta-analysis published to date to compare EVR and OSR of PAA. The present findings suggest that EVR of PAA is a feasible and safe procedure. EVR was shown to have primary patency rates equivalent to OSR. However, only five studies were included in this meta-analysis and the quality of evidence was low.

The first meta-analytic review comparing EVR and OSR of PAA was published in 2008. Lovegrove et al. analyzed three studies containing 141 patients (37 EVR, 104 OSR).22,26,29,30 The data from all three studies were included in the present meta-analysis. No differences were found in the results between the present analysis and the one performed by Lovegrove et al.30

In 2014, Joshi et al. published a Cochrane review comparing EVR and OSR.12 Joshi et al. included only one study, which is also part of the present analysis. 22 The

Table 2. Grading of Recommendations Assessment, Development and Evaluation (GRADE) evaluation.

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>No. of participants (studies)</th>
<th>Risk of bias</th>
<th>Inconsistency</th>
<th>Indirectness</th>
<th>Imprecision</th>
<th>Publication bias</th>
<th>Overall quality of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary patency</td>
<td>652 (5)</td>
<td>Serious</td>
<td>Serious</td>
<td>No</td>
<td>Serious</td>
<td>NA</td>
<td>Very low</td>
</tr>
<tr>
<td>Limb salvage</td>
<td>448 (3)</td>
<td>Serious</td>
<td>Serious</td>
<td>No</td>
<td>Serious</td>
<td>NA</td>
<td>Very low</td>
</tr>
<tr>
<td>Mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 d mortality</td>
<td>637 (5)</td>
<td>Serious</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>NA</td>
<td>Low</td>
</tr>
<tr>
<td>2 y mortality</td>
<td>400 (3)</td>
<td>Serious</td>
<td>Serious</td>
<td>No</td>
<td>No</td>
<td>NA</td>
<td>Very low</td>
</tr>
<tr>
<td>Peri-operative details</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operative time</td>
<td>149 (1)</td>
<td>Serious</td>
<td>NA</td>
<td>No</td>
<td>No</td>
<td>NA</td>
<td>Low</td>
</tr>
<tr>
<td>Length of hospital stay (d)</td>
<td>447 (4)</td>
<td>Serious</td>
<td>Serious</td>
<td>No</td>
<td>No</td>
<td>NA</td>
<td>Very low</td>
</tr>
<tr>
<td>30 d re-intervention</td>
<td>344 (2)</td>
<td>Serious</td>
<td>No</td>
<td>No</td>
<td>Serious</td>
<td>NA</td>
<td>Very low</td>
</tr>
<tr>
<td>30 d thrombosis</td>
<td>344 (2)</td>
<td>Serious</td>
<td>No</td>
<td>No</td>
<td>Serious</td>
<td>NA</td>
<td>Very low</td>
</tr>
</tbody>
</table>

Note. GRADE working group levels of evidence: high quality = further research very unlikely to change confidence in estimate of effect; moderate quality = further research likely to have an important impact on confidence in estimate of effect and may change estimate; low quality = further research very likely to have an important impact on confidence in estimate of effect and likely to change estimate; very low quality = very uncertain about estimate. NA = not applicable.

Table 3. Baseline patient characteristics.

<table>
<thead>
<tr>
<th></th>
<th>EVR</th>
<th>OSR</th>
<th>p</th>
<th>OR/MD (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>91</td>
<td>95</td>
<td>.20</td>
<td>0.65 (0.33–1.27)</td>
</tr>
<tr>
<td>Age, mean ± SD (y)</td>
<td>75 ± 6a</td>
<td>68 ± 3b</td>
<td>&lt;.001</td>
<td>6.95 (3.98–9.92)</td>
</tr>
<tr>
<td>Bilateral PAA</td>
<td>48</td>
<td>51</td>
<td>.71</td>
<td>0.93 (0.62–1.38)</td>
</tr>
<tr>
<td>AAA</td>
<td>23</td>
<td>36</td>
<td>.92</td>
<td>0.93 (0.24–3.63)</td>
</tr>
<tr>
<td>Symptoms</td>
<td>37</td>
<td>59</td>
<td>&lt;.001</td>
<td>0.38 (0.26–0.54)</td>
</tr>
<tr>
<td>Emergency cases</td>
<td>12</td>
<td>19</td>
<td>.60</td>
<td>0.78 (0.30–1.99)</td>
</tr>
<tr>
<td>Vessel runoff &lt;2</td>
<td>26</td>
<td>34</td>
<td>.48</td>
<td>0.79 (0.40–1.54)</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>35</td>
<td>31</td>
<td>.28</td>
<td>1.47 (0.74–2.92)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>72</td>
<td>73</td>
<td>.69</td>
<td>1.14 (0.60–2.16)</td>
</tr>
<tr>
<td>Hyperlipidaemia</td>
<td>45</td>
<td>49</td>
<td>.75</td>
<td>1.06 (0.73–1.54)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>20</td>
<td>22</td>
<td>.81</td>
<td>0.94 (0.57–1.54)</td>
</tr>
<tr>
<td>Smoking</td>
<td>68</td>
<td>61</td>
<td>.95</td>
<td>1.03 (0.47–2.23)</td>
</tr>
</tbody>
</table>

Note. Data are presented as % (n) unless otherwise indicated. Significant values are highlighted in bold. EVR = endovascular repair; OSR = open surgical repair; OR = odds ratio; MD = mean difference; CI = confidence interval; PAA = popliteal artery aneurysm; AAA = abdominal aortic aneurysm.

Table 4. Operation details.

<table>
<thead>
<tr>
<th></th>
<th>EVR</th>
<th>OSR</th>
<th>p</th>
<th>OR/MD (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operative time, min (mean ± SD)</td>
<td>163 ± 115</td>
<td>345 ± 92</td>
<td>&lt;.001</td>
<td>−182.00 (−220.09 to 143.10)</td>
</tr>
<tr>
<td>Length of stay, d (mean ± SD)</td>
<td>3.5 ± 1.4a</td>
<td>7.3 ± 4.0b</td>
<td>&lt;.001</td>
<td>−3.73 (−4.74 to −2.72)</td>
</tr>
<tr>
<td>30 d graft thrombosis, % (n)</td>
<td>9 (17/191)</td>
<td>2 (7/302)</td>
<td>.01</td>
<td>3.16 (1.31–7.62)</td>
</tr>
<tr>
<td>30 d re-intervention, % (n)</td>
<td>9 (18/191)</td>
<td>4 (14/302)</td>
<td>.04</td>
<td>2.15 (1.02–4.55)</td>
</tr>
</tbody>
</table>

Note. Significant values are given in bold. EVR = endovascular repair; OSR = open surgical repair; OR = odds ratio; MD = mean difference; CI = confidence interval.

a n = 150.
b n = 327.
Cooper author found complementary results to the present review, and the researcher drew similar conclusions.

Graft thrombosis was more likely following EVR during the first 30 post-operative days. Reasons for early stent graft thrombosis include inadequate stent graft expansion, stent graft kinking, or inappropriate inhibition of platelet activity. Inadequate expansion can cause graft migration, and the formation of endoleaks. Therefore, common complications of EVR are stent graft thrombosis, migration, kinking, fractures, and the occurrence of endoleaks. Further development of stent graft material might diminish the high rate of stent graft thrombosis. The stent graft material, which is placed into the popliteal artery, needs to be very flexible. The popliteal artery is bent many times daily, which is associated with popliteal artery compression or occlusion. Therefore, common complications of EVR are stent graft thrombosis, migration, kinking, fractures, and the occurrence of endoleaks.

In 2010, Midy et al. presented higher complication rates after the use of Wallgraft stent grafts (Boston Scientific, Natick, MA, USA) than with Viabahn (Gore) stent grafts in PAA. Apparently, owing to reduced flexibility, Wallgraft stent grafts occluded more easily and were associated with more endoleaks. In the present meta-analysis only Viabahn (Gore) and Hemobahn (Gore) (i.e., no Wallgraft) stent grafts were used for endovascular stenting. Despite the better flexibility of stent graft material, patients in the present review experienced stent graft thrombosis, stent graft migration, and the formation of endoleaks.

It is not only the mechanical properties of stent grafts that are under constant development; the surface in contact with blood is also under development: in a recent study, Lammer et al. provided promising results with regard to the new generation stent graft with a heparin bonded surface and contoured proximal edge. The researcher demonstrated significant patency benefits for heparin bonded covered stent grafts compared with bare metal stent grafts in femoropopliteal artery lesions. In contrast, the new concept of multilayer flow modulating stent grafts, introduced by Thakar and Chaudhuri showed poor results. The researcher implanted six multilayer stent grafts in six patients with PAA. They reported a thrombosis rate of 50% after 6 weeks.

The advantages of EVR are low invasiveness, with the avoidance of general anesthesia; minor blood loss; and a short duration of intervention. Further major benefits of this minimally invasive procedure are a short hospitalization and short recovery times with fewer wound complications. However, the use of EVR is limited by the patient’s anatomy. For a successful stent graft implantation, patients with at least two runoff vessels and suitable proximal and distal landing zones (2 cm) are preferred.

Despite gaining wide acceptance of EVR for PAA and its acceptable results, the US Food and Drug Administration has not yet approved this technique. As a consequence, many vascular surgeons, even outside the USA, are reluctant to use EVR, especially in younger patients with acute symptoms. This is reflected by the baseline characteristics of the patients reviewed here: patients receiving EVR were significantly older and less symptomatic than surgically treated patients, which is in line with the previous literature. Respecting patients’ specific risk profiles, this may limit the generalizability of the findings of this review.

Currently, high quality studies comparing the main repair methods of PAA are lacking. All currently published data on EVR for PAA come from a heterogeneous patient population. Unfortunately, this heterogeneity cannot be investigated statistically at present because the necessary data are not available. As a consequence of limited evidence, EVR has not yet been recommended as a routine procedure. Prospective RCTs comparing EVR and OSR are frequently called for in the literature. However, the carrying out of valid randomized trials is complicated owing to the low prevalence rates of PAA, with long recruitment periods and divergent study populations. To provide a large number of patients and appropriate medical evidence, population based registries need to be established, such as the Swedish registry in Sweden, or the VASCUNET collaboration (Europe, Australia, New Zealand).

The results of such a population based register were recently published by Galifianes et al., who compared short-term outcomes after EVR and OSR of PAAAs in 2,962 patients in the USA. After 1 and 3 months, EVR was
associated with higher re-intervention rates but did not offer mortality or cost benefits over OSR.

At the moment, it is not possible to determine the best treatment method for patients with PAAs. Further research is necessary and long-term results of population based registries are required. Currently, there is an ongoing multicenter RCT (NCT01817660) comparing EVR and OSR, which might bring more clarity to this topic in the future.12

**Limitations**

The present review has many strengths including the large sample size and detailed patient information, but it is also not without weaknesses. First, a comparatively small number of publications was identified for inclusion in the meta-analysis. Second, the selected studies were retrospective reviews and did not follow identical study protocols. Finally, study follow up periods were short and lost to follow up rates high. Owing to the low quality of primary studies, the overall quality of evidence was deemed “low” and “very low”. Therefore, caution should be taken when drawing conclusions from the data presented.

**Conclusion**

This systematic review and meta-analysis suggests that endovascular aneurysm repair may be a safe and efficient therapeutic method for PAAs with suitable anatomy. Midterm primary patency rates did not differ between EVR and OSR, but 30 day re-intervention and thrombosis rates following EVR were greater than OSR. Currently, the quality evidence for EVR is low, and for evidence based recommendations on EVR further research is absolutely necessary.

**CONFLICT OF INTEREST**

None.

**FUNDING**

None.

**APPENDIX A. SUPPLEMENTARY DATA**

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.ejvs.2015.04.036.

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