https://doi.org/10.23934/2223-9022-2019-8-4-437-442

Endovascular Treatment of Patients with Popliteal Artery Aneurysms (a Literature Review)

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ABSTRACT The purpose of this review is to evaluate the results endovascular treatment of popliteal artery aneurysms. Endovascular treatment using stent grafts is a safe and effective alternative to open surgical repair, has a lower wound complication rate and shorter length of hospital stay, satisfactory technical and clinical results even at long-term follow-up. In patients requiring long segment coverage or numerous stents, the poor state of distal blood flow may increase the risk of failure. Careful patient selection, proper operative technique and adequate sizes of stent grafts are required for good outcomes.

Keywords: popliteal artery aneurysms, stent graft, thrombolysis

For citation Prozorov SA. Endovascular Treatment of Patients with Popliteal Artery Aneurysms (a Literature Review). *Russian Sklifosovsky Journal of Emergency Medical Care.* 2019;8(4):437–442. https://doi.org/10.23934/2223-9022-2019-8-4-437-442 (in Russ.)

Conflict of interest Author declare lack of the conflicts of interests

Acknowledgments The study had no sponsorship

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EVS — endovascular surgery
ORS — open reconstructive surgery
PAA — popliteal artery aneurysm
SG — stent graft(s)

According to reports of all researchers [1–34], the majority of patients with popliteal artery aneurysms (PAA) are men (86–100%), often (over 95%) 60 (usually median 73–75 years ± 10 years). Women with PAA are older than men (men 66 ± 10 years old; women 71 ± 9 years old) [1].

Risk factors for the formation of PAA are considered to be: arterial hypertension (25.69%), smoking (19.5%), dyslipidemia (18.4%), diabetes mellitus (13.2%) [2]. Up to 78% of patients were current or former smokers, 25% had atrial fibrillation [3].

Aneurysms of both popliteal arteries occurred in up to 47.4% of cases [2]. Bilateral aneurysms were in 9.5% of women and in 27% of men [4]. In patients with PAA, abdominal aortic aneurysms were detected in 36.8% of cases; moreover, in patients with bilateral PAA, in 50% of cases, and in patients with unilateral PAA, in 25% of cases [2]. The prevalence of PAA among patients with abdominal aortic aneurysms was 19% with a PAA diameter greater or equal to 12 mm, and 11% with a diameter greater or equal to 15 mm [5]. In 94% of patients with PAA there were additional aneurysms of the lower extremities or the abdominal aorta [3].

The average diameter of the PAA was 3.4 cm, there were no differences in symptomatic and asymptomatic aneurysms [2]. The average diameter of the PAA is 30.9 ± 10.9 mm (range 17–60 mm) [6], 2.5 cm (1.1–4.5 cm), the average length was 5 cm (1.5–10 cm) [7], 3.2 cm (1.5-6.3 cm) [8]. Differences in the diameter of aneurysms: men - 30 mm (14−90); women - 26 mm (13−70) [1]. The average volume of the cavity of the aneurysm was 45.5 ± 3.5 ml [9]. The average growth rate of PAA was 1.22 mm per year (average observation time — 3.12 years, average initial diameter — 16.9 mm); while the average diameter of the PAA was 20 mm or more, the presence of an intramural thrombus in 57% of cases was a predictor of a subsequent increase in the diameter of aneurysms [3].

There are various forms of PAA: asymptomatic, symptomatic with acute or chronic ischemia, with thrombosis, with distal embolization, with rupture. Patients may have symptoms of ischemia, claudication, compression of the popliteal fossa, compression of the surrounding structures.

Femoral artery occlusion and lack of blood flow through the main arteries of the lower leg were associated with thrombosis of the aneurysm cavity. 2/3 of patients with PAA thrombosis had acute ischemia, 1/3 of the patients had some degree of claudication [2].

The condition of the distal bed affects the clinical manifestations of PAA. Atherosclerotic lesions of the femoral- popliteal segment were noted in 40.5% of cases, arteriomegaly in 26.2%, femoral artery occlusion in 16.7%, all 3 arteries were passable in 40.5% of cases, in 14.3% — 2 arteries, in 16.7% — one, in 28.6% there was no blood flow through any of the leg arteries [2]. In 98.1% of cases, at least one outflow vessel functioned [6]. The average number of outflow arteries was 1.84 (1 vessel — 42%; 2 vessels — 32%; 3 vessels — 26%) [10].

The main methods of treatment for PAA are surgical and endovascular ones. According to researchers from Sweden [11], the number of operations for PAA was 15.7 per 1 000 000 annually: 29.4% were treated for acute ischemia, 2.2% — for rupture of the aneurysm, 17.7% — for other symptoms, and in 50.7% of patients, PAA was asymptomatic. There is a 3.6- fold increase in the number of endovascular interventions: from 4.7% of all interventions for PAA in 1994-2002 up to 16.7% in 2008−2012. Stent grafts (SG) were used in 16.4% of cases of acute ischemia.

Intra-arterial thrombolysis is a minimally invasive treatment option for acute ischemia in PAA thrombosis [2, 4-6, 12-14]; thrombolysis for embolism from PAA allowed to improve the outflow through the vessels of the leg. Thrombolysis was used for thrombosis of hypertension [15]; thrombolysis of thrombosed endoprostheses was successful in 91% [14]. According to the Swedish register, thrombolysis was used in 51% of cases of acute ischemia of the popliteal arteries in women [4]. Complications were rare: *M. Trinidad Hernandez et al.* [13] performed thrombolysis in 11 cases of acute PAA thrombosis, and one patient had intracranial hemorrhage.

Diagnosis of PAA is based on the results of ultrasound (ultrasound), CT angiography, and angiography. Ultrasound is used not only to identify and evaluate PAA. *A.O. Smialkowski , R.L. Huilgol* performed antegrade puncture of the femoral artery for implantation of SG under ultrosound guidance [10]. *A.R. Raney et al.* [16] implanted several *Viabah* SGs *to* 7 patients using intravascular ultrasound, which made it possible to have a complete understanding of the anatomy of PAA, thrombosis, accurately measure the diameter of the vessels and determine the proximal and distal locations of the desired zones for adequate isolation of the PAA. Monitoring after SG implantation at different times was performed using ultrasound [12, 17−20]. For implantation we used: *Viabahn / Hemobahn (W.L. Gore and Associates Inc, Flagstaff, AZ, USA), Fluency Plus Endovascular Stent Graft (C.R. Bard , Inc)*, flow modulating *Multilayer Aneurysm Repair System* stents *(MARS, Cardiatis S.A.)*. We installed 1-4 SGs in the popliteal artery. The average SG diameter was 8.84 mm (from 6 to 13) [10], the average length was 180 mm) [20]. *Giaquinta A. et al.* [21] implanted SG *Viabahn* into a bare metal nitinol stent, deployed at the level of an aneurysm in order to guarantee the external support of SG.

Implantation of SG was often performed by antegrade puncture of common femoral arteries, but, for example, *M. Trinidad-Hernandez et al.* [13] implanted 10 SG during the puncture, and 21 SG were installed through the incision on the hip.

The duration of endovascular surgery (EVS) is shorter than the duration of traditional open reconstructive surgery (ORS), for example, the implantation time of SG was 75.4 minutes in the endovascular group versus 195.3 minutes in the surgical group [21]. The hospitalization after EVS is significantly shorter than after ORS: 4.3 days for the endovascular group versus 7.7 days for the surgical group [21], 1.4 ± 1.9 days versus 3.8 ± 2.5 days [22], 1.6 days against 5.8 [24], 2 days against 12 [19]. Postoperative hospital stay was 2.6 days [23]; 1 day (0−12) [8].

Drug therapy in EVS included clopidogrel and/or aspirin [7, 15, 19, 25]. Aggressive antithrombotic, anticoagulant therapy was necessary; with its insufficiency, thrombosis of up to 50% of stents during the first 6 weeks is possible [17].

A number of authors perform EVS both in a planned manner and in symptomatic PAA, rupture, thrombosis, acute ischemia [7, 8, 10, 13, 18, 20, 26, 27].

M. Trinidad-Hernandez et al. [13] performed EVS in 25 patients (31 limbs). In 39% of cases, EVS were urgent (one case was PAA rupture and 11 cases were acute thrombosis). Technical success was 97%. Mortality within 30 days — 6.4% (0% — planned intervention and 16.7% — emergency intervention). Early complications: SG thrombosis — 6.4%, hematoma — 13%. Primary and secondary patency on day 30 were 93.6 and 96.7% (100% in the planned group and 83.3 and 91.6% in the emergency group). The primary patency in a year was 86% (95% in the planning group, 69% in the emergency), the secondary patency was 91% (100% in the planning group and 91% in the emergency). One limb was saved withj,hjcnfyin a year in 97% of cases. Two-year survival was 91% in the planned group and 73% in the emergency group. There were 5 occlusions of the SG after 30 days. SG encasement — one case, and fracture — one case. Three leaks (*endoleak*) of type II were revealed (10%). In one observation, additional SG was established to eliminate type I leak. In general, various problems arose after 11 EVSs (35.5%). Good results were achieved after planned EVS in anatomically suitable patients with an increased risk of acute respiratory infections, complications were more common after emergency EVS.

C. Möllenhoff et al. [26] analyzed 8 studies on *Hemobahn /Viabahn* SG *implantation in* 222 patients (251 PAA). Urgent EVS was performed for 3 PAA ruptures and in 10 patients with acute limb ischemia. Initial technical success was 99.2%. Mortality in the period of 30 days — 0.4%, postoperative complications occurred in 1.6% of cases. The examination revealed 42 occlusions and 4 stenosis, on average 10.8 months after the EVS. Primary and secondary patency were 85.6% and 93.4%, respectively, during the first year, 78.5% and 90.4%, respectively, during the second year. The limb was saved in 99.2%. The leak occurred in 6% (15 patients), SG migration in 5.2% (13 patients), SG fracture in 5.6% (14 patients), which led to SG occlusion in 6 patients; type III and IV leaks were observed in 2 patients. Repeated EVSs were performed in 18.7% (32 for occlusion, 4 for stenosis of hypertension, in 11 patients — to eliminate the leak).

M. Piazza et al. [9] performed 46 EVSs in 42 patients (in 2 patients with rupture and in one with acute thrombosis). Technical success was 98%. The primary patency during 1, 3 and 5 year was 82%, 79% and 76%, respectively, the secondary patency was 90%, 85% and 82%, respectively; within 5 years, limb was saved in 98% and survival rate was 84%. After 5 years, the volume of the PAA cavity decreased from 45.5 ± 3.5 ml to 23.0 ± 5.0 ml. The coverage of a segment more than 20 cm by the SG was a negative predictor in terms of its patency.

J.H. Saunders et al. [15]) implanted *Hemobahn and Viabahn SG* in 26 patients (in 32% of cases with acute symptoms (34 PAA). Technical success was achieved in all cases. In terms of 1, 3, 5 years, primary patency was 88%, 82% and 82%, respectively, secondary patency — 90%, 86%, and 86%, respectively. Survival without amputations within 1, 3, and 5 years was 97%, 94%, and 94%, respectively. During the observation, 5 occlusions of SG were revealed. Reintervention was performed in 12% of cases.

The condition of the vessels of the leg is important, as well as preservation of at least one vessel of the outflow [6]. The poor condition of the vessels of the outflow and the use of several stents lead to a decrease in the degree of patency [8]. The failure of stenting with one outflow vessel was statistically significant compared with patients with two or three outflow vessels. Poor distal outflow was a predictor of stenting failure [25].

Numerous comparisons of EVS with ORS have been made, different opinions have been expressed that depend on the experience gained and the results obtained.

In 2008, a group of researchers [28] from England from the Department of General Surgery published a meta-analysis of the treatment of non-thrombosed PAA (3 studies — 141 patients, 37 EVA and 104 ORS). There was no significant difference in the long-term results of primary patency. EVSs had the same medium-term benefits as ORS, however, SG thrombosis and the frequency of reinterventions were greater in number, therefore, the authors are against EVS.

A randomized controlled trial [29], containing one prospective study and 4 retrospective studies, with a total of 652 cases (236 EVS and 416 ORS) revealed equal patency of the popliteal artery for both types of treatment in an average of 33 months. The duration of surgery and hospitalization were shorter, and SG thrombosis and repeated interventions of 30 days were higher in patients in the group with EVS. There were no differences in mortality and limb loss in the groups. Endovascular treatment of PAA

has shown comparable medium-term results and appears to be a safe alternative to ORS.

M.H. Eslami et al. [22] performed a retrospective analysis of 390 patients with asymptomatic PAA (221 ORS, 169 EVS). Patients after ORS had a significantly longer period without major complications (95% versus 80%) and perioperative mortality (93% versus 80%) within one year after the intervention. The authors believe that ORS is associated with better results than EVS.

A.E. Leake et al. [24] reported the results of PAA treatment in one center (186 PAA in 156 patients: 110 ORS and 76 EVS). Open operations were more often performed in patients with PAA thrombosis (41.8 versus 5.3%), acute ischemia (24.5 versus 9.2%) and ischemic pain at rest (34.5 versus 6.6%). Complications were more frequent with acute respiratory infections within 30 days after surgery (22 versus 2.6%), mortality was 1.8%, with ALV — 0%; amputations in acute respiratory infections — 3.7%; with ALV — 1.3%. Primary, primary associated and secondary patency after 3 years were: ORS — 79.5, 83.7 and 85%, respectively; EVS — 73.2, 76.3 and 83% respectively. SG thrombosis after EVS occurred in 8 of 24 patients treated in 2006–2008, but only in 4 of 51 patients treated in 2009–2013. The authors conclude that EVS is a safe method with lower rates of complications and a shorter hospital stay.

The same authors [30] published a meta-analysis of 14 trials for treating 4880 PAA (ORS 3915, EVS 1210). Patients who underwent open surgery were younger and had a poor outflow of tibial veins, a higher incidence of local complications in the wound, and a lower incidence of thrombotic complications, a longer period of hospitalization and a lower percentage of reoperations. Primary permeability through one and after 3 years was better after ORS; there was not much difference in secondary permeability during these periods.

Emergency EVS and poor outflow are predictors of problems. These operations are justified in elderly patients of a high risk and with appropriate anatomy. In emergency interventions, problems are common with both methods [31].

A. Wrede et al. [32] compared the results of 102 operations (36 emergencies and 66 planned interventions). The group of planned EVSs was different in that they were older, had a higher ankle-brachial index, fewer cases of wound infection, fewer complications, bleeding, and shorter hospital stay. In a year, the endovascular group had a higher level of major amputations.

M. Wooster et al. [19] compared the treatment of 66 patients (75 PAA, 52 ORO and 23 EVO). Primary and secondary patency were 67.2% and 67.2%, respectively, after the EVO and 65.5% and 78.4%, respectively, for the acute respiratory disease after 4 years. Secondary interventions were required after 48.1% of endovascular and 54.1% of open surgeries.

S. Ronchey et al. [33] conducted a retrospective analysis of the treatment of 67 patients with PAA. Group *A* — EVS (25 patients); group *B* — a bypass from a large saphenous vein (28) and group *C* — installation of a synthetic prosthesis (14). Technical success was 100%, there was no postoperative mortality. Survival over 5 years was 78%. The primary patency for 5 years was 71%, 81% and 69% for groups *A*, *B* and *C*, respectively, the secondary patency was 88%, 85% and 84%, respectively, the absence of repeated interventions over a period of about 5 years was 62%, 84% and 70% respectively. The results of the EVS were not worse in comparison with the ORS: a shorter hospitalizatio, significantly less erythromass for transfusion. Thus, EVS can be successfully used even in common cases.

A. Cervin et al. [11] provided data on hospitals in Sweden for 2008–2012. Of 592 interventions (499 patients), 174 (29.4%) were performed for acute ischemia, 13 (2.2%) for rupture, 105 (17.7%) for other symptoms, and 300 (50.7%) PAA were asymptomatic. Patients who were treated endovascularly were older. Amputations within 30 days amounted to 14.8% after EVS, 3.7% after ORS and 17.4% and 6.8% in a year, respectively. Secondary patency after EVS was 94.5% 30 days after the operation and 83.7% in a year, compared to 98.8% and 93.5%, respectively, after open operations. Patency after EVS was lower than after ORS, especially in the treatment of acute ischemia, the risk of amputation was higher.

Women with both types of treatment showed lower primary patency and a tendency to lower limb safety compared to men [1].

R. Pulli et al. first presented their data [12], and then [34] analyzed the results of the treatment of PAA in 7 Italian vascular centers: 178 ORS and 134 EVS. Patients who underwent ORS were more often symptomatic (64%) than patients in the EVS group (34%); they often had acute limb ischemia (23% and 6.5%, respectively), more often less than 2 outflow arteries (39% and 26%, respectively). There were no fatalities in the ORO group; there were 6 thromboses (3.3%) and one amputation. In the EVS group, mortality was 1.5%; there were 13 thromboses (9.7%) and one amputation (0.5%). In the group of patients with acute respiratory infections, primary and secondary patency, the absence of reinterventions and the preservation of the limb for 48 months amounted to 63.5%; 76.5%; 72.5% and 89.7%, respectively, and in the group of patients with EVS, these indicators amounted to 73.4%; 85% 75% and 97% respectively. The authors believe that both types of treatment are safe, provide satisfactory early and long-term results, the choice of operation must be carried out depending on the clinical and anatomical characteristics of patients.

CONCLUSION

The treatment of popliteal artery aneurysms with stent-grafts is the alternative to open reconconstructive surgeries, especially in cases of contraindications to open surgery or refuse of patients to undergo open surgery. Good results were obtained with planned endovascular operations in anatomically suitable patients, complications are more common after emergency endovascular interventions. For good endovascular surgery results, careful patient selection, proper surgical technique and the appropriate stent grafts are necessary. The poor condition of the vessels of the outflow and the use of numerous stents lead to a decrease in patency. Implantation of stent grafts is an option of the popliteal artery aneurysms treatment.

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Received on 04.04.2019
Accepted on 30.05.2019