Continued sac perfusion of popliteal artery aneurysms after ligation and bypass. Relevance of duplex ultrasound surveillance and treatment

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Continued sac perfusion of popliteal artery aneurysms after ligation and bypass. Relevance of duplex ultrasound surveillance and treatment

AIM: *Conventional management of popliteal artery aneurysms (PAA) through a medial approach may be lon term ineffective. We report our long term rate of continued sac perfusion after ligation and bypass, combined to duplex ultrasound (DUS) surveillance protocol.*
PATIENTS AND METHODS: *Follow-up data of 24 PAA (mean diameter 37.5 ± 8.8 mm) treated by ligation and bypass with eventual adjunctive procedures (direct sac embolization or resection) were collected. The endpoints of the study were the long term rate of continued sac perfusion and the freedom from any reintervention.*
RESULTS: *Twentyfour PAA were treated in 20 patients. Long term follow-up was complete for 19 graft (79.1%). During a median follow-up of 71.2 months (4-168), persistent sac flow was found in 5 legs (26.3%), 4 to 36 months after surgery, without enlargement or rupture. The cumulative Kaplan-Meier survival free from PAA reperfusion at 1, 3, and 6 years was 91.5%, 77.5%, and 71.5%, respectively. Basing on DUS surveillance, late additional procedures were required in 5 patients (25%), to treat sac reperfusion or preserve graft patency. The cumulative Kaplan-Meier survival free from any reintervention at 1, 3, and 6 years was 91.5%, 72.8%, and 67%, respectively.*
CONCLUSIONS: *Conventional management of PAA through a medial approach may be associated to progressive sac expansion. The DUS surveillance protocol remains strongly recommended to detect sac perfusion and suggest the timing of reintervention before rupture occurs. Adjunctive intraoperative procedures could improve the long term results, but further studies on large series are needed.*

KEY WORDS: Acrylic glue, Duplex ultrasound study, Femoropopliteal bypass, Popliteal artery aneurysm, Ultrasound-guided embolization

Conventional management of popliteal artery aneurysms (PAA) includes proximal and distal aneurysm ligation combined with bypass grafting, through a medial approach. However, due to the presence of patent geniculate arteries, failure of sac exclusion can be demonstrated in 1/3 of cases leading to progressive expansion, similarly to what happens following endovascular aneurysm repair [1,5].

As a consequence, a more radical treatment, consisting in endoaneurysmectomy and graft interposition through a posterior approach to oversew the geniculate arteries, has been proposed with some anatomical limitations, mainly in case of longitudinal extension of the sac, proximal to the adductor hiatus [6-8].

Although PAA vascular exclusion can be considered long term ineffective, medial approach for popliteal artery

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reconstruction has continued to be the preferred surgical technique in our center. According to literature data and basing on our previous clinical experience, since 2009 we have adopted some adjunctive intraoperative procedure, consisting in partial sac resection and intraoperative direct embolization of the non resected sac, associated to a duplex ultrasound (DUS) surveillance protocol after surgery, in order to detect any continued sac reperfusion, requiring corrective treatment.
In this study we report our data on long term rate of continued sac perfusion after conventional PAA surgical repair, combined to DUS surveillance, with particular emphasis on late reintervention.

Patients and Methods

Data from PAA surgical repair (2009-2023) were prospectively collected in a dedicated database, which included demographic data, preoperative risk factors, clinical presentation, pre- postoperative PAA axial diameter, details of surgery (run off vessels, site of anastomosis, type of conduit), 30 days outcomes. Popliteal aneurysms were diagnosed by clinical examination, DUS evaluation, computed tomography, or a combination of these modalities. Repairs were performed for symptomatic popliteal aneurysm (acute thrombosis, rupture, peripheral embolization) or asymptomatic with a maximum diameter exceeded 2 cm.
The surveillance program consisted of clinical and DUS examinations at 1, 6, and 12 months and yearly thereafter. A list of all patients with PAA treated by ligation and bypass grafting through a medial approach was constructed (January 2009 – February 2023), including the follow-up data.
Patients undergoing aneurysm resection with prosthetic interposition through a posterior approach were excluded from the study, as patients undergoing endovascular repair.
Patients who did not accomplish vascular examinations at any time during the years of follow-up were recalled to perform a new clinical and strumental assessment, as patients with a follow-up evaluation dating more than 6 months from June 2023. DUS scanning and clinical follow-up were focused on sac diameter, presence of flow inside the sac, graft patency, PAA related events, type of reintervention, and mortality for any cause. Continued sac perfusion was defined as presence of flow inside the aneurysm at DUS examination, confirmed by contrast enhanced CT-scan.
Reintervention was defined as surgical or percutaneous procedure to restore the aneurysm vascular exclusion or graft patency.
The association between continued sac perfusion and categorical variables (pre- postoperative diameter, contralateral PAA, site of proximal and distal anastomosis, intraoperative glue embolization, partial/total aneurismectomy) was evaluated.

Operative Details

Femoropopliteal bypass associated to proximal and distal aneurysm ligation was performed trough a medial approach, using autologus reversed saphenous vein or PTFE graft as second choice. Inflow vessels were common or superficial femoral artery (CFA, SFA), as proximal as possible to the aneurysm, and outflow vessels were below-knee popliteal artery or a patent tibial vessel. Thromboembolic involvement of the run-off vessels was treated by Fogarty embolectomy, without preoperative thrombolysis. In case of large diameter (>40 mm), associated procedures, such as partial sac resection with suture of patent geniculate arteries or intraoperative direct embolization of the non resected sac using acrylic glue (Glubran 2, GEM, Viareggio - Italy), were performed according to the judgement of the operator.

DUS protocol. The surveillance protocol included measurement of ankle-brachial index (ABI) and color duplex scanning, according to the guidelines of the Italian Society for Vascular Investigations [9]. The entire popliteal aneurysm repair was imaged, including the inflow and distal arteries. The popliteal aneurysm and tibial bifurcation were explored using B-mode and color/power Doppler modalities, with transversal and longitudinal sections to measure the aneurysm diameter and the presence of residual flow inside the sac. Peak systolic velocities (PSVs) were recorded along the vein/prosthetic graft segments to detect stenosis (PSV > 200 cm/sec) or identify the development of an abnormal low flow (PSV< 45 cm/s).

Secondary procedures. A secondary procedure was indicated in case of continued aneurysm perfusion or symptomatic graft occlusion, and consisted in DUS-guided percutaneous sac embolization with acrylic glue (Glubran 2, GEM, Viareggio - Italy) or other surgical procedures, mainly required to correct native arterial or graft stenosis, not related to aneurysm reperfusion.

Endpoints. The primary endpoint was the rate of continued sac perfusion, defined as patient survival free from PAA reperfusion. The secondary endpoint was the freedom from any reintervention.

Statistical Analysis

Quantitative variables are expressed as mean ± range. Categorical variables are presented as numbers with percentage. Rates of continued sac perfusion and freedom from any reintervention were estimated using the Kaplan-Meier method. The Fisher exact test, as appropriate, were used to assess associations with binary outcomes, such as sac reperfusion. Values of $P<0.05$ were considered statistically significant.

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Results

Between January 2009 and February 2023, 24 PAAs were treated by ligation and bypass grafting through a medial approach in 20 patients. Baseline clinical characteristics and risk factors are reported in Table I. About 40% of patients presented with symptoms of peripheral embolization, eventually associated to critical limb ischemia. The mean diameter of the aneurysm at the first observation was 37.5 mm (range 25-55 mm). Most patients presented with at least 2 run-off vessels (Tab.II).

Operative Treatment.

Surgical treatement consisted in aneurysm ligation and bypass grafting, through a medial approach, combined with additional procedures in 45.8% of cases (Table III). No patient died in the peri-operative period and there was no peri-operative limb loss. An early reintervention secondary to surgical bleeding was necessary in 3 cases (12.5%).

Table I - *Demographic data.*

	N.	%
Patients	20	
Mean age (y)	62.7 ± 9.9	
Male/female	19/1	
Coronary artery disease	9	45
Hypertension	15	75
Diabetes mellitus	3	15
Dyslipidemia	16	80
Smoking	9	45
CHR	2	10
COPD	10	50
Associated AAA	4	20
Associated contralateral PAA	12	60

CHR, chronic renal failure; COPD, chronic obstructive pulmonary disease; AAA, abdominal aortic Aneurysm; PAA, popliteal artery aneurysm.

Table II - *Politeal aneurysms data.*

	N.	%
Legs	24	
Sac size (mm)		
Mean diameter	37.5 ± 8.8	
Range	25-55	
Run-off vessels		
One	6	25
Two	7	29.1
Three	11	45.9
Claudication/CLI	10	41.6

CLI, critical limb ischemia

Table III - *Operative data.*

	N.	%
Proximal anastomosis		
CFA	4	16.7
SFA	20	83.3
Distal anastomosis		
ATK popliteal artery	5	20.8
BTK popliteal artery	16	66.7
Tibial vessels	3	12.5
Type of graft		
Autologus saphenous vein	16	66.7
HB PTFE graft	7	29.1
Composite graft	1	4.2
Additional intraoperative procedures		
Glue embolization	5	20.8
Partial aneurysmectomy	6	25

CFA, common femoral artery, SFA, superficial femoral artery; ATK, above the knee popliteal artery; BTK, below the knee popliteal artery,;HB, heparine bonded.

Table IV - *Late results of ligation and bypass (19 PAA, mean follow-up 71.2 months, range 4-168)*

	N.	%
Mean aneurysm diameter (mm)	29.3 ± 13.3	
Sac size		
Decreased (>10%)	9	47.3
Unchanged	10	52.7
Persistent sac flow	5	26.3
Rupture (PTFE graft infection)	1*	5.2
Graft thrombosis	5	26.3
Late additional procedures	7	36.8

*septic false aneurysm on the site of proximal anastomosis

Long Term Follow Up

At the end of the study (Table IV), follow-up data were complete for 17 patients (70.8%) and 19 graft (79.1%). Graft resulted occluded in 5 out of 19 bypass (26.3%), with no limb loss. One patient died 12 years after the first operation, as a consequence of stroke. During a median (range) follow-up of 71.2 months (4-168), persistent sac flow was evident in 5 legs (26.3%) of 3 patients, 4 to 36 months after surgery, without a significative increase of the aneurysm size. One patient, who presented a persistent flow from a patent geniculate artery still evident 20 months after surgery (Fig. 1) was successfully treated with TC-guided percutaneous sac embolization with acrylic glue. The same procedure was performed in a second patient with bilateral PAA, who presented persistent sac flow in left and right leg, respectively 11 and 36 months after surgery. Despite the suc-

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TABLE V - *Summary of reinterventions*

	PAA diameter (mm) Preop	Postop	Anastomosis Prox	Dist	Reintervention (months)	Follow-up (months)
B.A.	49	40	SFA	ATK	Resection* (30)	lost (60)
C.L.	39	39	SFA	BTK	AGE (20)	complete (60)
I.F.^	49	49	SFA	BTK	AGE (11)	complete (140)
I.F.^	49	49	SFA	BTK	EVR (84)	complete (140)
I.F.^	51	51	SFA	BTK	AGE (36)	complete (128)
R.L.	30	30	SFA	BTK	PTA+stent (24)	complete (156)
T.M.	28	10	SFA	BTK	PTA+stent (3)	complete (21)

^ same patient, bilateral PAA
*septic false aneurysm

SFA, superficial femoral artery; ATK, above the knee popliteal artery; BTK, below the knee popliteal artery, AGE, aneurysm glue embolization; EVR, endovascular repair; PTA, percutaneous angioplasty.

TABLE VI - *Risk factors analysis for PAA reperfusion (Fisher exact test).*

PAA diameter >30mm	
Preoperative	P =1
Postoperative	P =0.325
PAA diameter >40mm	
Preoperative	P =0.629
Postoperative	P =0.270
Contralateral PAA	P =0.327
Site of proximal anastomosis (CFA, SFA)	P =0.544
Site of distal anastomosis (ATK, BTK)	P =0.544
Intraoperative glue embolization	P =0.0785
Partial/total aneurismectomy	P =0.280

PPA, popliteal artery aneurysm; CFA, common femoral artery; SFA, superficial femoral artery; ATK, above the knee popliteal artery; BTK, below the knee popliteal artery.

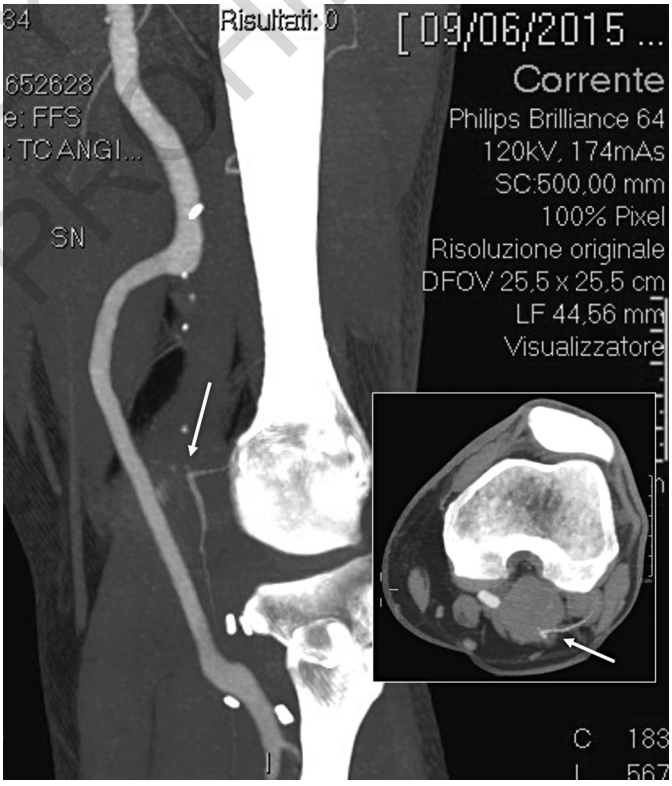

Fig. 1: Persistent flow in left PAA from a patent geniculate artery still evident 20 months after surgery.

cessful percutaneous embolization, a new sac perfusion was noted in the left side of this patient, 84 months after the first operation, as a consequence of retrograde flow from the popliteal artery that required an endovascular stentgraft exclusion (Fig. 2). In a third patient with bilateral PAA and persistent sac flow, a conservative treatment was preferred considering the short follow up period (<14 months) and the low flow of reperfusion (Fig. 3). Late additional procedures to preserve graft patency were required in 2 patients presenting with subacute limb ischemia, 3 and 24 months after surgery. One rupture requiring urgent surgical correction occured 30 months after surgery, as a consequence of a septic false aneurysm of the PTFE graft, in a previously asymptomatic patient lost at regular follow-up. Summary of reintervention is listed in Table V. The cumulative Kaplan-Meier patient survival free from PAA reperfusion at 1, 3, and 6 years was 91.5%, 77.5%, and 71.5%, respectively (Fig. 4).

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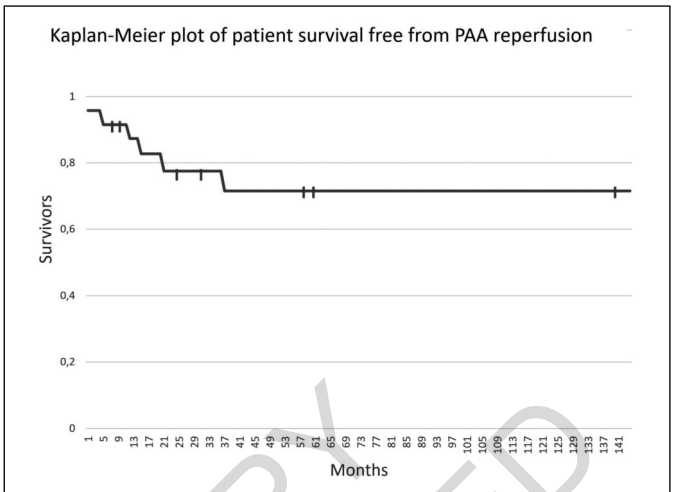
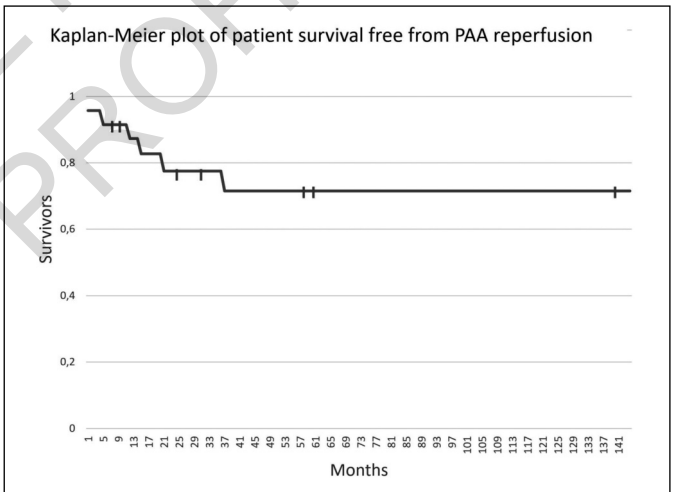
Fig. 2: Continued sac perfusion in left PAA 84 months after surgery, despite a previous successful percutaneous embolization (A). CT-scan control (B) showing the definitive vascular exclusion after the endovascular treatment on the left leg and the absence of continued sac perfusion on the right leg, more than 5 years after percutaneous acrylic glue embolization.



Months	0	12	24	36	72
Operation (n. at risk)	24	23	19	16	13
Freedom from reperfusion (%)	95.8	91.5	82.7	77.5	71.5

Fig. 4: Cumulative Kaplan-Meier survival free from PAA reperfusion.

Fig. 3: Bilateral continued sac perfusion 1 year after surgery, in a patient undergoing conservative treatment.



Months	0	12	24	36	72
Operation (n. at risk)	24	23	19	16	13
Freedom from reperfusion (%)	95.8	91.5	82.7	77.5	71.5

Fig. 5: Cumulative Kaplan-Meier survival free from any reintervention.

Statistical analysis did not show correlation between categorical variables and continued sac perfusion (Table VI). The cumulative Kaplan-Meier patient survival free from any reintervention at 1, 3, and 6 years was 91.5%, 72.8%, and 67%, respectively (Fig. 5).

Discussion

Surgical repair of PAA is a safe procedure, with low perioperative complications and excellent durability [10-13]. However, vascular exclusion may be not complete after ligation and bypass performed through a medial approach, as a consequence of the back flow in the aneurysm sac, from patent geniculate arteries, resulting in an unex-

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pectetd PAA growth [1-5]. Mehta et al. presented a series of 23 patients undergoing 26 PAA surgical exclusions, showing a rate of 38% of persistent collateral flow, 23% of aneurysm enlargement, and 12% of aneurysm rupture, over 7 years after the operation [1]. Similar findings have been reported by other studies [2-4], and confirmed by a large swedish registry on 717 legs, that documented an expansion rate of 33% after a median of 7 years, in the group patients operated using ligation and bypass [13].
Although endovascular repair has been regarded as an actractive alternative to open repair [14-17], continued blood flow in the aneurysm sac can occur as well, with risk for enlargement and rupture. In a recent sudy, focused on contrast enhanced DUS [18], type II endoleak was detected in more than 50% of PAA after stentgtaft repair (follow-up 57 months, range 33-143), suggesting that endovascular treatment may be not a definitive solution.
As alternative to conventional treatment, endoaneurysmectomy with prosthetic graft interposition using a posterior approach has been proposed to reduce the long term persistent collateral flow into the aneurysm sac. This technique has proven to be effective as a result of the complete saccotomy, but it may be associated to some technical issues, including the occurence of peripheral nerves injury, mainly in case of large diameter or longitudinal extension of the aneurysm [6-8,16].
According to previous experiences [10-13,19-22] the present report confirms that medial approach can be still regarded as a good surgical option for PAA, showing good results, in terms of survival free from reperfusion and reintervention, intended as sac embolization or procedures to restore the graft patency. However, despite the surgical upgrading (partial sac resection and intraoperative glue embolization), continued sac perfusion can be limited, but not completely eliminated, whereas at least 25% of patients experienced PAA reperfusion over the time, with no clear predictive factor.
The value of DUS surveillance after PAA repair is well documented in literature [16,18,23] and DUS remains a key point to detect a possible reperfusion of the sac, suggesting the timing of reintervention, as confirmed by the present series, in which no local complication or PAA rupture occured. In this regard, DUS-guided sac embolization we used as first line treatment, may be considered as an effective alternative to traditional surgery, according with recent literature [16,22,24,25].

Conclusions

Conventional management through a medial approach offers many advanteges for the PAA treatment (traditional surgical access, availability of the saphenous vein, complete tibial vessels control), but can be long term ineffetive, as a consequence of pressurization of the sac by patent genicular branches generating an endotension mechanism. Some intraoperative procedures, such as partial resection of the sac and direct glue embolization may be associated with a lower reperfusion rate, but further studies on large series are needed.
However, with the aim to prevent any long term adverse event after ligation and bypass, the DUS surveillance protocol remains strongly recommended to detect sac perfusion and suggest the timing of reintervention.

Riassunto

INTRODUZIONE E SCOPO DELLO STUDIO: Il trattamento convenzionale degli aneurismi dell'arteria poplitea (PAA) prevede la legatura dell'aneurisma ed il confezionamento di un bypass femoro-popliteo, con accesso chirurgico mediale. Tuttavia, l'esclusione vascolare a lungo termine non è sempre garantita, per causa del flusso retrogrado proveniente dalle arterie genicolari, con possibile espansione dell'aneurisma, fino alla rottura. In questo studio vengono riportati i risultati a lungo termine di aneurismi poplitei trattati con metodica tradizionale, seguita da un rigoroso follow-up strumentale, al fine di identificare riperfusioni della sacca aneurismatica e di provvedere tempestivamente al trattamento.
MATERIALI E METODI: Studio retrospettivo su 24 PAA in 20 pazienti (19 maschi, 1 femmina, età media 62.7 ± 9.9) sottoposti a legatura e bypass femoro-popliteo (2009-2023), ricontrollati periodicamente con ecocolor-Doppler ed eventuale angio-TC, al fine di evidenziare l'incompleta esclusione vascolare dell'aneurisma. Endpoint dello studio: tasso di riperfusione della sacca a lungo termine e libertà da reinterventi tardivi.
RISULTATI: Ventiquattro PAA con diametro medio di 37.5 ± 8.8 mm (range 25-55 mm), sono stati trattati con legatura e bypass per via mediale. In 11 casi (45.8%) sono state eseguite procedure aggiuntive, quali resezione parziale dell'aneurisma ed embolizzazione intraoperatoria di colla al cianoacrilato (Glubran 2, GEM, Viareggio - Italy). Al follow-up medio di 71.2 mesi (4-168), era evidente all'ecocolor-Doppler un flusso arterioso persistente all'interno della sacca in 3 pazienti, 5 arti (26.3%), da 4 a 36 mesi dopo la chirurgia. Tre casi venivano trattati con successo, mediante embolizzazione ecoguidata di cianoacrilato, mentre in altri 2 casi si preferiva un trattamento conservativo. Il tasso di riperfusione della sacca aneurismatica secondo la curva di Kaplan-Meier a 1, 3 e 6 anni era rispettivamente 91.5%, 77.5% e 71.5%. Il tasso di libertà da reintervento secondo la curva di Kaplan-Meier a 1, 3 e 6 anni era rispettivamente del 91.5%, 72.8% e 67%.
CONCLUSIONI: Il trattamento convenzionale dei PAA attraverso l'approccio mediale si associa a buoni risultati a distanza, in termini di assenza di riperfusione della sacca residua. Tuttavia, in circa il 25% dei pazienti l'esclusione vascolare dopo chirurgia non è completa. L'adeguato follow-up clinico e strumentale identifica

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questa eventualità ed indica l'opportunità o meno di un trattamento, che può essere rappresentato dalla embolizzazione percutanea ecoguidata con cianoacrilato.

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