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A New Technique for the Treatment of Venous Popliteal Aneurysms Using the Axillary Vein: Medium and Long-Term Results

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Background: Venous popliteal aneurysms are a rare but serious disease due to the risk of pulmonary embolism (PE). Aneurysms larger than 20 mm in diameter or with an embolic episode should be treated. The classic surgical technique is the tangential resection of the aneurysm with venorrhaphy, which may raise the risk of recurrence. We report a series of patients treated with a new technique consisting of aneurysmal resection and reconstruction using the axillary vein. The primary objective was to evaluate the patency of the transposed venous graft. The secondary objectives were to study the feasibility of the technique, the continence of the transplanted valve, the risk of aneurysmal recurrence, and the clinical consequences on the treated lower limb and at the donor site.

Methods: All the adult patients treated with this technique between October 2006 and May 2023 were included. Post-traumatic venous aneurysms, iatrogenic aneurysms, and those associated with vascular malformations were excluded. Ultrasound follow-up was obtained 3, 6, and 12 months after the operation, then annually and evaluated the patency and the diameter of the venous graft, and the continence of the valve. The clinical consequences at the donor and recipient site were collected.

Results: Eleven patients were enrolled, including 7 men, with an average age of 55 (46–77) years. All the patients had symptoms: 10 had a history of PE and 1 suffered from deep venous insufficiency with dyspnea. The average diameter of the venous aneurysm was 29 mm (14–45 mm). The mean follow-up was 65 months (4–191) with only 1 patient lost to follow-up after 9 months. No bypass thrombosis was observed with ultrasound and venous-computed tomography follow-up, and the transposed valve remained continent in all the patients. There were no embolic recurrences after surgical treatment. The average diameter of the venous bypass was 10.5 mm (7–12), without aneurysmal recurrence. No complications were observed at the harvesting site.

Conclusions: Our study confirmed the feasibility of this alternative technique, with good long-term results with a 100% patency rate without any aneurysmal recurrence. It confirmed the continence of the transposed valve with a good tolerance at the donor site. The number of patients treated in this study was limited, but it highlights an interesting alternative to treat these venous lesions.

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INTRODUCTION

The first case of popliteal venous aneurysm was reported by May and Nissl in 1968.[1] It is a rare disease, with an estimated prevalence in the literature between 0.1% and 0.2%,[2,3] but potentially fatal, due to the increased risk of deep vein thrombosis and pulmonary embolism (PE). This most serious complication is also the most common one, reported in about 50% of the patients presenting a venous popliteal aneurysm.[4] The other clinical presentations are mostly local symptoms, with in the majority of cases a popliteal palpable mass with walking difficulties (15−35%),[4−6] deep venous insufficiency (13%)[6] or deep vein thromboses without PE (7%).[4,6] The 2022 European Society for Vascular Surgery recommendations define venous aneurysms by a maximum diameter of the vein reaching twice the diameter of the healthy downstream vein measured by ultrasound in the upright position.[7]

At present, surgical intervention is recommended for venous aneurysms that have resulted in thromboembolic complications independently of their diameter, saccular or thrombus-containing aneurysms of whatever size, or fusiform aneurysms larger than 20 mm in diameter (*Class IIa*, *Level C*).[7] This management has been adopted since the years 2000 with the publication of Sessa et al. on the surgical management and follow-up of 25 patients with this pathology.[4] An aggressive interventional attitude is justified in this pathology even more so if the patients present a history of thromboembolism. In fact, medical management alone with long-term anticoagulation showed an approximately 80% recurrence rate in patients who presented a first episode of pulmonary embolus.[4] There are 2 types of interventions for the treatment of popliteal venous aneurysms, aneurysmorrhaphy and ablation with reconstruction.

Aneurysmorrhaphy consists of a tangential resection of the aneurysm with venorrhaphy. This is the most common technique. Nevertheless, it exposes to the risk of recurrence by suturing in potentially pathological areas.[8,9] Complete aneurysmal resection with terminal venous anastomosis in a healthy zone requires the interposition of a venous autograft. The vascular substitute used varies according to the team. The use of the lesser saphenous vein, of the greater saphenous vein,[10] of the contralateral femoral vein or the jugular vein[4] is found in the literature. Other techniques were also described including the interposition of a spiraled[11] or longitudinally paneled[12] saphenous vein, or using external wrapping with polytetrafluoroethylene to limit aneurysmal recurrence of on a fragile venous wall in the cases treated tangential resection and venorrhaphy.

We were looking for a substitute with a diameter matched to the caliber of the popliteal vein and allowed a valve transposition to preserve the continence of the functional deep venous network. The diameter of saphenous grafts is too small which often obliges to duplicate them and suppresses the valves and the continence of the vein. Internal jugular veins are unvalved and external jugular veins have inconstant diameters. Lastly, the use of the femoral vein permits a caliber adequation with the popliteal vein and valvular transposition, but the choice of this conduit can lead to deep venous insufficiency in the contralateral harvested lower limb. In addition, the femoral vein is harvested in supine position whereas in the majority of cases popliteal venous aneurysms are treated via a posterior approach in prone position, which would therefore require a change in patient installation during the intervention.

We designed a new technique consisting of a complete resection of the aneurysmal zone with in situ reconstruction by axillary venous transposition with preservation of the continent valve.[13] This technique allows the use of a graft with a diameter adapted to the popliteal vein, while maintaining a continent valve. We report a series of patients treated by this method. The primary objective was to evaluate the patency of the transposed venous grafts. Secondary objectives were to evaluate the feasibility of the technique, the continence of the transplanted valve, the recurrence of the disease, and the clinical consequences on the treated lower limb and at the donor site.

MATERIALS AND METHODS

Study Design and Population

Between October 2006 and May 2023, we retrospectively included all the patients having popliteal venous reconstruction by transposition of the axillary vein to treat a popliteal venous aneurysm. The patients presented symptomatic venous aneurysms with at least 1 embolic episode or whose largest diameter exceeded 20 mm on 2 imaging studies.

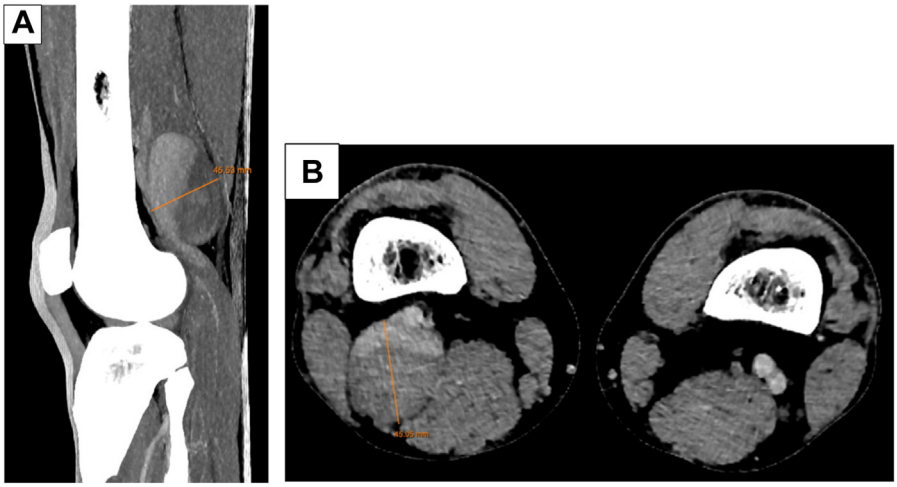

Fig. 1. **(A)** CT angiography of the left popliteal region with delayed phase imaging: Sagittal view of a 45 mm venous aneurysm. **(B)** CT angiography of the left popliteal region with delayed phase imaging: Axial view of a 45 mm venous aneurysm.

All patients had preoperative Duplex ultrasound and angio-computed tomography (angio-CT) with delayed phase imaging of the lower limbs (Fig. 1). Post-traumatic and iatrogenic venous aneurysms, and those associated with vascular malformations, as well as patients under the age of 18 years were excluded. Patients' demographic and medical characteristics, as well as preoperative ultrasound and angio-CT data with measurements of the maximum transverse diameter were recorded.

Operative Technique

The patient had venous Doppler ultrasound of the 2 upper limbs to choose the best venous graft by selecting a brachio-axillary segment of about 10 cm in length, centered on a valve and with the most suitable diameter. In right-handed patients, the left arm was preferred. The intervention was done in prone position, with a 90° abduction of the harvested arm. The popliteal venous aneurysm was approached via a posterior route, with a bayonet shaped incision as described by Branchereau et al.[14] In the event of an extension of the aneurysm to the superficial femoral vein, an internal approach was done (Fig. 2).

The healthy popliteal vein was dissected downstream of the aneurysm, avoiding mobilization to decrease the embolic risk. After systemic heparinization (50 IU/kg), the downstream popliteal vein was clamped and the aneurysm was dissected to the upstream healthy popliteal segment. The upstream popliteal vein was then clamped. The aneurysm was resected then replaced by the harvested humero-axillary venous segment. Anastomoses were done with 6/0 Prolene running sutures (Fig. 3). After unclamping we tested the watertightness of the anastomosis and the continence of the valve with a Valsalva maneuver work to increase the venous pressure.

Follow-up

Duplex ultrasound was performed 3, 6, and 12 months after the operation, and then every year. Postoperative ultrasound data including bypass patency, valvular continence (Fig. 4), graft diameter, as well as clinical data comprising the diameters of the homolateral and contralateral calves and potential lower limb neurological consequences (Fig. 5), in particular the presence of paresthesia, were recorded.

RESULTS

A total of 11 patients, including 7 men, were included in this study with an average age of 55 years (46—77). All patients had symptoms: 10 had a history of 1 or more PE and 1 patient had deep venous insufficiency with unexplained dyspnea. The average size of the popliteal venous aneurysm was 29 mm (14—45 mm). Two patients presented an aneurysm smaller than 20 mm: 14 mm (Patient 10) and 17 mm (Patient 6), and the operative indication was addressed on the symptomatology of the patients who experienced 1 severe (Patient 6) and 1 moderate (Patient 10)

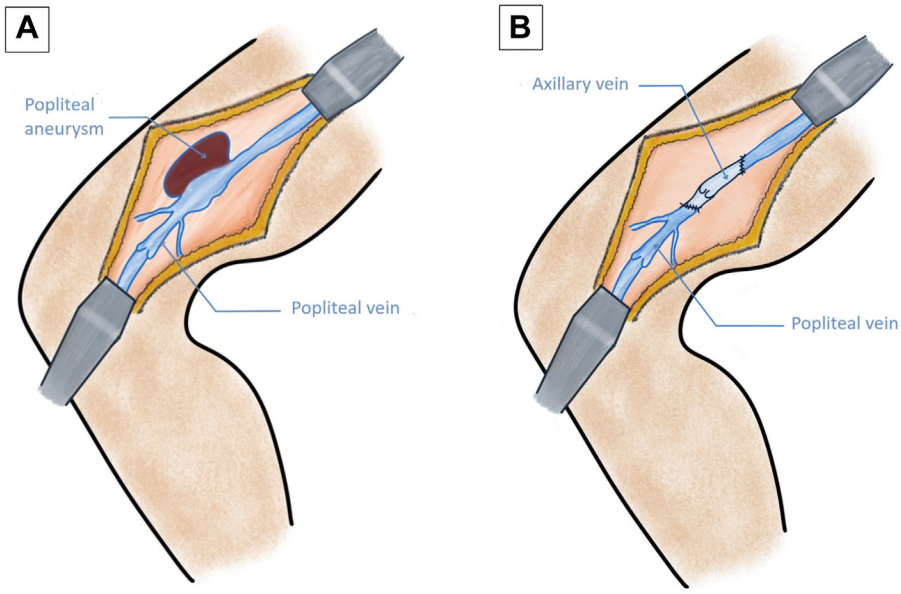

Fig. 2. (A) Preoperative schematic representation of a high popliteal venous aneurysm. **(B)** Postoperative schematic representation of a high popliteal venous aneurysm.

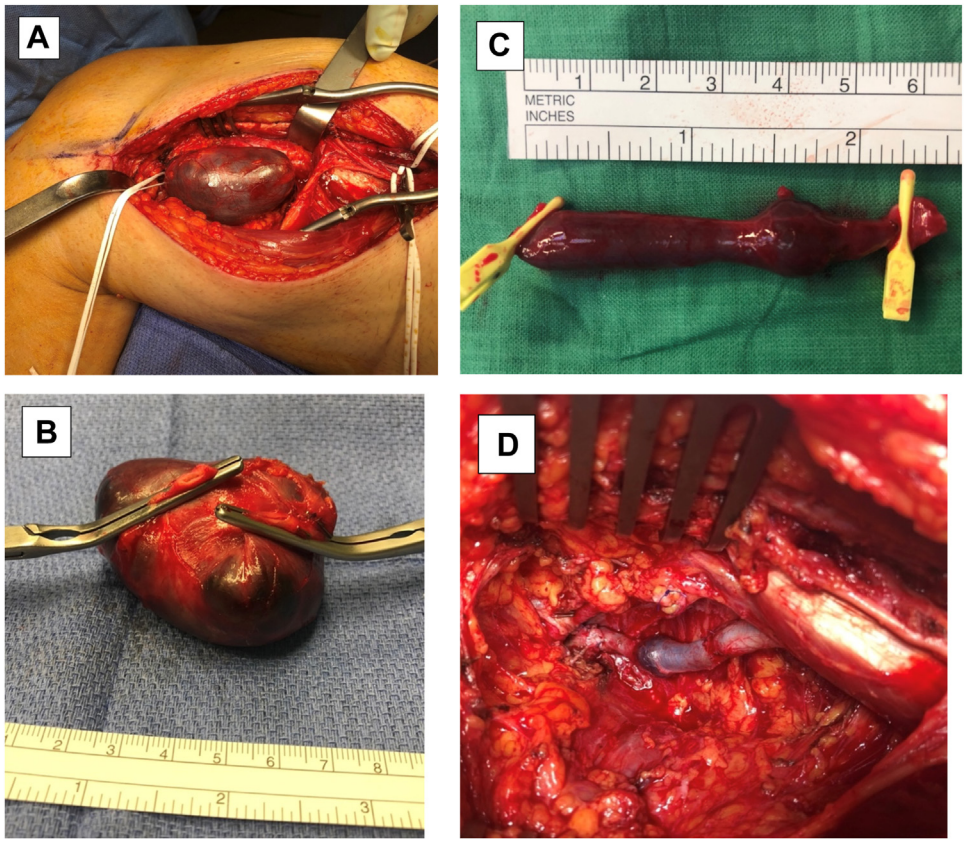

Fig. 3. (A) Operative view of a 45 mm popliteal venous aneurysm. **(B)** Aneurysm resection. **(C)** Brachial axillary venous bypass. **(D)** Operative view of in situ vascular reconstruction.

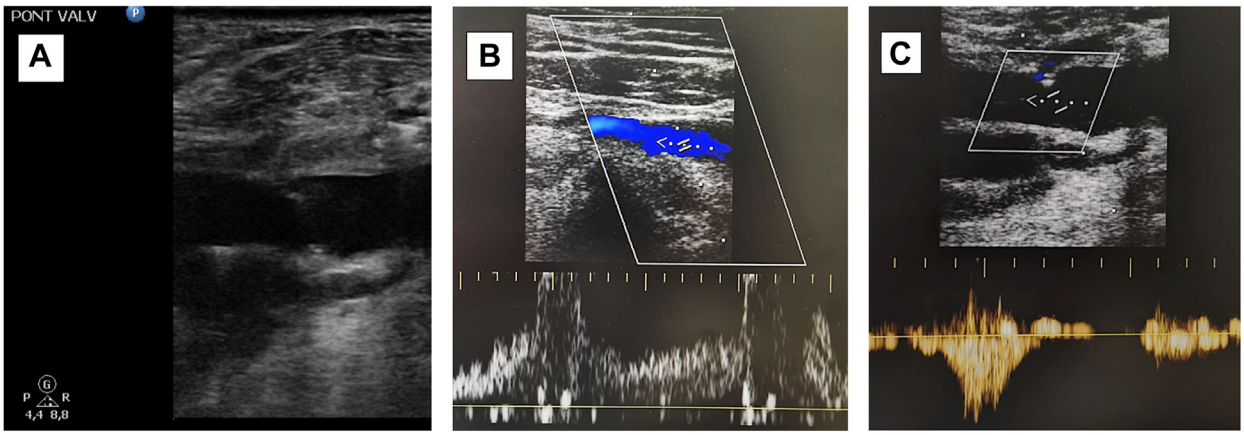

Fig. 4. (A) Ultrasound sagittal view of the venous bypass visualizing the transposed valve. **(B)** Doppler ultrasound showing the axillary venous graft patency. **(C)** Valvular continence during a Valsalva maneuver.

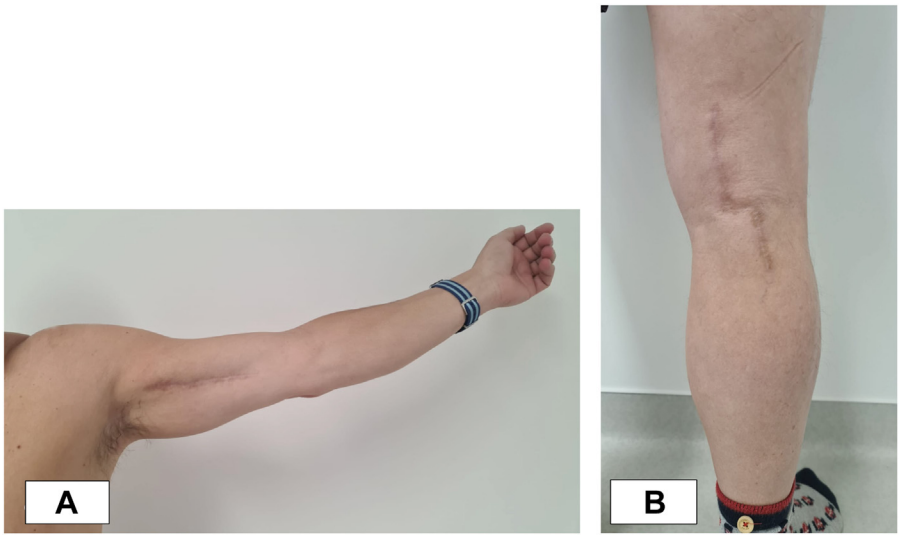

Fig. 5. (A) Patient 10−14-month follow-up. Popliteal vein harvesting zone. **(B)** Recipient site in the popliteal fossa.

bilateral proximal PE. Surgical technique was feasible in all the patients. One reoperation was needed to evacuate a popliteal hematoma. The data are listed in Table I.

The average follow-up was 65 months (4−191 months). Only 1 patient was lost to follow-up after 9 months. No bypass thrombosis occurred during follow-up, and the transposed valve was described as continent in all patients during follow-up. There was no anastomotic stenosis of the venous bypass, and no aneurysmal evolution was observed at the anastomotic sites. There was no recurrence of PE during the postoperative follow-up. The mean venous bypass diameter was 10.5 (7−12) mm.

Two patients reported postoperative paresthesia, but without repercussions on their daily life (Patients 10 and 11). One patient was reoperated on D15 to evacuate a hematoma (Patient 11), and the healing was acquired 6 weeks after operation. This patient presented a circumference difference between the treated lower limb and the contralateral lower limb. At the harvesting site, no patients presented upper-limb paresthesia. All the venous grafts

Table I. Clinical and paraclinical preoperative and postoperative data of patients with a popliteal venous aneurysm

	Pt 1	Pt 2	Pt 3	Pt 4	Pt 5	Pt 6	Pt 7	Pt 8	Pt 9	Pt 10	Pt 11
Gender	F	M	M	F	M	M	M	F	M	M	F
Date of operation	January 10, 2006	September 18, 2008	January 06, 2009	January 16, 2015	February 29, 2016	March 15, 2016	November 30, 2018	November 2, 2020	April 2, 2021	March 31, 2023	May 15, 2023
Age (years)	51	47	50	65	46	64	51	57	77	52	50
Side of lesion	Left	Right	Right	Left	Left	Left	Right	Right	Right	Right	Left
Symptoms	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Type of symptoms	PE in 2005	PE in 2008	PE in 2008	2 PEs, 2007 and 2014	2 PEs 2014 (CRA) and 2015	DVT with PE, 2012 and 2014	Bilateral EP with CRA	Bilateral EP, 2019	DVT and PE, 2020	Repeated DVT, PE in 2022	DVI and dyspnea
Severity of PEs	Nonsevere PE	Nonsevere subsegmental PE	Nonsevere EP	Nonsevere subsegmental PE	Severe bilateral proximal PE	Severe bilateral proximal PE	Severe bilateral proximal PE	Severe bilateral proximal PE	Nonsevere subsegmental PE	Nonsevere bilateral proximal PE	NA
Aneurysm size (mm)	22	34	30	35	36	17	45	23	38	14	21
Side of harvesting	Left	Left	Left	Left	Left	Left	Left	Left	Left	Left	Left
Bypass patency	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Popliteal vein continence	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bypass diameter (mm)	12	11	10	12	12	9	8	10	12	12	7
Paresthesia	No	No	No	No	No	No	No	No	No	Yes	Yes
Difference in calf circumference (cm)	0	0	0	0.5	0	0	0	0	0	0	5
Difference in forearm circumference (cm)	0	0	0	0	0	0	0	0	0	0	0
Follow-up (months)	191	128	9	96	85	84	57	28	29	14	4
Postoperative anticoagulant (months)	12	6	6	Long term	12	12	12	12	Long term	3	6

Pt, patient; EP, pulmonary embolism; CRA, cardiorespiratory arrest; DVT, deep venous thrombosis; DVI, deep venous insufficiency.

were harvested from the left upper limbs. There was no difference in circumference between the 2 upper limbs. The axillary vein was described as patent downstream from the harvesting zone in all the patients during follow-up. This was explained by the duplication of the brachial vein and the good collaterality of the axillary vein, which is reinjected via the subcapsular and cephalic veins downstream from the harvesting zone.

Ten patients received postoperative curative anticoagulation in combination with compression stockings for an average duration of 9 months. In 1 patient, long-term anticoagulation not related to the surgical procedure was required on the advice of vascular physicians.

DISCUSSION

The definition of venous aneurysms remained unclear for a long time, with venous dilation thresholds varying according to the authors. McDevitt et al. considered that a vein was aneurysmal when its diameter reached more than twice the upstream healthy venous,[15] while for Maleti et al. the threshold was at least 3 times the normal vein diameter.[16] Finally, the 2022 recommendations of the European Society for Vascular Surgery define venous aneurysms with a maximum diameter reaching twice the diameter of the downstream vein measured in the upright position.[7]

The pathophysiology of this venous disease remains unclear. Primary forms due to the fragility of the venous wall associated with hyperpressure in relation with a downstream obstruction or deep venous reflux,[13] and secondary post-traumatic or inflammatory forms, have been suggested. Histological analyzes demonstrate a decrease in the media thickness, and show a fine and fibrous venous intima associated with a rarefaction of the medial smooth muscle cells.[4,13]

The usual surgical technique consists of aneurysmorrhaphy because of its simplicity and its low complication rate. It is performed in 62−78% of cases and allows to re-establish a normal venous diameter and a laminar blood flow, and reduces the risk of thrombotic recurrence.[4,12,17] There are very little data in the literature about the long-term outcomes after aneurysmorrhaphy, and thus the recurrence rate of venous popliteal aneurysms. In Bergqvist et al.'s literature review, out of 105 patients, 50 patients were not followed up, and only 14 patients were followed up for 1 year or more.[6] However, several cases of aneurysmal recurrence were reported with this venorrhaphy technique.[8,9] In fact, with this technique, the pathological venous wall is not totally resected. The histological analyzes carried out suggest the complete resection of the pathological zone with graft interposition and anastomoses in healthy zones. This is the reference technique used in arterial surgery to limit the risk of recurrence.

In our study, we observed no aneurysmal recurrence with an average follow-up of 62 months. The number of patients in this series was limited, but with an average follow-up of more than 5 years it allows to demonstrate that it is a reliable and sustainable technique. Our surgical technique of transposing the brachial-axillary vein has long been known as an alternative to valvular repair in the context of lower-limb deep venous insufficiency due to post-thrombotic syndrome with valvular destruction.[18] The literature showed encouraging results with up to 95% of symptoms improvement in patients treated with this technique[19] and a 10-year 83% patency rate.[20] It also showed the absence of incontinence of the transposed axillary valve despite different hemodynamic conditions in the lower limb.

We choose the axillary vein for 2 reasons: 1) its diameter is perfectly congruent with the popliteal vein and, 2) it allows the transposition of a continent valve to the popliteal level, a critical drainage area just above the venous pump of the calf muscles.[19] In popliteal venous aneurysms, valve continence is no more be effective due to the wall dilation. With the most frequent surgical treatment consisting of a tangential resection with venorrhaphy, valvular continence is not restored. In our view, this is problematic because 55% of popliteal venous aneurysms are diagnosed during the assessment of a post-thrombotic syndrome or a superficial venous insufficiency.[4] We definitely think it is necessary to preserve as much as possible the continence of the deep venous network. By the way, 1 of our patients was treated for this type of symptoms with a total disappearance of the deep venous insufficiency symptomatology in postoperative (Patient 11).

With this technique of aneurysmal resection and brachial-axillary venous transposition with valve preservation, the popliteal venous aneurysm is radically treated. Valvular continence is reestablished, which reduces the risk of chronic venous insufficiency. To evaluate the effectiveness of this management, we systematically evaluated the continence of the transposed valve, and continence was confirmed in 100% of our patients, as well as the diameter of the calf of the treated leg compared to the contralateral calf, without any difference in 90% of the cases. The only patient with a circumference difference

between his 2 calves had previously been treated for chronic venous insufficiency, but no preoperative measurements had been done. It seems likely that the difference in circumference had been even more important in preoperative because the patient's symptoms were really improved after surgery. In a normal subject, the popliteal vein diameter is generally between 5 and 12 mm in women and 7 and 13 mm in men.[21] In our series, the mean diameter of the transposed brachial-axillary vein was 10.5 mm (7−12 mm) on postoperative Duplex examination, which confirms the good congruence between the transposed brachial-axillary vein and the popliteal vein.

Three literature reviews on the subject were published. After the 25 patients Sessa et al. added in 2000 to 92 other reported cases,[4] which made a total of 117 analyzed cases, 147 cases were identified by Bergqvist et al. in 2006,[6] and Maldonado-Fernandez analyzed 102 cases in 2013.[17] After the removal of duplicates, the total number of patients reported in 2013 was 212. Our review is the latest on popliteal venous aneurysms.

The clear feminine predominance in the Sessa's series with 20 women out of 25 patients reported in 2000 was lower in the subsequent reviews of the successive with 56% of women for Bergqvist[6] and 52% for Maldonado-Fernandez,[17] which suggests that the high feminine predominance was do the analysis of a limited group of patients. Our series consists of 7 men and 4 women, which is consistent with a sex ratio close to 1 on the whole literature. The average age of our patients at the time of treatment was 55 years, in the range of the literature which reports a mean age of 59 years for Sessa,[4] a median age of 51 years for Bergqvist,[6] and a mean age of 45 years for Maldonado-Fernandez.[17]

Regarding the associated medical treatment, the need for postoperative anticoagulation was not demonstrated, but most teams recommend curative anticoagulation for a duration varying from 3 to 6 months, or even long-term anticoagulation.[4,6,17,22] We have made the choice of an anticoagulation on a case-by-case basis on a systematic advice from our vascular medicine colleagues. However, we always prescribed a 3-month anticoagulation and the postoperative wearing of compression stockings as recommended by Sessa.[4]

CONCLUSION

This study confirmed that this new alternative technique for the treatment of venous popliteal aneurysms is feasible and shows good results with an excellent patency of venous bypass grafting after more than 5 years. Our series is small, but we observed a 100% patency rate with a long-term follow-up. This surgical technique also permits the long-term continence of the transposed axillary valve in the popliteal position which maintains its function without deterioration over time. It allows a radical treatment with an absence of aneurysmal recurrence. It is also very well tolerated in the upper limb, without neurological sequela, without increase in the circumference of the arm, and without any impact on the venous circulation. The size of our study was limited, but it highlights an alternative to the most frequently used technique to treat popliteal venous aneurysms, that is tangential resection and venorrhaphy.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Charles Sadoul: Writing − original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nicla Settembre:** Writing − review & editing. **Victor Nabokov:** Formal analysis. **Abdulrahman Alblowi:** Resources. **Rabie Ali Belkorissat:** Investigation. **Serguei Malikov:** Writing − review & editing, Validation, Supervision.

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