Seminars in VASCULAR SURGERY

Acute Limb Ischemia Due to Popliteal Artery Aneurysm: A Continuing Surgical Challenge

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Up to 50% of all popliteal artery aneurysms (PAA) present with acute limb ischemia (ALI). ALI due to PAA is a difficult surgical problem, with a 20% to 60% incidence of limb loss and up to 12% mortality reported in the literature in the last three decades. Imminent limb threat requires emergency infrainguinal reconstruction, preferably with autogenous conduit. ALI due to PAA is limb-threatening, often due to obliteration of the tibial vessels in addition to thrombosis of the PAA itself. Arteriography is needed to define inflow vessel and outflow vessel anatomy followed by thrombectomy of the run-off vasculature to establish an appropriate target for bypass. Patients without evidence of neurologic deficit are best served by formal arteriography. Intraarterial thrombolysis is used to establish an outflow vessel for bypass if no runoff vessels are visible. In general, emergency operations are associated with inferior patency and limb salvage compared to elective procedures. Endovascular exclusion of PAA with covered stent graft is used increasingly in the elective setting and has been reported in patients presenting with limb ischemia. The following discussion outlines our algorithm in managing ALI from PAA and reviews management decisions and results of treatment.
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Overview of Popliteal Artery Aneurysms

POPLITEAL ARTERY ANEURYSMS (PAA) have a prevalence of less than 1.0%. Nevertheless, they are the most common peripheral arterial aneurysm. It is accepted that a popliteal artery greater than 15 mm is, by definition, aneurysmal,[1] although aneurysms greater than 10 cm in size have been reported. They occur almost exclusively in men (96%) and are discovered most commonly in the 6th and 7th decades of life.[1,2] Patients with PAAs frequently have other arterial aneurysms, ie, 50% to 64% will have a contralateral PAA,[1,3] 40% to 62% will have an abdominal aortic aneursym (AAA),[3,4] and 40% will have a femoral aneurysm.[5] Conversely, patients with a known AAA have been reported to have an incidence of PAA of 1% to 14%.[3,6] PAAs are generally degenerative in etiology, although familial, mycotic, syphilitic, and traumatic popliteal aneurysms have been described.[7-9]

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The natural history of PAAs is variable. Approximately 55% to 66% of PAAs are symptomatic, with lower extremity ischemia from either acute or chronic thrombosis and/or distal embolization accounting for 85% of symptomatic cases. In addition to acute limb threat, these patients commonly present with claudication, rest pain, ulceration, or "blue toe syndrome."[1,2,4,10] A small number of symptomatic patients present with compressive symptoms (eg, pain, deep venous thrombosis) due to aneurysm expansion and a small minority present with aneurysm rupture.[1] Asymptomatic PAAs cause complications in 15% to 25% at 1 year and 60% to 75% at 5 years, if left untreated.[4,11] Although consensus has not been reached, most authors recommend repair of asymptomatic aneurysms when they reach 2 cm in diameter or possess significant mural thrombus, given the significant rate of limb loss and mortality and inferior results generally reported with emergency repair.[2,12-15]

The most dreaded complication of PAA, acute limb ischemia, is reported to occur in 17% to 46% of cases.[5,10,13,16] One large national registry (Swedish Vascular Registry)[17] confirmed that of 743 patients who underwent repair during a 15-year period, 235 presented with acute ischemia. Acute limb ischemia (ALI) due to PAA is an ominous problem for even an experienced vascular surgeon; this subset of patients with ALI will be the focus of this discussion.

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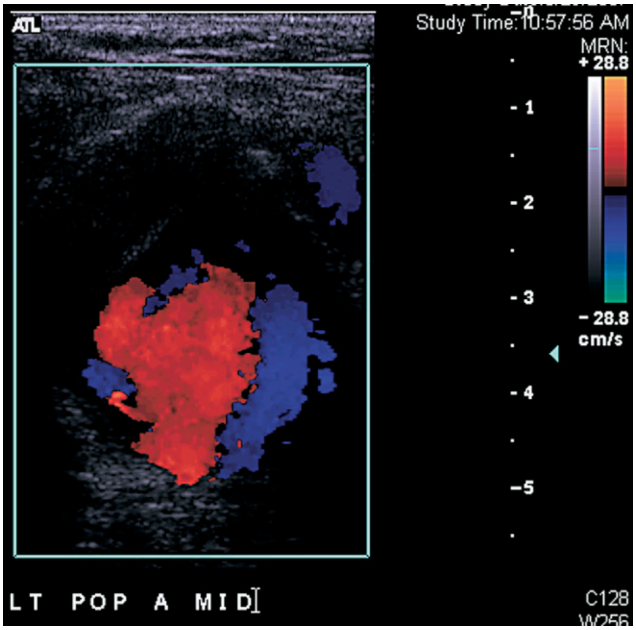

Figure 1 Duplex ultrasound with color flow imaging of a 3.5-cm popliteal aneurysm with moderate mural thrombus in a 65-year-old male with prominent popliteal pulses on physical exam.

Pathophysiology of ALI due to PAA

Thromboembolism from PAA can be a progressive process in which the popliteal artery and crural arteries are obliterated over time. ALI may be brought on by acute thrombosis of the popliteal artery. Ninety percent of patients have abnormalities in their tibial arteries, with 22% to 38% of patients having only single vessel runoff and 17% having no tibial vessels in continuity with the pedal arch[18,19] Bouhoutos and Martin[16] reported that 34% of patients who present with aneurysm thrombosis have occlusion of their tibial vessels. Marty et al[20] reported that patients who presented with grade IIa ischemia due to PAA had arteriographic occlusion of their PAA and absence of runoff in 12 of 13 patients (including 10 with no visualization of tibial vessels). Lack of a visible runoff vessel leaves the vascular surgeon with no target for revascularization and puts the patient at particularly high risk for limb loss.

Clinical Presentation of ALI due to PAA

Patients with ALI present with abrupt onset of foot coolness, foot or leg pain, and/or numbness. Careful questioning may elicit a history of recent claudication associated with compromise of popliteal and crural vessels that has progressed to limb threat, with occlusion of the popliteal artery, and/or remaining runoff. As in ALI of other etiologies, physical exam reveals a cold limb with diminished or absent distal pulses. Deficiencies in sensation and motor strength may be present depending upon the duration and severity of ischemia. Most patients present with grade IIa or IIb[21] ischemia.[1,2,10,22] A diagnosis of PAA is suggested by the presence of a prominent popliteal pulse, although a pulse often will not be palpable due to thrombosis. A prominent contralateral popliteal pulse or aortic pulsation should also raise the suspicion for PAA as the etiology of ischemia.

Diagnosis of Popliteal Artery in Setting of ALI

ALI in the clinical setting mentioned here should arouse suspicion of PAA. In this scenario, duplex ultrasound can be used to examine both the ipsilateral and contralateral popliteal arteries (Fig 1). Duplex ultrasound is more sensitive than physical examination in diagnosing PAA.[6,23] Furthermore, it provides information on the presence and velocity of flow, presence of mural thrombus, and patency of outflow arteries. Computed tomographic arteriography and magnetic resonance arteriography are useful adjuncts because they provide information on outflow and inflow as well as provide imaging of the artery in the popliteal space (Fig 2). To our knowledge, specific data regarding the utility of any of these modalities in the setting of ALI have not been published. Their usefulness would be dependent on their immediate availability in a particular center. The availability of duplex scanners in emergency rooms and their increasingly facile use by emergency physicians, house staff and fellows, and vascular surgeons is helpful for rapid diagnosis. Use of these modalities should not impede prompt revascularization in cases of limb threat.

Diagnosis of PAA in the setting of ALI is helpful because thrombosed PAA is not amenable to standard balloon catheter thromboembolectomy. Furthermore, a diagnosis of PAA will lead to a workup for concomitant aneurysms, help the surgeon develop a revascularization strategy, and provide prognostic information to the patient. However, the diagnosis may not be known at the time treatment is initiated and is

Figure 2 Magnetic resonance arteriogram of both lower extremities demonstrates bilateral popliteal aneurysms and disease of the tibial arteries.

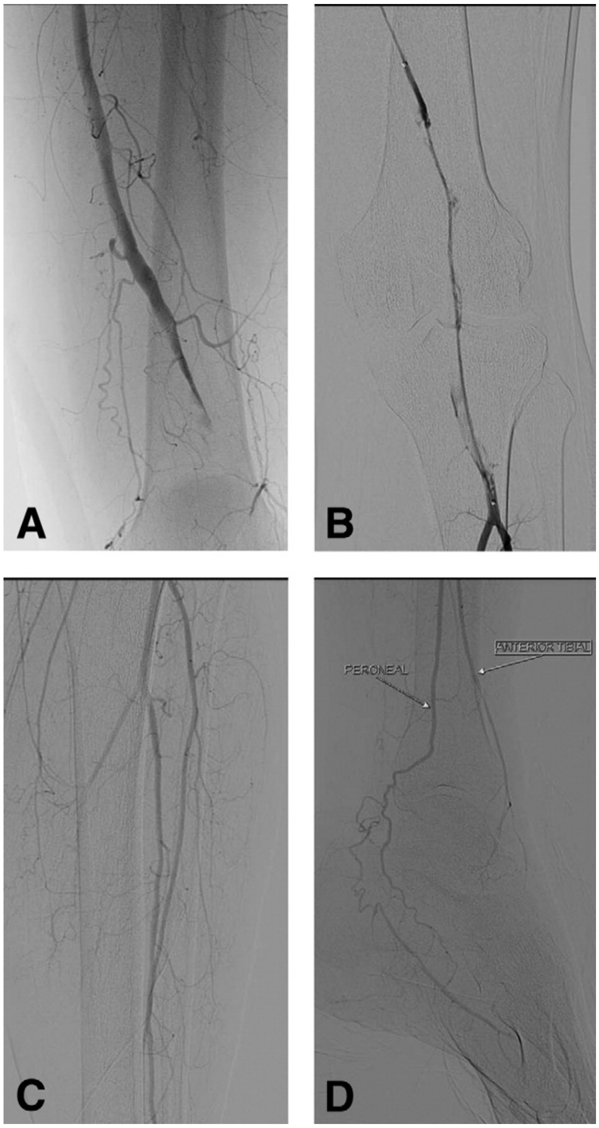

Figure 3 (A) Arteriogram demonstrating left popliteal artery occlusion in a patient presenting with acute limb ischemia (ALI) without neurologic deficit. (B) Arteriogram shows the thrombolysis catheter across the opened popliteal artery with filling of the proximal anterior tibial artery and tibioperoneal trunk. (C) Arteriogram demonstrates patency of the anterior tibial artery and peroneal artery to the level of the distal calf, (D) with continuity into the foot.

not essential in the setting of ALI. On-table arteriography may show ectasia of the superficial femoral artery (SFA) and popliteal artery suggestive of a PAA, but will likely demonstrate only popliteal occlusion with or without compromised infrageniculate flow (Fig 3).

Natural History of ALI Due to PAA

Acute thrombosis of a PAA without development of a collateral network makes this a particularly dangerous entity, demanding prompt revascularization in the physiologically stable patient. Management without attempts at revascularization results in above-knee amputation in up to 43% of patients.[1,2,4,5,10,15,22,24] While a heparin bolus (80 U/kg) followed by continuous infusion (18 U/kg/h) should be initiated in ALI in the absence of contraindications, anticoagulation alone would not be expected to be limb-saving. However, anecdotal evidence suggests preventing propagation of clot may impact the ability to preserve the knee joint should limb loss ensue.

Surgical Approach to ALI Due to PAA

Ischemia with Neurologic Deficit

As in any patient with ALI, the degree of ischemic insult determines the course of management (Fig 4). Patients with evidence of sensory loss or motor weakness, Rutherford class IIb and III ischemia, are in need of urgent revascularization and must proceed immediately to the operating room. These patients cannot tolerate additional ischemic time required by arteriography and thrombolysis. If PAA is either known or suspected based on preoperative studies, the focus should be on identifying an inflow vessel and a distal target for bypass with runoff to the foot. We prefer to begin with lower extremity arteriography via a percutaneous femoral approach. This often demonstrates abrupt occlusion of the popliteal artery with varying degrees of obstruction of the infrageniculate vessels (Fig 5A). In contradistinction to acute embolism, the distal superficial femoral and popliteal arteries are generally ectatic with luminal thrombus. If a patent runoff vessel is identified with flow to the ankle, we then proceed to bypass.

Inflow is generally provided by the distal SFA via a medial approach. The SFA can often be utilized as inflow unless there is evidence of severe ectasia or coexistent atherosclerotic disease throughout the vessel, which requires use of the proximal SFA or common femoral artery as inflow. Patency of SFA-origin bypass equals that of common femoral origin,[25] and a shorter segment of saphenous vein can be harvested from the distal thigh, often through extensions of the same medial incisions.

In most cases, a below-knee medial approach is then utilized to expose the distal popliteal artery, tibioperoneal trunk, or proximal posterior tibial artery for the distal spatulated end-to-side anastomosis. This exposure also provides access to the origins of the tibial and peroneal vessels should thromboembolectomy and/or intraoperative thrombolysis be required. Aneurysm exclusion with proximal and distal ligation above and below the knee can easily be accomplished with this medial exposure.

Autogenous vein, including arm vein if necessary, should be used preferentially because it has superior patency in comparison to prosthetic conduit.[13,15,26,27] A comprehensive review reported 5-year patency of synthetic bypasses ranging from 29% to 74%, while that of autologous vein was 77% to 100%.[28]

A distinctive feature of ALI due to PAA is the severely compromised infrageniculate flow. If intraoperative arteriography fails to demonstrate a patent infrageniculate vessel with runoff to the ankle, exploration and balloon catheter thrombectomy should be performed in an attempt to establish a target for bypass. Thrombectomy via a femoral or above-knee popliteal approach provides little chance of success given the

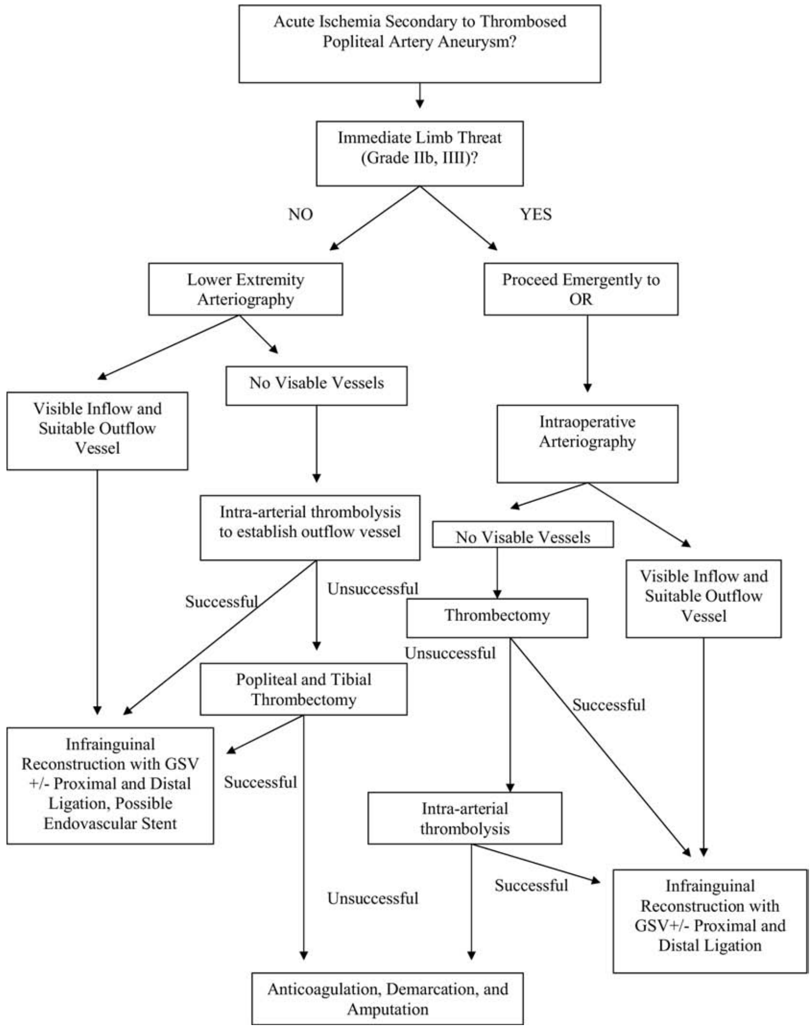

Figure 4 Proposed management algorithm for acute limb ischemia secondary to popliteal artery aneurysm.

thrombus burden in the PAA and runoff vessels. Trifurcation embolectomy via a medial incision is the first alternative (Fig 5B and C). Thrombectomy via arteriotomy in the posterior tibial or distal anterior tibial arteriotomy at the ankle may also be required to clear outflow.[29,30] Balloon thromboembolectomy must be performed carefully in these small-caliber vessels. Injections of intraarterial recombinant tissue plasminogen activator) may be a useful adjunct in this scenario (see report on intraoperative, intraarterial thrombolysis later in this issue). If flow can be established in a runoff vessel, we then proceed to bypass as mentioned here. Surgeons should use either duplex ultrasonography and/or completion arteriography to evaluate the bypass graft for technical error and presence of outflow to the foot. If a target cannot be established, the operation is terminated and anticoagulation with heparin continued; observation is undertaken to evaluate proper demarcation to determine an appropriate amputation level. Amputation is then performed at a second operation as dictated by clinical and physiologic findings.

In some instances, a patient with ALI in which the diagnosis of PAA is not known or suspected may be taken to the operating room for femoral exploration and thromboembolectomy. Failure to pass a Fogarty balloon past the popliteal artery should arouse suspicion for PAA. At this point, arteriography should be performed. As discussed, an enlarged or ecstatic SFA with occlusion of the popliteal artery strongly supports diagnosis of PAA. The necessity of four-compartment lower extremity fasciotomy should be determined based upon clinical examination and the length and degree of ischemia as in ALI of other etiologies.

Ischemia without Neurologic Deficit

If the patient has acute ischemia but no neurologic deficit (grade I, IIa ischemia), we anticoagulate with heparin and proceed to formal arteriography via the contralateral common femoral artery. If arteriography demonstrates an inflow source and suitable outflow, our preference is expeditious infrainguinal reconstruction with autogenous vein.

If the popliteal artery is thrombosed and there is no visible run-off vessel, intraarterial thrombolysis is initiated to restore patency to at least one tibial vessel (Fig 3). The technique of thrombolysis will be described.

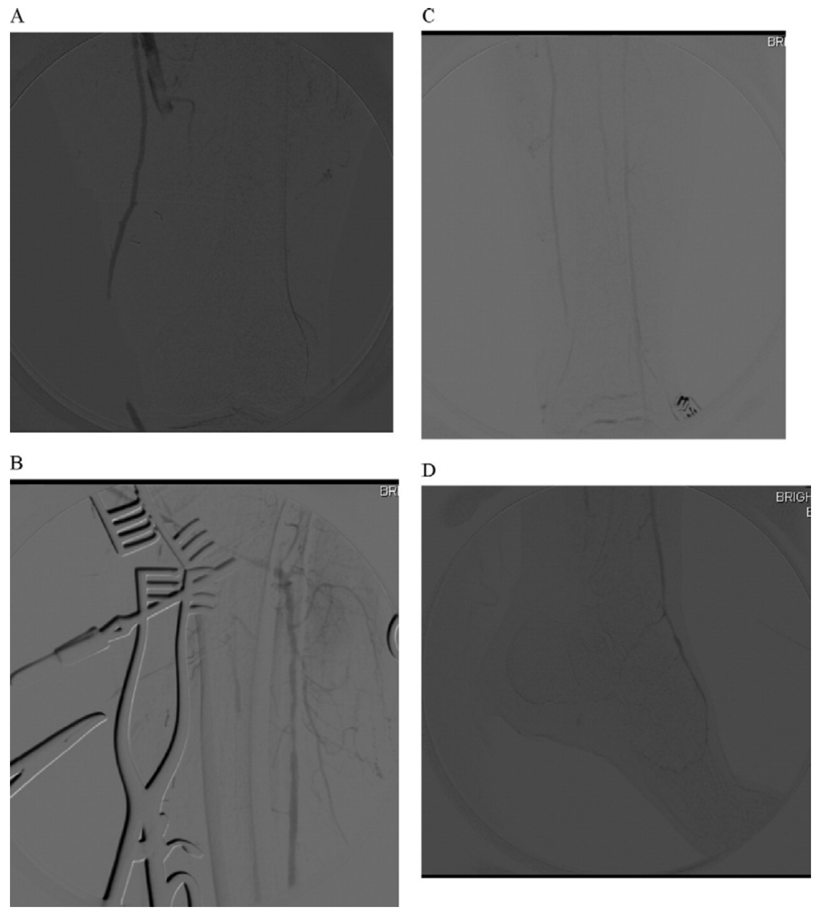

Figure 5 (A) On-table arteriogram demonstrating proximal popliteal occlusion in a patient with known popliteal aneurysm who had previously refused elective repair. (B) Thromboembolectomy of the popliteal trifurcation was performed via a medial approach. (C,D) Two vessel run-off to the foot was achieved and subsequent superficial femoral artery to below-knee popliteal bypass grafting was performed with reversed greater saphenous vein.

Technique of Thrombolysis

A 4Fr multihole catheter is positioned within the proximal thrombus of the PAA via an up-and-over maneuver from contralateral femoral access. Recombinant tissue plasminogen activator is infused with a bolus of 5 to 10 mg, followed by an infusion of 0.5 to 1.0 mg per hour. The catheter is advanced distally as lysis allows. Patients are admitted to the intensive care unit for monitoring of the ischemic limb, access site, evidence of hemorrhage, and neurologic status. Continuous anticoagulation with heparin for a goal partial thromboplastin time of 60 seconds is maintained. Patients are returned to the catheterization lab every 6 to 12 hours for repeat arteriography. When a flow channel through the PAA is achieved, the catheter is advanced over a guide wire into the distal popliteal artery for perfusion of recombinant tissue plasminogen activator into the tibial arteries. We terminate lysis when a single tibial artery in continuity with the pedal arch is demonstrated or there has been no progress in recanalization. The patient is then taken for expeditious infrainguinal reconstruction as described in this article. Thrombolysis should be terminated if hemodynamic instability, change in mental status, or bleeding requiring transfusion occurs.

If the patient shows progression in limb ischemia or failure of lytic therapy to recanalize outflow, we then proceed to trifurcation and/or ankle-level tibial thrombectomy, followed by attempts at bypass grafting as described here. Failure to establish a bypass target by either lytic or operative means may necessitate amputation at a time dictated by the patient's clinical condition.

Results of Surgical Therapy

Results of operative repair of PAA in the setting of ALI vary greatly. Graft patency in the setting of ALI is difficult to decipher accurately because these patients are few in number and often included as part of a larger report of patients with chronic symptoms or subacute ischemia. Five-year and 10-year patency rates are in the range of 39% to 68%[2,15,18,31,32] and 60%, respectively.[13] The incidence of limb loss in ALI has been reported as high as 20% to 60%, with mortality rates reported between 5% and 12%.[5,10,16,22,33]

More recently, groups have reported good results with repair of PAA in the setting of ALI.[19,22,26] Mahmood et al[22] report a 1-year and 5-year secondary patency of 94% and

80% in 13 patients with ALI who underwent immediate surgical repair. Limb salvage was 94% at 1 year and 80% at 5 years. Their approach was one of trifurcation and/or ankle-level thromboembolectomy in conjunction with autogenous bypass grafting and exclusion via a medial approach. They concluded that acute ischemia and bypass to crural vessels were not predictive of graft failure. Aulivola et al[26] report comparable results of popliteal aneurysm repair in the 14 emergent and 37 elective limbs. Initial arteriography demonstrated an average of 1.1 patent runoff vessels in ALI patients and 2.2 runoff vessels in elective repairs. The emergent group had a primary and secondary patency of 85% and 100% at both 1 and 5 years, which was similar to a primary and secondary patency of 85.6% and 95.7% at 5 years in the elective group. Limb salvage at 5 years was 93% in the emergent group and 100% in the elective group. It should be noted, however, that all three patients presenting with absence of pedal signals underwent thrombolysis to uncover a bypass target with success in two of three patients. This report supports the approach of immediate bypass grafting if there is at least one-vessel distal runoff and the reservation of thrombolysis for limbs without a target.

Elective repair can be accomplished via either a medial approach as described or a posterior approach with aneurysmorrhaphy or resection and interposition grafting. The posterior approach is suboptimal in the setting of ALI because it precludes arteriography and great saphenous vein harvest. It should be noted, however, that continued expansion and progressive compressive symptoms or rupture have been reported post-procedure due to failure to ligate feeding vessels with the medial approach.[34,35] Therefore, postoperative ultrasound surveillance of the excluded aneurysm is warranted.

Results of Elective PAA Repair

Overall results are superior in elective repair of asymptomatic patients compared to results in patients with acute or chronic symptoms.[2,5,10,18,32,33,36,37] Five-year graft patency rates in excess of 85% have been reported by multiple groups in elective patients.[18,26,27,32,36,38,39] At our institution, a 5-year primary patency of 92% ± 4% for vein grafts performed for PAA has been superior to that in patients with occlusive disease, a finding potentially related to beneficial graft remodeling in these patients.[39] Limb-salvage rates in excess of 90% are standard in asymptomatic patients.[1,10,13,15,26,27,32,37,38] Perioperative mortality is reported between 0 and 2%.[26,32,39]

Results of Thrombolytic Therapy for ALI due to PAA

Thrombolytic therapy for thrombosed PAAs was introduced in 1984.[40] Embolization and "packing-in" of thrombus in the runoff vessels is believed to account for the 20% to 40% major amputation rate for ALI due to PAA that was reported in some studies.[10,16,18] The rationale for thrombolysis before operation, therefore, is primarily to restore run-off for bypass grafting. Proponents also argue that there is a benefit to gradual reperfusion, which minimizes reperfusion injury and the ability to uncover underlying arterial lesions before bypass. Reports on thrombolytic therapy all include fewer than 14 patients, with the exception of a series of 100 patients from the Swedish Vascular Registry. Results of published series are summarized in Table 1.

The value of preoperative lysis lies in the ability to clear thrombus from the runoff vessel(s). One- or two-vessel runoff can be established in 77% to 100% of patients, including those in which all runoff vessels are occluded. In 1994, Carpenter et al[10] reported complete clearing of all runoff vessels in six of seven patients (and clearing of two vessels in the remaining patient) with ALI and thrombosis of PAA. These patients had 100% early graft patency and limb salvage, which was superior to comparable patients treated with emergency operation. Other studies have confirmed similar success (Table 1). Overall, early graft patency of 68% to 100% and limb-salvage rates of 73% to 100% compare favorably to the results of emergent open revascularization in most series, but are similar to the results reported by Mahmood and Aulivola.[22,26]

Conclusions from these studies must be drawn with caution. These series suffer from small numbers of patients and inevitable selection bias. Quite appropriately, patients selected for thrombolytic therapy in these series presented almost exclusively with Rutherford class I or IIa ischemia. Successful lysis generally requires 24 to 48 hours with repeated trips to the catheterization lab for catheter positioning. Patients with neurologic deficit should proceed immediately to operation as they cannot tolerate the additional ischemic time required by preoperative lysis.

Complications and Failure of Lytic Therapy

Thrombolysis is associated with major risks, including bleeding, intracranial hemorrhage, and stroke. The rate of bleeding complications is reported between 0 and 25% (Table 1). Furthermore, there is a risk of distant thromboembolism reported in up to 13% of patients,[41] an occurrence that could accelerate ischemia in previously stable patients. This is generally treated with continuing or increasing the rate of infusion.[42] Furthermore, thrombolysis may fail in up to 33% of patients.[20,43] This is likely the result of organized, "packed-in" clot in the runoff arteries from chronic embolization. Thrombolytics are known to be less effective in lysing older, organized thrombus.[24] These patients often go on to amputation as attempts at operative thrombectomy and bypass typically fail. One group had reported that the primary benefit of thrombolysis is to identify patients who should undergo primary amputation.[20] While this approach seems applicable to patients who are at high medical risk for multiple operations, we feel that operative thrombectomy and bypass should be attempted in most patients before committing to amputation. Furthermore, with development of hybrid operating rooms with high-quality fixed imaging and a full complement of endovascular devices, open and endovascular techniques can be combined more effectively.

Table 1 Patients Undergoing Preoperative Thrombolysis for Acute Limb Ischemia Due to Popliteal Artery Aneurysms

First Author	Year	Patients	No. with I or IIa/ IIb or III Ischemia	Agent and Average Dose	Duration Lysis (h)	Failure (%)	Hemorrhagic Complications (n)	Mortality (%)	Early Graft Patency (%)	Limb Salvage (%)
Schwarz[40]	1984	1		SK		0	0	0	100	100
Ferguson[48]	1986	10		SK		?	?	0	?	70
Bowyer[43]	1990	9		SK		33	2 major, 2 minor	11	100	100
Thompson[49]	1993	6		SK and r-tPA		0	0	0	100	100 at 30 d
Ramesh[24]	1993	12		SK and r-tPA		17	3	0	?	83 at 18 mo
Carpenter[10]	1994	7 (1*)		SK and UK		0	0	0	100	100 at 62 mo
Varga[1]	1994	18 (9*)		?		11	0	0	73	73 at 30 d
Garramone[50]	1994	3		UK		0	0	0	100	100
Hoelting[51]	1994	9		UK		0	2	0	100	100 at 5 yr
Debing[52]	1997	2		UK		0	0	0	100	100 at 5 yr
Taurino[53]	1997	8		?		13	0	?	?	87
Greenberg[54]	1998	6 (1)*		rtPA		0	0	0	83	100 at 2 yr
Marty[20]	2001	13	1 I, 12 IIa	UK 2,400 ± 800 K	32 ± 15	23		15	68	83 at 30 d
Dorigo[42]	2002	14	14 I and IIa	UK		28	0	0	74% mo	86 at 30 d
Ravn[55]	2007	41	?	UK, SK, tPA	Median 23.7	?			?	90.2% at 1 yr

Abbreviations: K, 1,000; SK, streptokinase; r-tPA, recombinant tissue plasminogen activator; tPA, tissue plasminogen activator; UK, urokinase.

Endovascular Popliteal Aneurysm Repair

Endovascular repair of PAAs with covered stent grafts in the elective setting has produced good short-term results. Two-year primary and secondary patency rates of 77% to 87% and 87% to100%, respectively, have been reported.[44-46] Results at 5 years are limited, but the primary and secondary patency rates of 70% and 76% that have been reported appear inferior to that of open repair.[47] To our knowledge, only one existing report has included patients with ALI (five patients with Rutherford class IIa ischemia).[46] At this stage, endovascular repair in the setting of ALI cannot be recommended. It would only be possible after thorough lysis of popliteal artery occlusion to allow passage and deployment of the stent graft through the aneurysm. However, further investigation of this therapy in patients who would require below-knee bypass with prosthetic conduit due to lack of autogenous vein or those medically unfit for operation is warranted.

Conclusions

In summary, ALI from PAA remains a challenging surgical disease, which demands excellent clinical judgment and aggressive and meticulous surgical management. The last two decades have seen considerable growth in the tools available to vascular surgeons to diagnose and treat this condition. Operative and thrombolytic therapy should be seen as complementary techniques best managed by a vascular surgeon experienced with the natural history and surgical management of ALI and PAA. Good bypass graft patency and limb salvage can be achieved with proper patient selection for primary operative and thrombolytic therapy. The challenge of ALI due to PAA underscores the importance of repair in the elective setting when possible.

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