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The Society for Vascular Surgery clinical practice guidelines on popliteal artery aneurysms

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ABSTRACT

The Society for Vascular Surgery clinical practice guidelines on popliteal artery aneurysms (PAAs) leverage the work of a panel of experts chosen by the Society for Vascular Surgery to review the current world literature as it applies to PAAs to extract the most salient, evidence-based recommendations for the treatment of these patients. These guidelines focus on PAA screening, indications for intervention, choice of repair strategy, management of asymptomatic and symptomatic PAAs (including those presenting with acute limb ischemia), and follow-up of both untreated and treated PAAs. They offer long-awaited evidence-based recommendations for physicians taking care of these patients. (J Vasc Surg 2022;75:109S-20S.)

Keywords: Acute limb ischemia; Guidelines; Popliteal artery aneurysms; Thrombolysis

TABLE OF CONTENTS

SUMMARY OF RECOMMENDATIONS

1. We recommend that patients who present with a PAA are screened for both a contralateral PAA and an AAA. **Level of recommendation: grade 1 (strong); quality of evidence: B (moderate)**
2. We recommend that patients with an asymptomatic PAA ≥20 mm in diameter should undergo repair to reduce the risk of thromboembolic complications and limb loss. Level of recommendation: **grade 1 (strong); quality of evidence: B (moderate)**. For selected patients at higher clinical risk, repair can be deferred until the PAA has become ≥30 mm, especially in the absence of thrombus. **Level of recommendation: grade 2 (weak); quality of evidence: C (low)**
3. We suggest that for patients with a PAA <20 mm, in the presence of thrombus and clinical suspicion of embolism or imaging evidence of poor distal runoff, repair should be considered to prevent thromboembolic complications and possible limb loss. **Level of recommendation: grade 2 (weak); quality of evidence: C (low)**
4. For asymptomatic patients, with a life expectancy of ≥5 years, we suggest open PAA repair, provided that an adequate saphenous vein is present. For patients with a diminished life expectancy, if intervention is indicated, endovascular repair should be considered. **Level of recommendation: grade 2 (weak); quality of evidence: C (low)**
5. We recommend that intervention for thrombotic and/or embolic complications of PAA be stratified by the

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Author conflict of interest: none.

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Independent peer review and oversight has been provided by members of the Society for Vascular Surgery Document Oversight Committee (Ruth Bush, Chair, Marc Schermerhorn, Vice-Chair, Keith Calligaro, Yazan Duwayri, Raul Guzman, Gregory Landry, Mahmoud Malas, Katherine McGinigle, J. Sheppard Mondy, John Rectenwald, William Robinson, Britt Tonnessen, and Greg Westin).
0741-5214

https://doi.org/10.1016/j.jvs.2021.04.040

severity of ALI at presentation. We recommend that patients with mild to moderate ALI (Rutherford grade I and IIa) and severely obstructed tibiopedal arteries undergo thrombolysis or pharmacomechanical intervention to improve runoff status, with prompt transition to definitive PAA repair. We recommend that patients with severe ALI (Rutherford grade IIb) undergo prompt surgical or endovascular PAA repair, with the use of adjunctive surgical thromboembolectomy or pharmacomechanical intervention to maximize tibiopedal outflow. Nonviable limbs (Rutherford grade III) require amputation. **Level of recommendation: grade 1 (strong); quality of evidence: B (moderate)**

6. We recommend that patients who undergo OPAR or EPAR should be followed up using clinical examination, ABI, and DUS at 3, 6, and 12 months during the first postoperative year and, if stable, annually thereafter. In addition to DUS evaluation of the repair, the aneurysm sac should be evaluated for evidence of enlargement. If abnormalities are found on clinical examination, ABI, or DUS, appropriate clinical management according to the lower extremity endovascular or open bypass guidelines should be undertaken. Level of recommendation: **grade 1 (strong); quality of evidence: B (moderate)**. If compressive symptoms or symptomatic aneurysm sac expansion are noted, we suggest surgical decompression of the aneurysm sac. **Level of recommendation: grade 1 (strong); quality of evidence: C (low)**
7. We suggest that patients with an asymptomatic PAA who are not offered repair should be monitored annually for changes in symptoms, pulse examination, extent of thrombus, patency of the outflow arteries, and aneurysm diameter. **Level of recommendation: grade 2 (weak); quality of evidence: C (low)**

Popliteal artery aneurysms (PAAs) are the most common peripheral arterial aneurysms, defined as aneurysms outside the aortoiliac system or the brain, accounting for 70% of all peripheral arterial aneurysms.[1] They are more common in men (95%)[2,3] and tend to occur in the sixth and seventh decades of life.[1] Few modern studies have been performed on the natural history of PAAs, and many of these were retrospective reviews of surgical patients. As such, the timing and details of PAA management remain nuanced.

The popliteal artery begins as the superficial femoral artery emerges from the adductor hiatus. It courses behind the knee enveloped in a sheath and surrounded by a fat pad.[4] The popliteal artery gives off genicular branches that surround the knee, acting as important pathways for collateral circulation, and divides into the anterior tibial artery and the tibioperoneal trunk in the proximal calf. The normal popliteal artery measures 5 to 9 mm in diameter and is generally larger in men by 1 to 2 mm.[5-8] It is generally considered aneurysmal when its diameter exceeds 15 mm or when it is 1.5× larger than its normal diameter.[1,9-11] Asymptomatic PAAs that are <20 mm in diameter can be expected to have a growth rate of 0.3 to 1.5 mm annually.[12-14] The rate of growth for aneurysms >20 mm in diameter is variable from no growth reported for most patients to ≤3 mm/y in others.[9,13,15] Independent factors associated with PAA growth include the initial aneurysm diameter and the presence of mural thrombus.[16] A prospective analysis showed that the initial PAA size influenced the rate of subsequent growth. When stratified by the initial size, PAAs <20 mm grew at 1.5 mm/y, PAAs 20 to 30 mm grew 3 mm/y, and those >30 mm grew 3.7 mm/y. The most recent retrospective analysis of 87 asymptomatic PAAs demonstrated that smaller size aneurysms may demonstrate a slower growth rate for a number of years before an accelerated growth phase occurs,[16] confirming previous observations that PAAs with greater diameters will enlarge more rapidly than those with smaller diameters.[12-14,16,17]

Most patients with PAAs will be asymptomatic at the time of detection. In a review of multiple studies, totaling >4000 patients, ~40% of patients were asymptomatic at repair.[2] Among asymptomatic patients with PAAs, 14% to 24% will become symptomatic within 1 to 2 years and 31% to 68% will develop complications during the patient's lifetime.[15,18-20] Symptoms usually result from acute or chronic limb ischemia caused by distal embolism to the tibial runoff vessels with or without associated aneurysm thrombosis.[21] The progression to PAA thrombosis has been associated with inflow and/or outflow occlusion.[22] Patients presenting with a thrombosed PAA can have severe limb ischemia owing to disruption of the collateral circulation and loss of outflow vessels owing to chronic silent thromboemboli that often precede the acute event. These patients require an expeditious diagnosis and treatment to prevent limb loss. In a systematic review of 895 cases of acute limb ischemia (ALI) due to PAA, the early amputation rate was 14%.[23] Patients presenting with chronic symptoms can be clinically indistinguishable from those presenting with atherosclerotic arterial occlusive disease. A high index of suspicion is, therefore, necessary to distinguish patients with chronically symptomatic PAAs from those with symptoms due to peripheral arterial occlusive disease (PAD). PAAs can also present with rupture, although this is rare.[1] Compressive symptoms resulting in venous congestion, leg swelling, deep vein thrombosis, and/or neuropathy have also been reported but are very uncommon.[1,2]

Frequently, the patient history will not be diagnostic and the physical examination findings will be insensitive even when detecting a prominent popliteal artery. The diagnosis of PAA, therefore, requires confirmatory imaging studies, which will also be helpful in treatment planning.[24]

Duplex ultrasound (DUS) has been shown to be highly sensitive and specific for the detection of PAAs, with a reported accuracy close to 100%.[24,25] Computed

Table. Society for Vascular Surgery clinical practice guidelines on popliteal artery aneurysms: recommendations

Investigator	Population	Interventions	Outcomes	Methodologic quality
Recommendation 1:We recommend that patients who present with a PAA are screened for both a contralateral PAA and an AAA (**grade 1B**)				
Dawson et al,[1] 1997	Patients with PAAs (review of literature)	Variable	For >1600 cases reported, average rate of bilateral PAA was 50%, and average rate of associated AAAs was 36%	Mix of mostly retrospective and a few prospective studies
Tsilimparis et al,[2] 2013	Tabular review of series of PAA patients	Variable	In >2600 patients from studies reported in previous 25 years, average rate of bilateral PAA was 48% and of concomitant AAA was 38%	Mix of mostly retrospective and a few prospective studies
Recommendation 2:We recommend that patients with an asymptomatic PAA >20 mm in diameter should undergo repair to reduce the risk of thromboembolic complications and limb loss (grade 1B). For selected patients at higher clinical risk, repair can be deferred until the PAA has become >30 mm, especially in the absence of thrombus (**grade 2C**)				
Cousins et al,[16] 2018	Asymptomatic PAAs treated for ≥1 year of medical and observational management before repair	Variable	87 PAAs in 65 patients were evaluated; mean initial diameter at diagnosis was 16.9 mm; multivariable analysis determined that initial diameter (OR, 5.53; $P = .007$) and presence or development of mural thrombus (OR, 4.00; $P = .008$) independently predicted for PAA diameter growth	Retrospective study
Lowell et al,[17] 1994	Consecutive patients with symptomatic or asymptomatic PAAs	Variable	161 PAAs in 106 patients were followed up for a mean of 6.7 years (range, 3 days to 12.1 years); 15 limbs presented with acute symptoms, 52 with chronic symptoms, and 94 were asymptomatic; ≥1 of 3 risk factors (size, >2 cm, thrombus, poor runoff) was initially present in 11 of 12 limbs (91.7%) compared with 9 of 24 control limbs (37.5%) that remained asymptomatic ($P < .05$)	Retrospective study
Galland et al,[29] 2005	Consecutive patients with symptomatic or asymptomatic PAA	Variable	116 PAAs in 73 patients, 39 (34%) with acute ischemia; size and distortion were greater in PAAs presenting with acute ischemia than in asymptomatic PAAs ($P < .01$); degree of distortion differentiated symptomatic from asymptomatic PAAs ($P = .0066$); size was not significantly different between these 2 groups; for PAA ≥3 cm in diameter with ≥45° distortion, sensitivity, specificity, and positive and negative predictive values for thrombosis were 90%, 89%, 83%, and 94%, respectively	Prospective study
Recommendation 3: We suggest that for patients with a PAA <20 mm, in the presence of thrombus and clinical suspicion of embolism or imaging evidence of poor distal runoff, repair should be considered to prevent thromboembolic complications and possible limb loss (**grade 2C**)				
Ascher et al,[30] 2003	34 PAAs in 25 patients; 14 (41%) had no symptoms (group 1) and 20 (59%) had symptoms (group 2)	Bypass surgery	PAA diameter averaged 2.8 ± 0.7 cm (range, 1.8-4.5 cm) in group 1 and 2.2 ± 0.8 cm (range, 1.3-4.0 cm) in group 2 ($P < .03$); PAA thrombosis was present in 7 of 20 limbs in group 2; 4 of these patients had ipsilateral SFA thrombosis; evaluation of infrapopliteal arteries in group 1 showed 3-vessel runoff in 7 limbs, 2-vessel runoff in 3 limbs, 1-vessel runoff in 2 limbs, and no vessel runoff in 2 limbs; all infrapopliteal arteries were either occluded or significantly stenotic in 14 limbs (70%); in group 2, 1-vessel runoff was observed in 5 limbs, and 2-vessel runoff in 1 limb	Retrospective study

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Table. Continued.

Investigator	Population	Interventions	Outcomes	Methodologic quality
Dawson et al,[20] 1994	Asymptomatic PAAs	Observation	42 Patients with mean PAA diameter of 3.1 cm (range, 1.8-8.0 cm); 1 or both ankle pulses were absent in 18/42 limbs; during follow-up, 25/42 asymptomatic PAAs under observation had complications at mean observation of 18 months (range, 1 day to 65 months); absent ankle pulses at initial examination significantly predicted for natural history of asymptomatic PAA; risk of complications was also greater with increasing diameter (≥2 cm)	Retrospective study
Recommendation 4: For asymptomatic patients with a life expectancy of ≥5 years, we suggest open PAA repair, provided that an adequate saphenous vein is present; for patients with a diminished life expectancy, if intervention is indicated, endovascular repair should be considered (**grade 2C**)				
Garg et al,[31] 2012	21 PAA patients	EPAR	3 Graft failures of 20 procedures; open thrombectomy (n = 2) and femorotibial bypass (n = 1); significantly increased graft failure rate with 1-compared with 2- or 3-vessel runoff	Retrospective study; moderate methodologic quality
Serrano Hernando et al,[32] 2015	171 PAAs in 142 men; 53.3% asymptomatic	139 OPAR, 32 EPAR	27 Occlusions (14.4% OPAR, 21.8% EPAR); only variable associated with patency on multivariate analysis was poor runoff	Retrospective study; moderate methodologic quality
Beuschel et al,[33] 2020	—	—	Meta-analysis of mainly nonrandomized studies (1 small RCT) showed that, compared with EPAR, OPAR was associated with greater primary patency at 1 year (OR, 2.13; 95% CI, 1.45-3.14) and 3 years (OR, 1.41; 95% CI, 0.99-2.01), lower occlusion rate at 30 days (OR, 0.41; 95% CI, 0.24-0.68), and fewer reinterventions but longer hospital stay and more wound complications; no significant difference was found in mortality (OR, 0.28; 95% CI, 0.06-1.36 at 30 days; OR, 0.49; 95% CI, 0.21-1.17 at longest follow up), secondary patency (OR, 1.59; 95% CI, 0.92-3.07 at 1 year), or amputation rate (OR, 0.85; 95% CI, 0.56-1.31) between OPAR and EPAR; certainty for these estimates was, in general, low	Systematic review of 1 high risk of bias RCT and observational studies
Eslami et al,[34] 2015	Asymptomatic PAAs in VQI from 2010 to 2013	221 OPAR, 169 EPAR; MALE, loss of primary patency, and MALE-free survival were compared	OPAR patients had significantly greater MALE-free survival (95% vs 80%; $P < .001$) and MALE-POD—free survival (93% vs 80%; $P < .001$) rates at 1 year after procedure; OPAR was associated with lower hazard of MALE (HR, 0.35; 95% CI, 0.15-0.86; $P < .05$), MALE-POD (HR, 0.28; 95% CI, 0.13-0.63; $P < .05$), and primary patency loss (HR, 0.25; 95% CI, 0.10-0.58; $P < .05$)	Retrospective, multi-institutional registry study; moderate methodologic quality
Galinanes et al,[35] 2013	PAA repair in Medicare beneficiaries, 2005-2007	Comparison of 2962 Medicare patients after OPAR (n = 2413) and EPAR (n = 549); reintervention rates, LOS, and charges	Greater LOS and hospital charges for OPAR; greater 30- and 90-day reinterventions for EPAR (4.6% vs 2.1%; $P = .001$; 11.8% vs 7.4%; $P = .0007$, respectively)	Retrospective administrative database; moderate to low methodologic quality

Table. Continued.

Investigator	Population	Interventions	Outcomes	Methodologic quality
Pulli et al,[36] 2012	PAA repair	Comparison of 43 OPAR and 21 EPAR outcomes	Equal outcomes across all compared between OPAR and EPAR	Retrospective single-institution analysis; moderate methodologic quality
Pulli et al,[37] 2013	PAA repair	Comparison of 178 OPAR and 134 EPAR outcomes, including primary patency and limb loss	Similar outcomes noted between OPAR and EPAR	Retrospective multi-institution analysis; moderate methodologic quality
Leake et al,[38] 2017	PAA repair	Meta-analysis of 14 studies, including 4880 PAA repairs (OPAR, 3915; EPAR, 1210)	OPAR had longer LOS (SMD, 2.158; 95% CI, 1.225-3.090; $P < .001$) and fewer reinterventions (OR, 0.275; 95% CI, 0.166-0.454; $P < .001$); primary patency was better for OPAR at 1 and 3 years (RR, 0.607 [$P = .01$]; RR, 0.580 [$P = .006$], respectively); no difference in secondary patency at 1 and 3 years (RR, 0.770 [$P = .458$]; RR, 0.642 [$P = .073$], respectively)	Systematic review of one low-quality RCT and observational studies
Antonello et al,[39] 2005	Patients with PAA	15 OPAR, 15 EPAR, comparison of outcomes	Similar outcomes between OPAR and EPAR	Single-center, prospective randomized trial of low power but appropriate method
Recommendation 5: We recommend that intervention for thrombotic and/or embolic complications of PAA be stratified by the severity of ALI at presentation. We recommend that patients with mild to moderate ALI (Rutherford grade I and IIa) and severely obstructed tibiopedal arteries undergo thrombolysis or pharmacomechanical intervention to improve runoff status, with prompt transition to definitive PAA repair. We recommend that patients with severe ALI (Rutherford grade IIb) should undergo prompt surgical or endovascular PAA repair, with the use of adjunctive surgical thromboembolectomy or pharmacomechanical intervention to maximize tibiopedal outflow. Nonviable limbs (Rutherford grade III) require amputation (**grade 1B**)				
Marty et al,[40] 2002	12 Patients with ALI, Rutherford grade IIa; 1 with ALI, Rutherford grade IIb	All patients received preoperative thrombolysis	Thrombolysis failures (3/13) predicted for bypass failure and AKA; thrombolysis for ALI IIb resulted in rhabdomyolysis and death	Retrospective study; moderate methodologic quality
Pulli et al,[41] 2006	17 Patients with ALI, Rutherford grade I-IIa; 19 with ALI, Rutherford grade IIb	17 Patients with Rutherford grade I-IIa received preoperative lysis; 19 with Rutherford grade IIb underwent open repair	11/17 Thrombolysis patients (64.5%) had restoration of patency of PAA and ≥1 tibial vessel	Retrospective study; moderate methodologic quality
Kropman et al,[23] 2010	895 Patients with ALI (122 with Rutherford grade noted: 101, IIa; 18, IIb; 3, III)	313, Lysis (255 preoperatively); 551, OPAR; 31, primary amputation	Pre- and intraoperative thrombolysis plus bypass yielded improved graft patency rates at 1 year but no change in amputation rates compared with surgical thrombectomy plus bypass	Systematic review (8 prospective, 25 retrospective); good methodologic quality
Pulli et al,[37] 2013	51 Patients with ALI: 40, Rutherford grade I-IIa; 11, IIb	Patients with I-IIa received lysis then repair (30 OPAR; 10 EPAR); patients with IIb received OPAR	At 48 months, limb salvage was 81.5%	Multicenter retrospective study; moderate methodologic quality
Dorigo et al,[42] 2002	24 Patients with ALI, Rutherford grade I-IIa	10 Patients received OPAR; 14, lysis followed by OPAR	Perioperative (30-day) limb salvage was 70% for OPAR, which improved to 86% with addition of thrombolysis	Retrospective comparative study; moderate methodologic quality
Dorigo et al,[43] 2018	13 Patients with ALI (8 with Rutherford grade I-IIa)	8 Patients treated with lysis	6/8 (75%) Successful	Retrospective multicenter study; moderate methodologic quality
Huang et al,[44] 2007	358 Cases of PAA in 289 patients; 74 (21%) with ALI	74 Patients with ALI; 24 received preoperative lysis	30-Day primary patency for ALI grade II patients increased with lysis (96% ± 4% vs 80% ± 9%)	Retrospective, single-center study; moderate methodologic quality

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Table. Continued.

Investigator	Population	Interventions	Outcomes	Methodologic quality
Recommendation 6: We recommend that patients who undergo OPAR or EPAR should be followed up using clinical examination, ankle brachial index (ABI), and DUS at 3, 6, and 12 months during the first postoperative year and, if stable, annually thereafter. In addition to DUS evaluation of the repair, the aneurysm sac should be evaluated for evidence of enlargement. If abnormalities are found on clinical examination, ABI, or DUS, appropriate clinical management according to the lower extremity endovascular or open bypass guidelines should be undertaken (grade 1B). If compressive symptoms or symptomatic aneurysm sac expansion are noted, we suggest surgical decompression of the aneurysm sac (**grade 1C**)				
Zierler et al,[45] 2018	SVS review of multiple endovascular and open lower extremity revascularization procedures	DUS, ABI, and physical examination surveillance recommended at 1, 6, and 12 months, then annually	Numerous studies (≥2300) have demonstrated that identifying and repairing graft-threatening lesions prolongs bypass patency	Retrospective and meta-analysis
Stone et al,[46] 2005	55 Patients with PAAs	DUS at discharge, every 3 months for 2 years, then every 6 months	One third of PAAs repaired by OPAR or EPAR required secondary intervention within 2 years	Retrospective review; moderate methodologic quality
Piazza et al,[47] 2014	46 EPARs	DUS surveillance at 1, 6, 12 months, then annually	11 Stent-graft failures; 63% within first year	Retrospective review; moderate methodologic quality
Davies et al,[48] 2010	48 Patients with 63 PAAs	DUS surveillance but no schedule reported	5 PAAs with flow into sac and aneurysm growth	Retrospective review; moderate methodologic quality
Recommendation 7: We suggest that patients with an asymptomatic PAA who are not offered repair should be monitored annually for changes in symptoms, pulse examination, extent of thrombus, patency of the outflow arteries, and aneurysm diameter (**grade 2C**)				
Dawson et al,[20] 1994	42 Patients with asymptomatic PAAs	Monitored for symptoms and complications	24% Developed complications within 1 year, and 68% developed complications due to PAAs within 5 years; absence of ankle pulses was a strong predictor of complications	Retrospective case series
Ascher et al,[30] 2003	34 Patients identified retrospectively with PAA	Variable	Size did not accurately predict for complications; aneurysms <2 cm still posed risk of thrombosis and complications	Retrospective case series
Dawson et al,[1] 1997	Review of 13 retrospective case series; 437 aneurysms total	Variable	Complications developed at a mean observation time of 18 months; complication rate varied, 8%-100%; amputation rate with complications, 25%	Retrospective case series
Schröder et al,[49] 1996	Retrospective review of 217 patients	Variable	53% of patients treated conservatively were free of symptoms at 5 years	Retrospective case series
Farina et al,[50] 1989	Retrospective review of 50 aneurysms	Variable	36% of 14 patients treated conservatively had complications at a mean of 26 months	Retrospective case series

AAA, Abdominal aortic aneurysm; *ABI,* ankle brachial index; *AKA,* above the knee amputation; *ALI,* acute limb ischemia; *CI,* confidence interval; *DUS,* duplex ultrasound; *EPAR,* endovascular popliteal artery aneurysm repair; *HR,* hazard ratio; *LOS,* length of stay; *MALE,* major adverse limb events; *OPAR,* open popliteal artery aneurysm repair; *OR,* odds ratio; *PAA,* popliteal artery aneurysm; *POD,* perioperative death; *RCT,* randomized controlled trial; *RR,* relative risk; *SFA,* superficial femoral artery; *SMD,* standardized mean difference; *SVS,* Society for Vascular Surgery; *VQI,* Vascular Quality Initiative.

tomography angiography and magnetic resonance angiography can be used to identify the proximal and distal extent of the PAA, assess arterial inflow and outflow, and to plan the repair. Catheter-directed digital subtraction angiography has mainly been used for ALI when thrombolytic therapy is needed, when evaluating for concurrent endovascular repair, or to better assess a distal arterial target for open repair using lower extremity bypass.

Although very few PAA-specific studies have been reported on the optimal medical management, given that PAAs and atherosclerotic occlusive disease often occur together, the risk modification strategies and guidelines established for asymptomatic PAD or aortic aneurysmal disease are often followed for patients with PAAs.[26,27] Thus, patients with a PAA who smoke should be counseled to cease smoking and be medically treated to control hypertension, hyperlipidemia, and diabetes, as part of an atherosclerotic factor control strategy. Although statins and antiplatelet agents may be indicated for that purpose, they have not been definitively shown to affect the natural history of PAAs. The only study that evaluated the effect of medication (eg, statins, anticoagulant agents, β-blockers, and antiarrhythmic agents) on PAA growth found no correlation, although the sample size was too small for meaningful conclusions.[16]

When surgical treatment of a PAA is indicated, both open and endovascular approaches can be used. Endovascular PAA repair (EPAR) is a less invasive procedure in which a stent-graft is deployed across the PAA. In open PAA repair (OPAR), if the medial approach is used, the aneurysm should be bypassed with proximal and distal ligation of the aneurysm sac. Sac obliteration is desirable but can be technically difficult to complete. If the posterior approach is used, bypass and aneurysmorrhaphy should be performed. In patients with very large PAAs and compressive symptoms, the posterior approach is advantageous because it allows for complete decompression of the aneurysm sac. In some patients with PAA who present with ALI, thrombolysis has been used as an adjunct to EPAR or OPAR.

The reported data on PAAs were exhaustively evaluated by a working group of experts appointed by the Document Oversight Committee of the Society for Vascular Surgery (SVS). This working group identified seven guidelines from the available reported data using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach[28] that represent the most salient elements surrounding the treatment of patients with PAAs and in the present report has presented these guidelines, the evidence table (Table), and the relevant literature to support their use. It is important to note that in the management of PAAs, a dearth of high-quality evidence is available to guide clinical decision-making. Rigorous well-controlled studies are badly needed to establish further clarity in this clinical area. As such, experienced clinicians can exercise considerable latitude in their approach to treating these complex patients.

METHODS

Guideline framework. Our expert panel used the GRADE approach to rate the quality of the available evidence and to grade the strength of the recommendations. This system, adopted by many other organizations, categorizes the recommendations as strong GRADE 1 or weak GRADE 2 according to the quality of the evidence, the balance between desirable and undesirable effects, the patient's values and preferences, and the required resources, feasibility and acceptability. GRADE 1 recommendations are meant to identify clinical practices for which the associated benefit clearly outweighs the risk. These recommendations can be made by clinicians and accepted by patients with a high degree of confidence. GRADE 2 recommendations are made when the benefits and risks are more closely matched and, as such, are more dependent on specific clinical scenarios. In general, clinician and patient preferences will play a more important role in the decision-making process in such circumstances. The SVS adjusted the GRADE rubric such that the level of evidence to support the recommendation is divided into three categories: A, high quality; B, moderate quality; and C, low quality. Conclusions based on high-quality evidence are unlikely to change with further investigation. In contrast, those based on moderate-quality evidence are more likely to be affected by future research. Finally, those based on low-quality evidence are the least supported by the current data and the most likely to be subject to change in the future. On occasion, a GRADE 1 recommendation can be made from low-quality (C) evidence.[28] The expert panel reached a consensus for all the recommendations and their level of supporting evidence. These guidelines represent a "living document," because new evidence is continually being collected and, as such, will require periodic updates as more is learned about the evaluation and management of PAAs.

Evidence to decision framework (decisional factors). Little is known about the values and preferences of patients with PAAs owing to the rarity of the condition. Therefore, the guideline committee members used their clinical expertise and assumed patient values from interactions with their patients. Most patients consider mortality and amputation as the most critical outcomes, followed by reintervention and patency. Patients would likely prefer an endovascular approach, unless it was clearly inferior in terms of its effect on these outcomes. This is consistent with the patient values derived from other similar contexts in vascular surgery, such as abdominal aortic aneurysms (AAAs).[51] Interviews with patients with small AAAs have demonstrated that they cared the most about postoperative morbidity and mortality compared with the need for surveillance and the risk of long-term problems with endovascular repair.[51] In terms of cost, an evaluation of the Centers for Medicare and Medicaid Services Inpatient claims (2005-2007) suggested that the medical and surgical supply charges for endovascular repair of PAAs ($15,029) are considerably greater than those for open surgery ($3188). However, open repair overall costs more than the endovascular approach ($43,180 vs $35,540, respectively).[35] In contrast, a decision analysis suggested that traditional open repair with great saphenous vein (GSV) bypass might be the preferred treatment for 65-year-old asymptomatic patients with PAAs when all outcomes are considered.[52] The guidelines committee did not conduct a formal cost-effectiveness analysis, and cost was not considered a major factor in making the recommendations. Endovascular and open approaches were both considered acceptable by patients and feasible in most settings if surgical expertise is available.

Evidence synthesis. The expert panel commissioned a systematic review of the MEDLINE, Embase, and Cochrane databases and Scopus that focused on evaluating two seminal research questions that relate to the management of PAAs. The first question evaluated the natural history of PAAs in an attempt to assess the timing of intervention. The second question appraised and compared the efficacy of OPAR and EPAR. The Mayo Clinic Evidence-Based Practice Center conducted the reviews. The search strategy identified 2191 references, of which 33 original studies and 4 systematic reviews were included. One systematic review of 13 studies and two additional original studies (836 PAAs) had evaluated the natural history question, and 3 meta-analyses and 31 studies (5381 patients and >5000 PAAs) had evaluated the comparative question. The methodology group performing the systematic review independently selected and appraised the studies and subsequently collaborated with the expert panel to integrate evidence into recommendations.[33]

Guidelines. Recommendation 1:***We recommend that patients who present with a PAA are screened for both a contralateral PAA and an AAA (grade 1B)***

The incidence of PAAs in the general population is relatively low, ranging from 0.1% to 2.8%.[10,53] Given their rarity, screening unselected patients or patients undergoing AAA screening has not been found to be cost-effective.[54] Patients with a known PAA, however, have a greater risk of having a contralateral PAA or an AAA. Two separate reviews of the reported data, spanning two separate eras, both identified similar rates of contralateral PAAs (48% and 50%) and associated AAAs (36% and 38%).[1,2] Given these associations, we recommend that patients who present with a PAA undergo screening of their contralateral leg and abdomen for both PAAs and AAAs, if not already known, preferably using DUS. Such screening should be repeated every 5 years.

The incidence of a PAA in patients with an AAA has been reported to range from 3% to 11%.[24,54-56] This incidence appears to be greater in men with an AAA and in patients with larger AAAs. Routine screening of all patients with small AAAs for a PAA is controversial and may not be cost-effective.[54,57] Men with larger AAAs may benefit from DUS screening of their popliteal arteries to detect a PAA.[24,56]

Recommendation 2: ***We recommend that patients with an asymptomatic PAA >20 mm in diameter should undergo repair to reduce the risk of thromboembolic complications and limb loss (grade 1B). For selected patients at higher clinical risk, repair can be deferred until the PAA has become >30 mm, especially in the absence of thrombus (grade 2C).***

The optimal timing of intervention for asymptomatic PAA remains unclear. The primary concern with PAA is the development of thrombotic and embolic complications. Although the aneurysm diameter might not be the best predictor for future thrombosis, it is readily measurable and can be used broadly to stratify risk combined with other anatomic parameters. A decision to treat should balance the risk of thromboembolism with continued surveillance against the morbidity associated with procedural intervention.

Elective intervention of PAAs has been shown to be associated with superior outcomes in terms of limb salvage compared with PAAs treated emergently. Using size criteria alone, a general consensus has been reached that elective intervention should be considered for PAAs measuring ≥20 mm in diameter. This threshold was selected to deter resection of mildly dilated popliteal arteries and later reinforced given that symptomatic PAAs typically exceed 20 mm in diameter. In a study of 106 patients who were followed up for a mean of 6.7 years, 67 asymptomatic limbs were managed nonoperatively.[17] In this cohort, symptoms had developed in 12 limbs (17.9%). At least one of three risk factors (ie, aneurysm size >20 mm, presence of thrombus, and poor tibial runoff) was present in 91.7% of the symptomatic group compared with 37.5% of the control limbs that remained asymptomatic. These findings prompted recommendations that patients with PAAs with any of these factors should undergo elective repair.

However, other studies have suggested that a higher threshold for intervention may be appropriate. In a study of 87 PAAs, it was determined that the initial diameter at diagnosis and the presence of luminal thrombus were the most important factors in determining which PAAs will expand at the greatest rate.[16] The investigators recommended that for patients with good surgical risk, an asymptomatic aneurysm of ≥25 mm would benefit from repair. In a retrospective review of 116 PAAs, it was observed that as the PAA increased in diameter, the degree of proximal angle of distortion also increased.[29] Aneurysm size alone was not a significant predictor of symptom development. However, an increased diameter and degree of distortion occurred more often in PAAs associated with ALI than in asymptomatic PAAs. The investigators showed that a threshold of 30-mm diameter and >45° of distortion were highly predictive of thrombosis and provided a reliable method of differentiating aneurysms best fit for elective repair. Thus, physicians should, at their discretion, determine their patient's candidacy for repair and may consider a higher size threshold of 30 mm for those deemed at high surgical risk.

Recommendation 3: ***We suggest that for patients with a PAA <20 mm, in the presence of thrombus and clinical suspicion of embolism or imaging evidence of poor distal runoff, repair should be considered to prevent thromboembolic complications and possible limb loss (grade 2C).***

The probability of embolization and thrombosis may not necessarily be dependent on aneurysm size. Ascher et al,[30] in their retrospective series of 34 PAAs observed that patients with smaller PAAs (22 ± 8 mm) had a greater incidence of thrombotic complications and clinical symptoms than those with larger aneurysms (28 ± 7 mm).[30] Most of the small (ie, <20 mm) aneurysms

(64%) were partially thrombosed, although this incidence was not significantly different from that of the larger aneurysms (70%). The investigators also observed that thrombosis of the PAA did not correlate with aneurysm size.[30] When comparing runoff scores, these smaller symptomatic PAAs had poorer outflow vessels. Their study resulted in consideration of early intervention, even for PAAs <20 mm, when mural thrombus is present. However, no prospective evidence is available to further support this. Several studies have otherwise indicated that >70% of PAAs will contain some degree of thrombus and will form mural thrombus as the PAA enlarges. It remains controversial whether aneurysmal degeneration results in thrombus formation or if thrombus formation is responsible for the development of aneurysmal dilation. As such, surgical treatment determined by the presence of thrombus alone might lead to unjustifiable interventions.

Thrombus presence paired with impaired runoff, regardless of aneurysm diameter, however, might be a better marker to identify higher risk PAAs. Microembolism from the aneurysm can be responsible for blue toe syndrome, and such patients have a high risk of new arterial emboli, even after successful conservative treatment of the first event. Insidious microemboli can silently, yet significantly, compromise arterial runoff, with detrimental effects on the outcomes of subsequent interventions. Dawson et al,[20] in a retrospective study of 42 patients, demonstrated an increased risk of complications for patients with a PAA and no distal pulses compared with those with pulses present. These investigators suggested that such patients should not be classified as asymptomatic and should be considered for intervention.[20]

Recommendation 4: ***For asymptomatic patients with a life expectancy of ≥5 years, we suggest open PAA repair, provided that an adequate saphenous vein is present. For patients with a diminished life expectancy, if intervention is indicated, endovascular repair should be considered (grade 2C).***

Treatment of patients with an asymptomatic PAA should be directed toward the reduction of thrombotic sequelae related to PAAs. In these patients, the exclusion of the PAA from the circulation should be the main aim of therapy. This objective can be achieved using either OPAR or EPAR. For OPAR, exclusion requires bypass with interval proximal and distal ligation of the aneurysm sac. For EPAR, exclusion is accomplished by sealing off the aneurysm with an endograft. Although a paucity of adequately powered level 1 prospective data is available comparing these two modalities, several studies have reported better long-term outcomes (ie, better patency and fewer major adverse limb events) after OPAR, especially if a single-segment GSV was used for the arterial bypass.[32,34-39] Given these observations regarding the better long-term results, for patients who can tolerate either procedure with an anticipated life expectancy of ≥5 years, OPAR should be considered first if adequate GSV is available. An adequate GSV has been extrapolated from PAD studies to be a GSV >3 mm in diameter and free of intraluminal stenoses or synechiae.

In the absence of an adequate single-segment GSV, an alternative conduit such as an expanded polytetrafluoroethylene graft can be used with acceptable outcomes.[58] An alternative autogenous vein may not provide better long-term patency outcomes than an expanded polytetrafluoroethylene conduit.[59] The latter, using a posterior approach, often allows for a good size match for proximal and distal popliteal arteries in this patient population.[60]

Several studies that retrospectively compared the results of different PAA interventions have indicated that the number of tibial runoff vessels will affect the surgical outcomes. These studies suggested that the number of outflow arteries could adversely affect the results of EPAR but not OPAR.[31,32] In a recent large study of the long-term results of EPAR, the investigators found that aneurysm size, coverage below the knee, and single-vessel runoff were the only predictors of major adverse limb events.[61] Therefore, given the current data, for patients with poor tibial or pedal runoff, OPAR with GSV is considered preferential to EPAR for good-risk patients. High-risk patients, defined as those with a high cardiovascular risk or adverse anatomic criteria such as severe venous stasis or lymphedema, pose a challenge because the natural history of PAA is known only from purely retrospective data. As such, for patients with a poor life expectancy and an asymptomatic PAA, it may be reasonable to defer any intervention. If treatment of a PAA is indicated for such patients, because endovascular treatment is less taxing and has fewer postoperative complications, EPAR should be considered, regardless of the availability of the GSV or quality of the runoff vessels.

Our literature review suggests that younger age, the availability of single-segment GSV, challenged runoff vessels, and lower operative risk favor the choice of OPAR. However, greater equipoise for EPAR is present with advancing age, an insufficient GSV, the presence of satisfactory landing zones and tibial runoff, and higher operative risk. In the absence of robust comparative data, thoughtful judgment by an experienced vascular surgeon retains primacy in the selection of the optimal repair strategy.

Recommendation 5: ***We recommend that intervention for thrombotic and/or embolic complications of PAA be stratified by the severity of ALI at presentation. We recommend that patients with mild to moderate ALI (Rutherford grade I and IIa) and severely obstructed tibiopedal arteries undergo thrombolysis or pharmacomechanical intervention to improve runoff status, with prompt transition to definitive***

PAA repair. We recommend that patients with severe ALI (Rutherford grade IIb) should undergo prompt surgical or endovascular PAA repair, with the use of adjunctive surgical thromboembolectomy or pharmacomechanical intervention to maximize tibiopedal outflow. Nonviable limbs (Rutherford grade III) require amputation (grade 1B).

When patients present with an acutely thrombosed PAA, the degree of ischemic insult will determine the course of management.[23,37,43] ALI resulting from PAA thrombosis is frequently associated with a complete lack of patent tibiopedal runoff arteries. The indication for preoperative intra-arterial thrombolysis is restricted to selected patients who can withstand an additional period of limb ischemia (Rutherford grade I and IIa).[40,42] In this condition, the rationale for thrombolysis is primarily to restore runoff for bypass grafting or endovascular repair. If arteriography demonstrates thrombosis of the PAA alone, with a good inflow source and suitable outflow, lytic therapy is not indicated, and prompt surgical or endovascular reconstruction should be performed.[37] If the clot extends into the tibial arteries, without a visible runoff vessel, thrombolysis can be very useful to restore patency in at least one tibial vessel if the patient tolerates this intervention and ischemia is not worsened.[40-42,44] Patients with limb threatening ischemia (Rutherford grade IIb) cannot tolerate the additional ischemic time required by infusion thrombolysis and should urgently undergo surgical or endovascular revascularization,[23,40] with the use of adjuncts, including mechanical or aspiration thrombectomy, to clear runoff vessels. For these patients, combined mechanical and thrombolytic therapy (pharmacomechanical thrombolysis) may increase the lytic effect, reducing the procedural time. Depending on the severity and duration of ischemia and the physical examination findings, calf fasciotomies may be required after successful revascularization.

Failure to establish a bypass target vessel using either lytic or operative methods can necessitate amputation, depending on the patient's clinical condition.[40,42] Limbs that are not salvageable at presentation (Rutherford grade III) should undergo primary amputation rather than revascularization to avoid reperfusion injury, potential renal failure, and other complications attendant upon a nonviable limb.[23] The timing of the amputation is dictated by clinical and physiologic findings.

Recommendation 6: ***We recommend that patients who undergo OPAR or EPAR should be followed up using clinical examination, ankle brachial index (ABI), and DUS at 3, 6, and 12 months during the first postoperative year and, if stable, annually thereafter. In addition to DUS evaluation of the repair, the aneurysm sac should be evaluated for evidence of enlargement. If abnormalities are found on clinical examination, ABI, or DUS, appropriate clinical management according to the lower extremity endovascular or open bypass guidelines should be undertaken (grade 1B). If compressive symptoms or symptomatic aneurysm sac expansion are noted, we suggest surgical decompression of the aneurysm sac (grade 1C).***

Open surgical or endovascular treatment of PAAs requires a protocol of surveillance using DUS. Retrospective reviews have identified the incidence of secondary interventions ranging from 33% to 63% in the first 2 years after PAA repair. Specifically, of 48 surgical reconstructions, DUS identified 14 graft abnormalities in 12 reconstructions after the initial 30 days. Only seven endovascular reconstructions and two patients had presented with thrombosis of the stent-grafts within 2 months of treatment. The results from the other five DUS scans did not result in any intervention by the time of the report.[46,47] Stenosis is the principal cause of graft thrombosis, and the SVS guidelines for surveillance after arterial procedures are relevant to PAA repair, with the recommendation for DUS surveillance at 3, 6, and 12 months in the first year and then annually, coupled with a physical examination.[45] In addition, the surveillance of the residual aneurysm sac for enlargement is important, because an "endoleak" from genicular branches can result in sac enlargement after OPAR or EPAR.[48] An expanding PAA after treatment has been documented to be at risk of rupture.[62-65] Thus, evidence of residual aneurysm sac enlargement should encourage serial follow-up examinations and consideration of intervention to prevent potential aneurysm compression symptoms and/or rupture with clinical sequelae, including limb loss. Postprocedural use of atherosclerotic risk factor modification, smoking cessation, and pharmacotherapy with statins and antiplatelet agents should be continued, although data regarding these treatments have stemmed from management of PAD rather than PAAs.[27] No meaningful data are available regarding anticoagulation therapy after endovascular repair of PAAs, because most studies have not reported specific postoperative medical therapy. Those that have reported it used antiplatelet therapy. It is reasonable to use anticoagulation therapy instead of antiplatelet therapy, extrapolating from the favorable data for prosthetic graft patency with anticoagulation therapy. However, a large analysis of meta-analyses and randomized controlled trials concluded that the best prophylaxis for vein bypass is anticoagulant therapy and, for prosthetic grafts, dual antiplatelet therapy.[66-68]

Recommendation 7: ***We suggest that patients with an asymptomatic PAA who are not offered repair should be monitored annually for changes in symptoms, pulse examination, extent of thrombus, patency of the outflow arteries, and aneurysm diameter (grade 2C).***

Patients with PAAs require a rigorous surveillance protocol with DUS because the risk of complications increases with time.[49,50] Dawson et al[20] observed in a set of 42 patients with asymptomatic PAAs that 24% had developed complications within 1 year and 68% had developed complications within 5 years. In another report, Dawson et al[1] reported complications had occurred at a mean 18 months, and the amputation rate for patients with complications was 25%. Even aneurysms <20 mm in diameter have been shown to cause complications, as shown by Ascher et al.[30] PAAs, like most aneurysms, can result in complications that result in limb loss if a high index of suspicion is not used with serial surveillance.

Independent peer review and oversight has been provided by members of the Society for Vascular Surgery Document Oversight Committee (Ruth Bush, chair, Marc Schermerhorn, vice-chair, Keith Calligaro, Yazan Duwayri, Raul Guzman, Gregory Landry, Mahmoud Malas, Katherine McGinigle, J. Sheppard Mondy, John Rectenwald, William Robinson, Britt Tonnessen, and Greg Westin).

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Conception and design: AF
Analysis and interpretation: AF, NA, EA, LD, ME, PG, MH, JJ, EK, RP, JS, MM
Data collection: Not applicable
Writing the article: AF, NA, EA, LD, ME, PG, MH, JJ, EK, RP, JS
Critical revision of the article: AF, NA, EA, LD, ME, PG, MH, JJ, EK, RP, JS, MM
Final approval of the article: AF, NA, EA, LD, ME, PG, MH, JJ, EK, RP, JS, MM
Statistical analysis: Not applicable
Obtained funding: Not applicable
Overall responsibility: AF

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Submitted Apr 2, 2021; accepted Apr 3, 2021.