Outcomes of surgical management for popliteal artery aneurysms: An analysis of 583 cases

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Background: **This study aimed to analyze outcomes of surgical management for popliteal artery aneurysms (PAA).**
Methods: **This is a retrospective analysis of prospectively collected data regarding operations for PAA obtained from 123 United States Veterans Affairs Medical Centers as part of the National Surgical Quality Improvement Program. Univariate analyses and multivariate logistic regression were used to characterize 33 risk factors and their associations with 30-day morbidity and mortality. Survival and amputation rates, observed at one and two years after surgery, were subject to life-table and Cox regression analyses.**
Results: **There were 583 operations for PAA in 537 patients during 1994-2005. Almost all were in men (99.8%) and median age was 69 years (range, 34 to 92 years). Most had multiple co-morbidities, 88% were ASA (American Society of Anesthesiologists) class 3 or 4, and 81% were current or past smokers (median pack-years = 50). Only 16% were diabetic. Serious complications occurred in 69 (11.8%) cases, of which 37 (6.3%) required arterial-specific reinterventions. Eight patients died within 30 days, a mortality of 1.4%. Risk factors associated with increased complications included: African-American race (odds ratio [OR] 2.8 [95% confidence interval 1.5-5.2], $P = .002$), emergency surgery (OR 3.8 [2.0-7.0], $P < .0001$), ASA 4 (OR 1.9 [1.1-3.5], $P = .04$), dependent functional status (OR 2.5 [1.4-4.7], $P = .004$), steroid use (OR 3.2 [1.2-8.7], $P = .03$), and need for intraoperative red blood cell transfusion of any quantity (OR 6.3 [3.5-11.2], $P < .0001$). Independent predictors for complications in the multivariate model were dependent functional status (adjusted OR 2.1 [1.1-4.3], $P = .049$) and intraoperative transfusion (adjusted OR 4.5 [2.3-8.9], $P = .0002$). Postoperative bleeding complications within 72 hours independently predicted early amputation (adjusted OR 25.5 [1.7-393], $P = .02$). Unadjusted patient survival was 92.6% at one year and 86.1% at two years. Limb salvage in surviving patients was 99.0% at 30 days, 97.6% at one year, and 96.2% at two years. Dependent preoperative functional status was the only factor predictive of worse two-year limb salvage (adjusted OR 4.6 [1.9-10.9], $P = .001$), but remained high at 88.2% versus 97.1% in independent patients.**
Conclusions: **Surgical intervention for PAA is associated with low operative mortality and offers excellent two-year limb salvage, even in high-risk patients. Patients' preoperative functional status and perioperative blood transfusion requirements were the most predictive indicators of negative outcomes. (J Vasc Surg 2008;48:845-51.)**

Although rare, popliteal artery aneurysms (PAA) are the most common peripheral arterial aneurysms. They are usually found in older men.[1,2] They can be encountered incidentally on routine physical exam or present with local symptoms. The most severe threats of PAA are acute thrombosis, distal embolization, or to a much lesser degree aneurysm rupture leading to limb loss.[3] Management aims to achieve symptom alleviation and limb preservation, while considering the risks and benefits of any type of intervention.

Due to the disease's limited prevalence, most existing studies are small, retrospective, single-institution reports. Previous authors have attempted to analyze artery-specific or patient-specific factors like aneurysm morphology, aneurysm size, presence of symptoms, co-morbidities, and life expectancy to determine the optimal criteria for interventional versus expectant management. Many of the existing series seem to support early surgical intervention given the threat of acute limb ischemia.[3-10]

Even when PAA are initially asymptomatic, patients will develop symptoms at a mean rate of 14% per year (range, 5% to 24%),[11] and one-third will develop complications requiring emergent intervention within five years, resulting in poorer outcomes for both life and limb.[12] In patients selected for anticoagulation and/or routine surveillance due to small aneurysm size (2 to 3 cm) or coexisting cardiovascular or malignant disease thought to be life-limiting, 33% to 45% eventually needed surgical management anyway.[8,13]

Given that surgical management remains the definitive therapy, it is important to analyze outcomes using data powered to produce meaningful information that could assist in a surgeon's decision-making. A recently published study of procedures for PAA in Sweden explored technical factors such as conduit type and runoff status, but presented little data on patient risk factors and operative complications.[2,14] Our objective was to analyze – using a validated, peer-controlled, multicenter database – contemporary outcomes of surgical therapy for PAA in the United States.

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METHODS

Database. The Veterans Affairs National Surgical Quality Improvement Program (VA-NSQIP) is a widely accepted ongoing quality management initiative for surgical care that has been used in several previous investigations. Since its inception, VA-NSQIP has prospectively collected data on all major surgeries occurring at 123 participating VA medical centers (VAMCs) across the United States. A detailed account of NSQIP study design has been previously reported.[15] At the time of surgery, baseline clinical and demographic characteristics are obtained from the medical record, patient interview, or from the responsible surgeon by trained nurse reviewers. Descriptive data regarding the operation itself, anesthesia used, and post-operative complications are also recorded. Preoperative laboratory values are transmitted electronically from the VA's decentralized hospital computer system (VistA) to the coordinating center at the Denver VAMC and the University of Colorado Health Outcomes Program. All deaths reported are verified against the VA Beneficiary Identification and Records Locator System death records.

Sample selection. We queried VA-NSQIP for all surgical encounters for popliteal artery aneurysms from January 1, 1994 to January 1, 2005 as identified by the Current Procedural Terminology (CPT) codes 35151 and 35152. All patients returned by the query were included for analysis. Institutional review board approval was obtained. All patient information was completely stripped of identifiers and sent to the principal investigator in a secure fashion using file encryption and password protection.

Postoperative outcomes. Early outcomes of interest included in the analysis were the development of one or more postoperative complications, amputation, or death within 30 days of the index operation. Complications were reported by VA-NSQIP as a binary outcome within several defined categories, or detailed utilizing the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes. Complications were grouped into major cardiac, central nervous system, renal, respiratory, infectious, bleeding, and venous thromboembolic events. Emphasis was placed on any complication that required medical or surgical reintervention, represented organ system failure, and/or required transfer to an intensive care unit.

Late outcomes of interest were patient survival and limb salvage. Survival through one and two years after surgery was determined by accessing the VA Beneficiary Identification and Records Locator System (BIRLS) to obtain dates of death, if applicable, and cross-referencing these with the dates of operation for each patient. Similarly, limb loss was determined by searching NSQIP for all possible CPT codes describing lower extremity amputation in each patient through two years after the index operation for PAA.

Baseline patient demographic, comorbid, and operative characteristics. Thirty-three different risk factors were analyzed. Patient demographics included age, gender, and race. Clinical characteristics and co-morbidities included history of cerebrovascular accident (with and without neurologic deficit), transient ischemic attacks (TIA), congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), diabetes mellitus (none or diet-controlled vs. those requiring oral hypoglycemic agents or insulin), dyspnea at rest or with exertion, bleeding disorder, chronic dialysis requirement, acute preoperative renal failure, chronic steroid use, American Society of Anesthesiologists (ASA) classification, and presence of a do-not-resuscitate (DNR) order on the medical chart.

Preoperative functional status was defined by NSQIP as the level of self-care demonstrated in the 30 days prior to surgery, including activities of daily living such as bathing, feeding, dressing, toileting, and walking. Patients were considered independent if they did not require assistance of nursing care, equipment, or devices. "Partially dependent" patients required equipment or assistance from another person, like those needing home oxygen therapy or chronic dialysis. "Totally dependent" patients included intensive care unit or completely dependent nursing home patients.

Cigarette smoking history was recorded in terms of pack-years, and was considered current if the patient smoked within one year of the operation. Current alcohol abuse was defined as the consumption of more than two drinks per day over the two weeks before surgery.

Basic operative and anesthesia characteristics were recorded such as urgency of the case (elective vs. emergent), type of anesthesia used (general vs. regional), duration of the operation, and blood transfusion requirement within 48 hours prior to, during, or within 48 hours after surgery. Finally, preoperative lab values were also included on most patients, including serum albumin, hematocrit, white blood cell count, platelet count, prothrombin time, partial thromboplastin time, creatinine, sodium, and blood urea nitrogen.

Statistical analysis. Univariate analyses were performed considering each of the 33 included risk factors against early outcomes. Fisher's exact test or the chi-squared test was used for categorical variables and Student's t-test was used for continuous variables. All tests were two-tailed, and P values $< .05$ were considered significant.

A multivariate model was formulated using backward stepwise logistic regression, starting with all 33 variables, using consideration entry criterion of $P < .25$ and significance exit criterion of $P < .05$ for each primary 30-day outcome (one or more complication, amputation, and death). Forward stepwise logistic regression was also performed, and the same variables were identified as significant predictors, confirming the quality of the statistical data. Pseudo R-squared values and Hosmer-Lemeshow tests were examined to determine the "goodness-of-fit" of each model. Correlation matrices were created and examined in order to detect variable redundancy and avoid overfitting. Factor reduction would have been considered if any variable was found to be correlated to another at a level greater than 0.65, but in no case were any variables correlated at a level greater than 0.18.

Nominal variables with three or more options were converted to dichotomous variables in order to improve the

Table I. Demographic and risk-factor characteristics associated with 583 bypass operations performed at Veterans Affairs Medical Centers in the United States for popliteal artery aneurysms from January 1, 1994 to January 1, 2005

Characteristic	*Number*	*Percent*	*Characteristic*	*Number*	*Percent*	*Characteristic*	*Number*	*Percent*
Age			Dyspnea			DNR order on chart		
<60	136	23.3%	No dyspnea	455	78.0%	No	574	98.5%
61-69	165	28.3%	Minimal exertion	105	18.0%	Yes	3	0.5%
70-76	154	26.4%	Rest	15	2.6%	Chronic steroid use		
77+	128	22.0%	Diabetic status			No	564	96.7%
Gender			None/diet controlled	482	82.7%	Yes	19	3.3%
Male	582	99.8%	Yes, Oral meds	65	11.1%	Treatment year		
Female	1	0.2%	Yes, Insulin	30	5.1%	1994-1996	158	27.1%
Race			Pre-op dialysis			1997-1999	159	27.3%
Caucasian	449	77.0%	No	568	97.4%	2000-2002	90	15.4%
African-American	60	10.3%	Yes	8	1.4%	2002-2005	176	30.2%
Hispanic	22	3.8%	Acute renal failure			Anesthesia		
Asian + Other	37	6.3%	No	573	98.3%	General	413	70.8%
ASA classification			Yes	3	0.5%	Spinal	90	15.4%
ASA 1	3	0.5%	Hx bleeding disorder			Epidural	80	13.7%
ASA 2	68	11.7%	No	555	95.2%	Operative time		
ASA 3	434	74.4%	Yes	22	3.8%	<4 hrs	302	51.8%
ASA 4	78	13.4%	Pre-op transfusion			≥4 hrs	281	48.2%
Urgency of case			No (<4u)	577	99.0%	Intraoperative transfusion		
Elective	527	90.4%	Yes (>4u)	6	1.0%	0 units	519	89.0%
Emergent	56	9.6%	Alcohol abuse			1-2 units	38	6.5%
History of TIA			No	530	90.9%	>2 units	26	4.5%
No	549	94.2%	Yes	45	7.7%	Postoperative hemorrhage		
Yes	28	4.8%	Smoking status			No	575	98.6%
History of CVA			Current	224	38.4%	Yes	8	1.4%
No	515	88.3%	Pack yrs	50 [5-180]		Preop labs (Mean (SD))		
CVA, no deficit	28	4.8%	Ex-smokers	246	42.2%	Albumin (g/dl)	3.8 (0.5)	
CVA, w/deficit	34	5.8%	Pack yrs	50 [1-180]		BUN (mg/dl)	19 (9)	
CHF			Non-smoker	107	18.4%	Creatinine (mg/dl)	1.3 (1.2)	
No	564	96.7%	Pre-op functional status			Hematocrit	40.5 (5.7)	
Yes	19	3.3%	Independent	515	88.3%	Platelet (×1000/mm 3)	220 (72)	
COPD			Partially dependent	61	10.5%	PTT (s)	33.0 (10.7)	
No	469	80.4%	Totally dependent	7	1.2%	PT (s)	13.0 (1.8)	
Yes	114	19.6%				Sodium (mEq/L)	139 (3)	
						WBC (×1000/mm 3)	7.9 (3.7)	

ASA, American Society of Anesthesiologists; *BUN,* blood urea nitrogen; *CHF,* congestive heart failure; *COPD,* chronic obstructive pulmonary disease; *DNR,* do not resuscitate; *Hx,* history; *PT,* prothrombin time; *PTT,* partial thromboplastin time; *TIA,* transient ischemic attacks; *WBC,* white blood cell count.

sensitivity given the relatively small dataset. Using preoperative functional status as an example, only seven patients were "totally dependent" whereas 61 were "partially dependent": in this case the 68 were combined into "dependent" to compare against the 515 "independent" patients.

By study design, any categorical variable with missing values in greater than 3% would have been excluded, but this was not found in our dataset. Variable with missing data included race (2.6%), history of transient ischemic attacks (1.0%), history of cerebrovascular accident (1.0%), history of dyspnea (1.4%), diabetic status (1.0%), dialysis (1.2%), acute renal failure prior to surgery (1.2%), history of bleeding disorder (1.0%), alcohol use (1.4%), smoking status (1.0%), and DNR status (1.0%).

Continuous variables most commonly missing data were preoperative laboratory values, which were ordered at the physician's discretion.

Categorical indicator variables were created – and for missing laboratory data, mean values were imputed – in order to avoid losing patients in the multivariate model. These statistical alterations were minor, as complete case analysis was available in 93.0% of the patient set.

All statistical analyses were performed using the software package SPSS version 13.0 (SPSS, Inc., Chicago, Ill).

RESULTS

From January 1, 1994 to January 1, 2005, we identified 583 operations for PAA in 537 patients at 100 different institutions recorded in the VA-NSQIP database. Almost all (582, 99.8%) of the operations were in men, and the median age was 69 years (range, 34 to 92 years).

A complete description of demographics and risk factor distribution is outlined in Table I. Reflecting the overall health of the patient population, several key trends are noted. Most (88%) were considered ASA class 3 or 4, 81% were current or former cigarette smokers – with a median smoking history of 50 pack-years, and 12% demonstrated partial or complete functional dependence in performing activities of daily living. Only 16% were diabetic requiring

Table II. Incidence of post-operative complications and death as recorded in VA-NSQIP in 583 surgical bypasses for PAA

Complication	*Number*	*Percent*
Graft failure	26	4.5%
Wound dehiscence	12	2.1%
Unplanned post-operative reintubation	10	1.7%
Cardiac arrest requiring cardiopulmonary resuscitation	7	1.2%
Failure to wean from mechanical ventilatory support after 48 hours	7	1.2%
Hematoma, requiring surgical evacuation	6	1.0%
Sepsis	6	1.0%
Pseudoaneurysm	3	0.5%
Gastrointestinal hemorrhage	3	0.5%
Myocardial infarction	3	0.5%
Hydronephrosis	2	0.3%
Graft infection	1	0.2%
Compartment syndrome	1	0.2%
Heart failure	1	0.2%
Aspiration pneumonitis	1	0.2%
Seizure	1	0.2%
Embolic, thrombotic, or hemorrhagic vascular accident or stroke with deficits lasting > 24 hours	1	0.2%
Death	8	1.4%

Table III. Arterial-specific reinterventions performed within 30 days of surgical bypass for PAA, including amputation

Operation	*Number of cases*
Revision or other peripheral arterial bypass	15
Wound exploration, expanding hematoma	6
Amputation	6
Thrombectomy	5
Pseudoaneurysm repair	3
Lower extremity fasciotomy	1
Excision of infected graft	1

oral hypoglycemic medications or insulin therapy. About 10% were emergency cases.

Overall complication rate was 11.8% (69 of 583), with 37 (6.3%) requiring arterial-specific reintervention. The types and frequencies of serious complications are listed in Table II. The most common were graft failure (4.5%), wound dehiscence (2.1%), unplanned postoperative reintubation (1.7%), cardiac arrest (1.2%), failure to wean from mechanical ventilatory support after 48 hours (1.2%), sepsis (1.0%), and myocardial infarction (0.5%). The 37 arterial-specific reinterventions are listed in Table III, and include six amputations. Thirty-day operative mortality was 1.4% (eight deaths in 583 operations).

Risk factors associated with negative early outcomes are outlined in Table IV and Table V. On univariate analysis, those who experienced worse outcomes tended to be of African-American race, to undergo emergency operations, to be ASA class 4, to have dependent preoperative functional status, to be on chronic steroids, or to require an intraoperative red blood cell transfusion of any quantity (as little as one unit). Independent predictors for complications in the multivariate model were dependent functional status (adjusted OR 2.1 [1.1-4.3], $P = .049$) and intraoperative red blood cell transfusion (adjusted OR 4.5 [2.3-8.9], $P = .0002$). The need for any blood transfusion during the case and post-operative hemorrhage (more than four units of blood within 48 hours after surgery) were predictive of early amputation on univariate analysis. The rate of amputation increased from <1% (4/575) to 25% (2/8) when post-operative hemorrhage occurred, and this was found to be significant in the multivariate model (adjusted OR 25.5 [1.7-393], $P = .02$).

Unadjusted patient survival was 98.6% at 30 days, 92.6% at one year, and 86.1% at two years (Fig 1, *A*). Limb salvage in these time periods, calculated by observing survivors that remained amputation-free, was 99.0% at 30 days, 97.6% at one year, and 96.2% at two years (Fig 1, *B*). Cox regression analysis revealed that only preoperative functional status was predictive of any statistically significant difference in one-year and two-year limb salvage (Fig 2). Patients who were partially or completely dependent in performing their activities of daily living clearly did worse than those who were independent (adjusted OR 4.6 [1.9-10.9], $P = .001$). Despite the relative risk difference, absolute risk of limb loss after surgery was still low, with 2-year limb salvage in dependent patients at 88.2% (versus 97.1% in the independent patients).

DISCUSSION

Popliteal artery aneurysms are treated because of their poor natural history. Overall, in patients with PAA, limb-threatening ischemia has been documented to occur in 17-46% and rupture in 3%.[6,8,16-21] Limb loss from complications of PAA has been observed in as high as 67%.[7,22-25]

Some have suggested reserving operation for only those with symptoms who were deemed appropriate surgical candidates. A majority of patients (about two-thirds) with PAA will actually present with symptoms.[2,3] However, even a significant number of those initially asymptomatic will either develop symptoms at an appreciable rate per year or develop acute complications requiring emergent intervention.[8,11-13]

The few existing retrospective reviews that compare anticoagulation and expectant management versus surgical intervention tend to favor intervention. Dawson et al reviewed thirteen studies that included a total of 536 PAA managed conservatively, demonstrating that complication rates were 24% at one year and 68% at five years, with mean risk of ischemic complications of 36% (range, 8% to 100%).[3] Vargas et al described 58 patients that were initially followed expectantly based on perceived low-risk aneurysm factors and/or high-risk patient factors.[8] Median observed follow-up was 22 months. Of the 40 patients who did not die from other causes, almost half eventually needed surgical treatment.

We found that patients treated emergently had poorer outcomes than those treated electively. NSQIP defines

Table IV. Risk factors associated with increased operative morbidity and mortality when subject to statistical analysis

Clinical factor	*Reference*	*Odds ratio, 95% confidence interval*	*Adjusted odds ratio, 95% confidence interval*
African-American race	All other races	2.8 (1.5-5.2), $P = .002$	NS
Emergent case	Elective case	3.8 (2.0-7.0), $P < .0001$	NS
ASA class 4	ASA class 1-3	1.9 (1.1-3.5), $P = .04$	NS
Partially or totally dependent preoperative functional status	Independent	2.5 (1.4-4.7), $P = .004$	2.1 (1.1-4.3), $P = .049$
Chronic steroid use	No steroid use	3.2 (1.2-8.7), $P = .03$	NS
Any intraoperative transfusion (one unit of packed red bloods cells or more)	No intraoperative transfusion	6.3 (3.5-11.2), $P < .0001$	4.5 (2.3-8.9), $P = .0002$

Odds ratios are given for associations found on univariate analysis. Adjusted odds ratios represent associations significant in the multivariate model.

Table V. Risk factors associated with early amputation

Clinical factor	*Reference*	*Odds ratio, 95% confidence interval*	*Adjusted odds ratio, 95% confidence interval*
Any intraoperative transfusion (1 unit or more)	No intra-operative transfusion	7.2 (1.3-40.4), $P = .03$	NS
Postoperative hemorrhage requiring 4+ units in 72 hrs	0-3 units	47.6 (7.3-311), $P < .0001$	25.5 (1.7-393), $P = .02$

Though statistically significant, the wide ranges of the confidence intervals are reflective of the small sample size.

emergent cases as those performed within 12 hours after the patient is admitted to the hospital and deemed as such by both the involved surgeon and anesthesiologist. Aneurysms treated emergently were significantly more likely to require intraoperative transfusion ($P < .0001$), bleed postoperatively ($P < .0001$), experience early graft failure ($P = .007$), and die within 30 days ($P = .033$). Survivors after an emergent procedure were not necessarily at increased risk for amputation ($P = .106$).

The emergently-treated patients were more chronically ill: they had higher ASA class (OR 4.5 [2.4-8.3], $P < .0001$), poorer functional status (OR 3.3 [1.7-6.3], $P < .0001$), were more likely to have CHF (OR 3.6 [1.2-10.4], $P = .012$), and were more frequently dialysis-dependent (OR 3.6 [1.1-11.7], $P = .023$). Therefore, they may have already been considered to be of prohibitive risk for elective repair, managed expectantly, and already expected to do worse from an operation. This may explain why emergent status alone was not independently predictive in the multivariate model after adjusting for other factors, like functional status.

Preoperative functional status was found to be significantly predictive of morbidity, mortality, and limb salvage. However, it is important to realize that operative success remained robust. Partially-dependent patients required assistance from equipment and another person (eg, home oxygen or chronic dialysis) and totally-dependent patients could not perform any activities of daily living for themselves (including dependent nursing home or intensive care unit patients). Yet, in these groups limb preservation at two years was still almost 90%.

A minority (95 patients, 16%) of the subjects in our data set were diabetic; 65 requiring oral medications and 30 requiring insulin. This is similar to previous studies in which diabetes was only observed in 6%-17% of patients presenting with PAA.[6-8] Diabetes was specifically examined for any predictive value for each outcome of interest, but none were found (complications $P = .954$, amputation $P = .790$, and death $P = .633$).

The most common post-operative complications other than graft failure were cardiopulmonary or related to the surgical wound (Table II). The need for even one unit of intraoperative packed red blood cell transfusion greatly increased these risks, and bleeding within 48 hours after surgery was the single most predictive factor of early amputation. This relationship between transfusion requirement and poorer outcomes has been observed in other studies, including a review of percutaneous coronary interventions.[26] Yatskar et al examined patients who developed post-procedural access site hematomas. They demonstrated that mortality was independently predicted by transfusion requirement (AOR 3.6), even after adjusting for other significant factors such as older age, body mass index, female sex, and coexisting renal, cerebrovascular, peripheral vascular, and pulmonary disease.

Although our data did not show a statistically significant difference in outcomes based on the use of general versus regional anesthesia, this was probably due to the relatively limited sample size. A previous review of almost 15,000 infrainguinal lower extremity arterial bypasses demonstrated that postoperative complications and graft failure were reduced with the use of regional anesthetic.[27] The mechanisms were speculated to be transient sympathetic blockade (with reduction of flow-limiting vasoconstriction agents), modulated systemic surgical stress response, and reduction of perioperative hypercoagulability. While a sim-

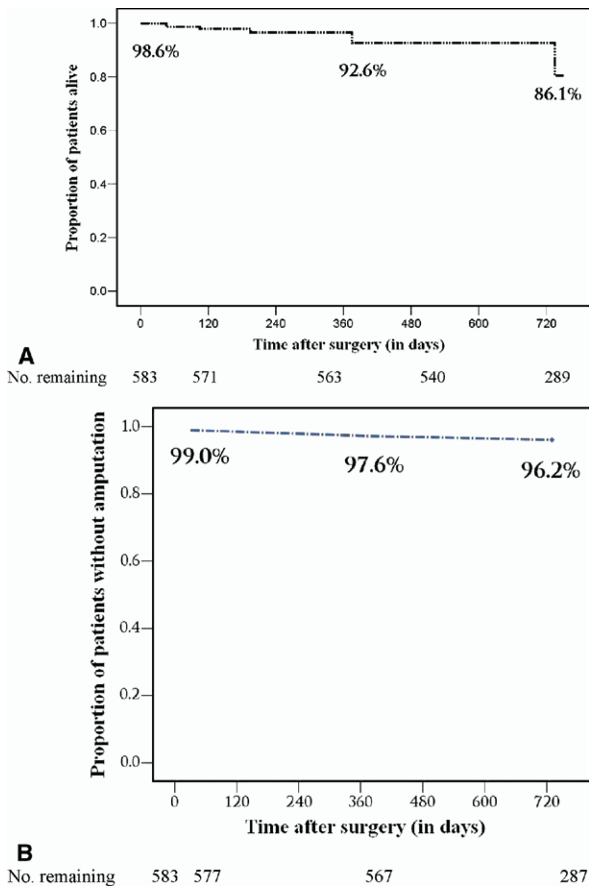

Fig 1. A, Life-table plot of unadjusted patient survival through two years after surgical bypass for PAA. **B**, Life-table plot of limb salvage in surviving patients through two years after surgical bypass for PAA.

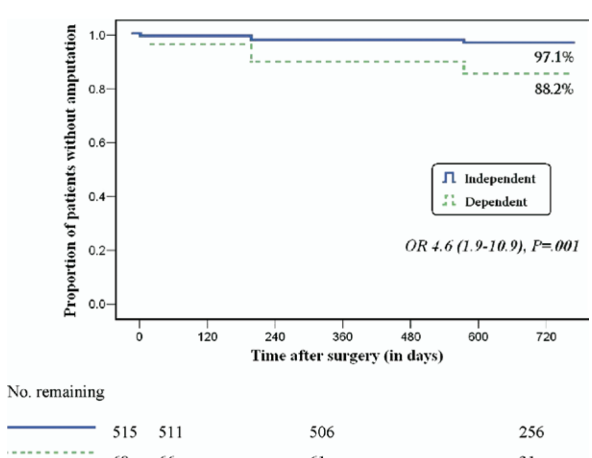

Fig 2. Cox regression analysis plot of adjusted limb salvage, by preoperative functional status, through two years after surgical bypass for PAA.

ilar approach may provide similar results when performing bypass for PAA, this was not detected in this study.

This review has inherent limitations despite the straightforward methodology. VA-NSQIP is not a vascular registry, so technical details regarding each individual case could not be analyzed or compared with existing studies. Thus, data such as the size of each aneurysm, surgical approach (posterior vs. medial), graft material (synthetic vs. autologous vein), runoff vessel characteristics, use of thrombolytics, and tibial reconstruction could not be analyzed. Although CPT coding can identify laterality with modifiers for "right" and "left," these were used inconsistently. We therefore assumed that all amputations were performed on the ipsilateral limb, giving a "worse-case scenario" analysis. Any that were, in reality, performed for the contralateral limb would only decrease the amputation rate. Given that, despite this assumption, limb salvage was still 96.2% at two years, any small increase would not significantly alter the conclusion that limb preservation after surgery is high.

Endovascular intervention is a potential method to achieve the same goals as surgical bypass while avoiding an operation in the high-risk patient. We could not analyze endovascularly repaired aneurysms (either as primary or secondary therapy), thrombolysis (either preoperatively to convert an urgent case into a delayed elective one or intraoperatively to clear distal runoff), or expectant management of PAA. Given that the entity is relatively rare, and that surgical management is considered definitive therapy, we aimed to identify any patient-related or procedure-related risk factors that, if taken into consideration, would optimize outcomes.

In conclusion, our data strongly suggest that even in high-risk patients with multiple co-morbidities and dependent functional status, surgical therapy for PAA can be performed with acceptable perioperative morbidity, low operative mortality, and excellent two-year limb salvage. The data suggest that paying particular attention to minimizing blood loss during and after operation is the most predictive (and potentially alterable) factor that can maximize the chance for good early outcomes.

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AUTHOR CONTRIBUTIONS

Conception and design: OJ, MS, RM, BF, AS
Analysis and interpretation: OJ, MS, RM, RA, AS
Data collection: OJ, MS, RM, BF, AS
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