Outcomes for popliteal artery injury repair after discharge: A large-scale population-based analysis

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BACKGROUND: Although short-term outcomes for popliteal artery injury after endovascular versus open repair appear similar, studies on outcomes after discharge are limited. We evaluated popliteal artery injury repair in a population-based data set. We hypothesized that postdischarge outcomes for open repair are superior to endovascular repair.

METHODS: Patients with popliteal artery injury were identified in the California Office of Statewide Health Planning and Development 2007–2014 discharge database. Popliteal artery injury and other lower-extremity injuries were identified using *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnosis codes. Procedure codes were evaluated to identify open repair, endovascular repair, fasciotomy, and amputation. Primary outcomes were mortality or amputation. The association between repair method and each outcome was evaluated with logistic regression. Postdischarge amputation and all-cause mortality were evaluated using survival analysis.

RESULTS: Among 769 patients with popliteal artery injury, open repair occurred in 456 (59.3%), endovascular repair in 37 (4.3%), combined endovascular and open in 18 (2.3%), and nonoperative management in 258 (33.6%). Fasciotomy was performed more frequently in open than endovascular repair ($p = 0.001$) during index admission. Amputation rate was also increased in open repair, but this was not significant ($p = 0.196$). Arterial thromboembolus during index admission was more likely after endovascular or combined endovascular and open compared with open (24.3%, 55.6%, 16.7%, respectively, $p < 0.001$). Patients requiring both endovascular and open were more likely to undergo amputation postdischarge (hazard ratio, 4.11; 95% confidence interval, 1.16–14.53). Patients undergoing endovascular repair were more likely to die postdischarge (hazard ratio, 4.43; 95% confidence interval, 1.06–18.56) compared with patients who had open repair (median, 98.5 days postdischarge).

CONCLUSIONS: In a large cohort with popliteal artery injury, open repair was associated with lower rates of index admission arterial thromboembolus as well as postdischarge amputation and all-cause mortality. We recommend conducting a prospective multicenter study to examine the appropriate use of endovascular repair for this injury. (*J Trauma Acute Care Surg.* 2019;86: 173–180. Copyright © 2018 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Therapeutic, level IV.

KEY WORDS: Popliteal artery injury; endovascular repair; open repair; amputation; mortality.

Injury to the popliteal artery, although infrequent, carries a high risk of limb loss if not rapidly identified and managed appropriately.[1,2] These injuries have traditionally been managed with open repair. The widespread use of endovascular techniques in elective vascular surgery has led to a decline in experience with open vascular exposure among surgeons.[3] The use of endovascular repair for trauma is also increasing.[4] Although studies demonstrate similar outcomes for endovascular and open repair, most are case reports, small series, or only report on outcomes during the index admission.[4–7] Data on long-term outcomes in larger populations are lacking. Comparison of outcomes beyond the index hospitalization is needed to determine if endovascular repair is a safe alternative to open repair of popliteal artery injury.

We evaluated trends and outcomes in the use of open and endovascular repair for patients with popliteal artery injury using a large statewide database. We hypothesized that postdischarge outcomes for open repair are superior to those for endovascular repair.

METHODS

We conducted a historical cohort study of adult trauma patients hospitalized in California between January 1, 2007, and December 31, 2014. Institutional review board approval was obtained from the California Health and Human Services Agency Committee for the Protection of Human Subjects and the Scripps Institutional Review Board. Study data originated from the California Office of Statewide Health Planning and Development patient discharge database that contains patient records from all licensed nonfederal California hospitals. Data included unique record linkage numbers, demographics, admission factors, discharge disposition, and *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnosis and procedure codes.

Patients aged 18 years and older at admission and who had an *ICD-9-CM* diagnosis code for popliteal arterial injury (904.4, 904.40, 904.41) were included and composed the primary data set for the analysis of index outcomes. For each patient, the index admission was defined as the first admission containing a popliteal arterial injury diagnosis code. Patients who lacked a valid record linkage number were excluded from the analysis of postdischarge factors and outcomes. The record linkage number is a unique patient identifier based on encryption of the social security number that allows for the identification of subsequent admissions to any hospital in the Office of Statewide Health Planning and Development data set.

Popliteal artery repair during the index admission was categorized as either open repair only, endovascular repair only, both open and endovascular repair, or nonoperative. Open repair was coded using the following procedure codes: 38.08, 38.38, 38.48, 38.68, 38.88, 38.09, 38.39, 38.49, 38.69, 38.89, 38.00, 38.30, 38.40, 38.60, 38.80, 39.30, 39.31, 39.32, 39.56, 39.57, and 38.58. Endovascular repair was identified with the following codes: 39.7, 39.90, and 39.79. Patients without any of the abovementioned procedure codes were categorized as nonoperative. Other procedures evaluated were fasciotomy (procedure code 83.14).

The primary outcome of interest was amputation, defined using diagnosis codes for lower-extremity amputation (V49.7, V49.70, V49.75, V49.76) and procedure codes for amputation of the lower limb (84.1, 84.10, 84.15, 84.16, 84.17, 84.91). Amputation was first evaluated during the index admission. Nonamputees of the index admission were evaluated for

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amputation during a subsequent admission. For postdischarge amputation, follow-up time was calculated as the difference between the date of the subsequent admission and index discharge date. All-cause mortality, length of stay, and hospital charges were evaluated as secondary outcomes. Hospital charges were adjusted for inflation to 2014-based values using Personal Consumption Expenditures from the Bureau of Economic Analysis, National Income and Product Accounts Tables.

Concomitant injuries included lower-extremity fractures, nerve damage, and other vascular conditions and injuries. For the purpose of this study, concomitant injuries were defined as only those closely associated with popliteal artery injury. Nerve damage was identified for the femoral nerve (diagnosis code 956.1), tibial nerve (diagnosis code 956.2), peroneal nerve (diagnosis code 956.3), and pelvic girdle nerves (diagnosis codes 956.5, 956.8, and 956.9). Fractures assessed included tibial fracture (diagnosis codes 823.80, 823.82, 823.92, 824.8, 824.9, 824.0, 824.1, 733.16, 823.20, 823.22, 823.32, 823.30, 823.40, 823.42, 823.02, 823.12, and 823.10), fibula fracture (diagnosis codes 823.81, 823.82, 823.92, 824.8, 824.9, 824.2, 824.3, 824.8, 824.9, 733.16, 823.41, 823.22, 823.32, 823.31, 823.01, 823.02, 823.12, and 823.11), and distal femur fracture (diagnosis codes 821). Other vascular conditions included embolism or thrombosis of the lower-extremity (diagnosis code 444.22), popliteal venous injury (diagnosis code 904.42), femoral vein injury (diagnosis code 904.2), and saphenous vein injury (diagnosis code 904.3). Repair-related complications evaluated included failure of the graft (diagnosis codes 966.1, 966.62, and 966.74) and reattachment failure (diagnosis codes 866.90, 866.95, and 966.96).

Other variables evaluated included age at admission, admission year, length of stay, charges for related hospitalizations, and characteristics of the admitting hospital including unique code, type, county, trauma center level, and United States zip code. Admitting hospitals were classified as a level I trauma center, level II trauma center, or other. The Trauma Mortality Prediction Model probability of mortality and New Injury Severity Score (NISS) derived by converting relevant *ICD-9-CM* codes to the Abbreviated Injury Scale score were calculated to assess injury severity.[8] The NISS was developed to overcome a weakness of the Injury Severity Score by taking the three highest scores regardless of anatomic area. It has demonstrated better predictive ability than the Injury Severity Score and provides broad availability for outcome analysis across hospitals of varying size.[9] Other variables identified through this process included mechanism of injury (blunt, penetrating, or other).

Annual trend analysis over the study period was performed using the Cochran-Armitage nonparametric test of trend for categorical variables and linear regression for continuous variables. Patient characteristics, clinical factors, and outcomes during the index admission were evaluated by surgical intervention type using χ^2 tests, analysis of variance, or Kruskal-Wallis tests, as appropriate. These statistical methods were also used to evaluate differences by trauma center classification. Heterogeneity of popliteal artery repair type across centers was evaluated using 2-level logistic regression for index admission amputation and the shared frailty survival model for postdischarge amputation. There was no significant heterogeneity in operative intervention type across centers in either model.

TABLE 1. Time Trends Based on Year of Index Admission

	2007	2008	2009	2010	2011	2012	2013	2014	Trend *p* Value
Sample size, n	97	101	107	92	80	97	99	96	
Age, mean (SD), y	37.5 (16.5)	39.5 (17.0)	39.6 (14.6)	38.9 (17.4)	36.6 (14.7)	38.8 (17.4)	39.9 (15.8)	37.8 (18.2)	0.560
Surgical method, %									0.377
Open	63.9	53.5	60.8	68.5	55.0	60.8	59.6	52.1	
Endovascular	4.1	6.9	2.8	7.6	3.7	3.1	7.1	3.1	
Both	3.1	2.0	0.9	0.0	1.3	2.1	2.0	7.3	
Nonoperative	28.9	37.6	35.5	23.9	40.0	34.0	31.3	37.5	
Level I trauma center admissions, %	26.8	32.7	35.5	33.7	38.8	28.9	25.3	37.5	0.752
Mechanism of injury, %									0.403
Blunt	47.4	54.5	48.6	53.3	61.3	48.5	54.6	43.8	
Penetrating	27.8	30.7	39.3	28.3	23.8	30.9	26.3	31.3	
Other/unknown	24.7	14.9	12.2	18.5	15.0	20.6	19.2	25.0	
NISS, median (IQR)	9 (4–13)	5 (4–10)	9 (4–10)	9 (4–17)	8.5 (4–9)	5 (4–10)	9 (4–10)	8 (4–10)	0.681
In-hospital death, %	2.1	3.0	1.9	2.2	3.8	4.1	3.0	0.0	0.777
Amputation, %	15.5	5.9	5.6	14.1	7.5	10.3	11.1	11.5	0.837
Postdischarge amputation,* %	10.2	20.0	13.0	12.5	13.2	10.7	4.7	9.5	0.178
Postdischarge all-cause mortality,* %	10.2	2.0	7.4	5.0	0.0	7.1	2.3	0.0	0.257
Index admission charge in thousands, median (IQR)	197.4 (96.8–396.0)	159.9 (84.5–292.8)	221.2 (117.3–386.7)	236.8 (123.2–469.7)	276.3 (120.9–468.7)	229.8 (139.4–426.8)	243.7 (136.2–524.0)	218.8 (116.9–426.8)	0.017

*Performed among patients with valid record linkage number.
Both, patients having endovascular and open popliteal artery repair during the index admission.

Thus, we elected to use logistic regression to calculate the adjusted association between surgical intervention and odds for amputation during the index admission. Among patients with a valid record linkage number, Cox proportional hazards models were developed to evaluate the adjusted association between index surgical intervention and risk for an eventual amputation. This analysis was only performed among patients who did not have an amputation during the index admission. Follow-up time was calculated from the index date of discharge to subsequent date of admission. Backwards stepwise methods were used to select covariates for adjustment. A p value of <0.050 was considered statistically significant. Data were managed and analyzed using Stata MP version 13.1 (StataCorp LP, College Station, TX).

RESULTS

We identified 769 patients with popliteal artery injury. Over the study period, there were no patient trends identified in mean age, surgical repair method, level I trauma center admission, mechanism of injury, or median NISS (Table 1). There were likewise no trends in either index or postdischarge clinical outcomes.

Demographic data, clinical characteristics, and study outcomes by surgical repair category are shown in Table 2. One third of injuries were treated nonoperatively. Primary open repair was performed 8 times more frequently than endovascular approaches. Patients who had only endovascular repair were

TABLE 2. Characteristics by Index Surgical Repair Category

Variable	Open Repair Only	Endovascular Repair Only	Both Surgical Methods	Nonoperative	*p*
Sample size, n (%)	456 (59.3)	37 (4.3)	18 (2.3)	258 (33.6)	
Index characteristics					
Age, mean (SD), y	36.3 (15.8)	50.9 (20.4)†	37.7 (16.4)	39.4 (16.1)†	<0.001
Male sex, %	84.9	59.5†	61.1†	76.7†	<0.001
NISS, median (IQR)	13 (9–17)	9 (4–22)†	17 (9–22)†	12 (8–22)	0.029
Mechanism of injury, %		†		†	<0.001
Blunt	43.9	46.0	55.6	64.7	
Penetrating	40.1	18.9	22.2	14.3	
Other/unknown	16.0	35.1	22.2	21.0	
Total vascular surgeries, median (IQR)	1 (1–2)	1 (1–1)†	2 (2–3)†	0†	0.001
Trauma center level, %		†		†	<0.001
I	32.7	13.5	16.7	35.3	
II	54.0	43.2	72.2	37.6	
Other	13.4	43.2	11.1	27.1	
Arterial thromboembolus, %	16.7	24.3	55.6†	12.4	<0.001
Fasciotomy, %	40.8	18.9†	50.0	28.3†	0.001
Index outcomes					
Amputation, %	10.5	2.7	0.0	11.2	0.196
In-hospital death, %	1.8	0.0	5.6	3.9	0.192
Length of stay, median (IQR), d	12.5 (6–23)	7 (4–15)†	12.5 (6–30)	10 (5–21)	0.008
Hospital charges in thousands, median (IQR)	237.9 (125.7–402.8)	195.0 (106.9–426.8)	476.3 (197.9–688.7)†	194.0 (85.5–417.4)†	0.009
Concomitant conditions					
Popliteal vein injury, %	28.5	2.7†	16.7	6.6†	<0.001
Femoral vein injury, %	4.6	0.0	0.0	0.0†	0.002
Saphenous vein injury, %	2.0	5.4	0.0	0.4	0.083
Femoral nerve injury, %	0.2	0.0	11.1†	0.0	<0.001
Tibial nerve injury, %	2.9	0.0	0.0	2.7	0.661
Peroneal nerve injury, %	5.9	5.4	11.1	7.0	0.789
Pelvic girdle nerve injury, %	4.4	0.0	0.0	5.4	0.367
Tibia fracture, %	27.4	21.6	22.2	38.0†	0.013
Fibula fracture, %	20.0	16.2	27.8	38.0†	<0.001
Distal femur fracture, %	23.7	18.9	50.0†	21.3	0.042
Postdischarge features*					
Postdischarge sample size, n	206	20	10	125	
Amputation, %	10.4	21.1	30.0	11.6	0.175
All-cause mortality, %	2.4	15.0†	0.0	6.4	0.032
Follow-up time to amputation, median (IQR)	132.5 (17–804)	402 (58–998)	81.5 (0.5–202)	224 (25.5–705)	0.195
Follow-up time to death, median (IQR)	188.5 (16–895)	476 (188.5–1299)	98.5 (0.5–238)	245 (27–740)	0.110
Hospital charges in thousands, median (IQR)	245.1 (124.5–457.2)	356.0 (168.6–502.1)	445.4 (181.5–881.7)	189.8 (92.4–444.0)	0.050

*Performed among patients with valid record linkage number.
†Denotes pairwise difference compared to open repair only group.

significantly older, more likely to be female, and more likely to be admitted to a non–level I trauma center. They were also less likely to undergo fasciotomy and had shorter median length of stay than other repair types. Patients who had a combination of open and endovascular repair were more likely to be admitted to level II centers and undergo fasciotomy. This group also had the highest median hospital charges. Patients having endovascular or combined endovascular and open procedures experienced significantly higher rates of arterial thromboembolus.

In the multivariable analysis, tibial nerve injury and fibula fracture were identified as independent variables affecting risk of index admission amputation (Table 3). The area under the receiver operating characteristic curve for the logistic regression model was 0.650 (95% confidence interval, 0.589–0.711). Tibial nerve injury, tibia fracture, distal femur fracture, and age at admission were identified as independent variables affecting risk of postdischarge amputation. There were no significant differences in index admission amputation between repair types. In contrast, undergoing both surgical repair types was highly associated with amputation after discharge compared with open repair (Fig. 1).

Among survivors of the index admission, there were 16 (4.4%) postdischarge deaths. Median follow-up times were 525 days (interquartile range [IQR], 194–1103) among patients who died and 210 days (IQR, 22–878) among those who did not die. Survival analysis by index surgical method revealed that endovascular repair patients carried over 4 times the risk for death after discharge compared with open repair patients (unadjusted hazard ratio, 4.43; 95% confidence interval, 1.06–18.56; $p = 0.042$; data not shown). Adjusted estimates of risk could not be calculated owing to the low event rate.

The analysis of variables by hospital classification yielded significant differences among patient characteristics and outcomes (Table 4). Patients admitted to a level I trauma center were more likely to undergo an amputation during the index admission. Patients admitted to other centers were older, less likely to be male, less severely injured, had a shorter length of stay, and had the lowest median hospital charges. Although these patients had a slightly higher rate of arterial thromboembolism, this did not achieve statistical significance. There were no differences detected among any postdischarge outcome by hospital classification.

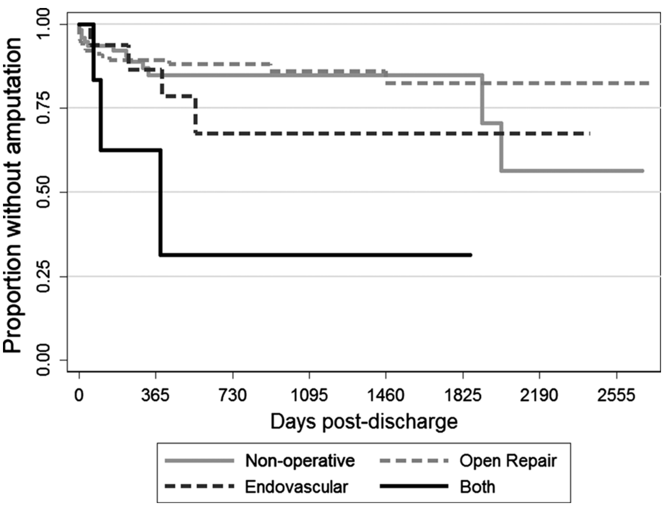

Figure 1. Survival curves for time to postdischarge amputation by index intervention. Patients who had both endovascular repair and open repair were more likely to have an eventual amputation postdischarge.

DISCUSSION

We hypothesized that postdischarge outcomes for open repair are superior to postdischarge outcomes for endovascular repair. Our study identified popliteal artery injury in 769 patients with median follow-up of 98 days, using a large statewide database. Postdischarge rates of arterial thromboembolism and mortality were higher in patients who underwent endovascular repair at the index admission. In addition, patients who had both endovascular and open repair had a much higher risk of postdischarge amputation. Open repair that followed endovascular repair was performed either promptly after the initial procedure or within a few days. This suggests that this group may have undergone a failed attempt at endovascular repair, although the design of our database precluded us from fully elucidating this. Compared with the open repair group, the endovascular repair group trended

TABLE 3. Adjusted Associations Between Surgical Intervention, Concomitant Injuries, and Amputation

	Index Admission Amputation			Postdischarge Amputation		
Variable	**Odds Ratio**	**95% CI**	***p***	**Hazard Ratio**	**95% CI**	***p***
Surgical intervention						
Open	1.00	—	—	1.00	—	—
Endovascular	0.25	0.04–1.91	0.183	1.20	0.38–3.78	0.759
Both	—	—	—	4.11	1.16–14.53	0.028
Nonoperative	0.90	0.54–1.49	0.683	1.16	0.56–2.38	0.704
Tibial nerve injury	3.00	1.04–8.66	0.042	5.59	1.54–20.30	0.009
Tibia fracture	—	—	—	2.09	1.07–4.09	0.031
Fibula fracture	2.49	1.52–4.09	<0.001	—	—	—
Distal femur fracture	—	—	—	1.50	1.06–2.11	0.021
Age at admission	—	—	—	1.03	1.01–1.05	0.010

Both, patients having endovascular and open popliteal artery repair during the index admission.

TABLE 4. Characteristics and Outcomes by Index Hospital Classification

	Level I Trauma Center	Level II Trauma Center	Other Center	*p*
Sample size, n	248	372	149	
Index characteristics				
Age, mean (SD), y	38.5 (16.9)	36.1 (14.5)	44.9 (18.7)†	<0.001
Male sex, %	81.9	86.8	61.7†	<0.001
NISS, median (IQR)	17 (12–22)	17 (12–22)	8 (5–12)†	<0.001
Arterial thromboembolus, %	12.5	17.2	21.5†	0.058
Fasciotomy, %	37.9	42.2	16.1†	<0.001
Index outcomes				
Amputation, %	13.3	10.5	4.0†	0.012
In-hospital death, %	3.2	3.0	0.0†	0.094
Length of stay, median (IQR), d	12 (6–23.5)	13 (6–25)	7 (4–13)†	<0.001
Hospital charges in thousands, median (IQR)	276.6 (143.0–483.4)	248.1 (144.2–485.1)	94.7 (0–195.0)†	<0.001
Postdischarge features*				
Postdischarge sample size, n	113	169	79	
Amputation, %	12.0	13.4	9.5	0.693
All-cause mortality, %	4.4	2.4	8.9	0.069

*Performed among patients with valid record linkage number.
†Denotes pairwise difference compared with level I trauma center.

toward an increased risk of postdischarge amputation, but this did not reach statistical significance.

When evaluating risk for postdischarge amputation, we considered factors known to increase risk of amputation.[10] In our data set, tibial nerve injury, tibia fracture, and distal femur fracture were associated with significantly higher risk of postdischarge amputation. There were no tibial nerve injuries in the endovascular or combined endovascular and open repair groups, and the rate of tibia fracture was lower in both of these groups when compared to the open repair group. We also controlled for presence of distal femur fractures, which were most common among patients who had both repair types performed. Patients who underwent endovascular repair were older than patients who received open repair, they also had lower calculated NISS (endovascular, 9; open, 13). Together, this suggests that the association of postdischarge amputation with failed endovascular repair may be even stronger.

Previous data on the management of popliteal artery injury suggest that outcomes for endovascular and open repair are largely similar during the index admission. A retrospective study using the National Trauma Database (NTDB) found an increasing trend in the use of endovascular repair from 2002 (1%) to 2010 (8%). The comparison of outcomes for open repair and endovascular repair revealed no significant differences in amputation rate (endovascular, 13.4%; open, 19.1%; $p = 0.25$), mortality (endovascular, 2.9%; open, 2.0%; $p = 0.6$), and days of hospital stay (endovascular, 15.4; open, 17.7; $p = 0.27$).[4] Because of limitations of the NTDB, this study only evaluated outcomes in the immediate perioperative period. Other studies on stent use in the superficial femoral and popliteal arteries, sites likely to experience repeated stress leading to fracture and in-stent stenosis, demonstrated a stent failure rate of up to 22% within 1 year.[11–18] This suggests that the evaluation of popliteal artery stent use beyond the immediate perioperative period is necessary to determine if outcomes in trauma patients are comparable.

We also compared outcomes for level 1 trauma centers to all other centers. Although postdischarge amputation rates were higher at non–level 1 centers, this did not reach statistical significance. Interestingly, endovascular repair occurred more often at non–level 1 centers, consistent with the results of the 2016 NTDB study.[4] Our study was not designed to determine the reason underlying this difference; however, it may be the result of a combination of factors. First, in our study, popliteal artery injury presented much less often to non–level 1 centers. Trauma surgeons at these centers may have been less comfortable with open popliteal exposure and more likely to refer to vascular surgeons. Second, experience with open vascular procedures is decreasing in vascular surgery training.[3] This may result in a bias among surgeons favoring endovascular over open repairs for the management of popliteal artery injuries.

During the index hospitalization, patients in our study who underwent endovascular repair had a shorter median length of stay and lower hospital charges compared with open repair. The inflation-adjusted median charges at level I and level II trauma centers did not vary. Other centers, on the other hand, had the lowest median charges. This may be because of patients in this group having the shortest lengths of stay and lowest injury severity compared with patients admitted to level I or level II trauma centers. In addition, 47% of patients admitted to other centers were initially managed nonsurgically and likely transferred upon stabilization to level I or II trauma centers for their vascular repair.

There are limitations to our study. The administrative nature of our patient discharge database, which relied on the *ICD-9-CM* coding system, barred us from fully describing the circumstances of each admission or specific patient details such as vital signs, laboratory data, specific cause of mortality, extent of popliteal artery injury, or extremity ischemia time. Second, this database did not allow us to analyze surgeon experience, facility capability, or other factors that may have contributed to the decision to perform endovascular or open repair. Third, we were unable to identify specific cause of death because of limitations of the database. Fourth, we found no statistical difference in index amputation rates by surgical repair type despite a 7.8% rate difference. Although other studies found no difference in amputation rates by surgical repair type, in our study, this may have been because of the relatively low sample size of patients who underwent endovascular repair only. In addition, while our data set included all licensed nonfederal hospitals in the state of California, we were unable to evaluate patients who received treatment and then left the state or those who received care at federal or unlicensed facilities. We nonetheless expect that this number was low within the analyzed follow-up time. Lastly, postdischarge outcomes were only reported on approximately 50% of each group. It is reasonable to assume that most patients without information on postdischarge outcomes did not require further care. Thus, no additional records were available for matching.

In conclusion, open repair was associated with lower rates of arterial thromboembolus during the index admission and both amputation and all-cause mortality after discharge in this study of a large cohort with popliteal artery injury. Our results underscore the need for a prospective multicenter study to examine the appropriate role for endovascular repair in the management of this injury.

AUTHORSHIP

W.J.B conducted the literature search. W.J.B, R.Y.C, J.M.B, L.E.W, C.B.S., V. B., and M.J.S designed the study. W.J.B and R.Y.C acquired and analyzed the data. W.J.B, R.Y.C, J.M.B, L.E.W, C.B.S., V.B., and M.J.S participated in drafting the article and critically revising it. All authors approved the final version of the article.

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Debakey ME, Simeone FA. Battle injuries of the arteries in World War II; an analysis of 2,471 cases. *Ann Surg*. 1946;123:534–579.
2. Gupta R, Quinn P, Rao S, Sleunarine K. Popliteal artery trauma. A critical appraisal of an uncommon injury. *Injury.* 2001;32(5):357–361.
3. Duran C, Bismuth J, Mitchell E. A nationwide survey of vascular surgery trainees reveals trends in operative experience, confidence, and attitudes about simulation. *J Vasc Surg*. 2013;58(2):524–528.
4. Tan TW, Armstrong FD, Zhang WW. Review of surgical treatment of popliteal artery injury: outcomes of open vs endovascular repair. *Vasc Dis Manag*. 2016;13(8):176–182.
5. Luh J, Choi L, Cheng CC, Cheema ZF, Silva MB Jr. Endovascular repair of blunt popliteal artery injury via retrograde tibial access. *J Vasc Surg*. 2012;56(6):1819.
6. Hutto JD, Reed AB. Endovascular repair of an acute blunt popliteal artery injury. *J Vasc Surg*. 2007;45(1):188–190.
7. Brandt MM, Kazanjian S, Wahl WL. The utility of endovascular stents in the treatment of blunt arterial injuries. *J Trauma*. 2001;51(5):901–905.
8. Sacco WJ, MacKenzie EJ, Champion HR, Davis EG, Buckman RF. Comparison of alternative methods for assessing injury severity based on anatomic descriptors. *J Trauma*. 1999;47(3):441–446; discussion 446–447.
9. Osler T, Baker SP, Long W. A modification of the injury severity score that both improves accuracy and simplifies scoring. *J Trauma*. 1997;43(6): 922–925.
10. Mullenix PS, Steele SR, Andersen CA, Starnes BW, Salim A, Martin MJ. Limb salvage and outcomes among patients with traumatic popliteal vascular injury: an analysis of the National Trauma Data Bank. *J Vasc Surg*. 2006; 44(1):94–100.
11. Allie DE, Herbert CJ, Walker CM. Nitinol stent fractures in the SFA: the biomechanical forces exerted on the SFA provide a "stiff" challenge to endovascular stenting. *Endovasc Today.* 2004;22–34.
12. Berry JL, Manoach E, Mekkaoui C, Rolland PH, Moore JE Jr., Rachev A. Hemodynamics and wall mechanics of a compliance matching stent: in vitro and in vivo analysis. *J Vasc Interv Radiol*. 2002;13(1):97–105.
13. Duda SH, Bosiers M, Lammer J, Scheinert D, Zeller T, Oliva V, Tielbeek A, Anderson J, Wiesinger B, Tepe G, et al. Drug-eluting and bare nitinol stents for the treatment of atherosclerotic lesions in the superficial femoral artery: long-term results from the SIROCCO trial. *J Endovasc Ther*. 2006;13(6): 701–710.
14. Krankenberg H, Schlüter M, Steinkamp HJ, Bürgelin K, Scheinert D, Schulte KL, Minar E, Peeters P, Bosiers M, Tepe G, et al. Nitinol stent implantation versus percutaneous transluminal angioplasty in superficial femoral artery lesions up to 10 cm in length: the femoral artery stenting trial (FAST). *Circulation*. 2007;116(3):285–292.
15. Geraghty PJ, Mewissen MW, Jaff MR, Ansel GM; VIBRANT Investigators. Three-year results of the VIBRANT trial of VIABAHN endoprosthesis versus bare nitinol stent implantation for complex superficial femoral artery occlusive disease. *J Vasc Surg*. 2013;58(2):386–395.e4.
16. Rachev A, Manoach E, Berry J, Moore JE Jr. A model of stress-induced geometrical remodeling of vessel segments adjacent to stents and artery/graft anastomoses. *J Theor Biol*. 2000;206(3):429–443.
17. Sabeti S, Mlekusch W, Amighi J, Minar E, Schillinger M. Primary patency of long-segment self-expanding nitinol stents in the femoropopliteal arteries. *J Endovasc Ther*. 2005;12(1):6–12.
18. Schillinger M, Sabeti S, Loewe C, Dick P, Amighi J, Mlekusch W, Schlager O, Cejna M, Lammer J, Minar E. Balloon angioplasty versus implantation of nitinol stents in the superficial femoral artery. *N Engl J Med*. 2006;354(18):1879–1888.

DISCUSSION

Dr. David V. Feliciano (Edgewater, Maryland): This was an eight-year review of a California administrative patient discharge data base on 769 patients, or 96 patients per year in the state, with injuries to the popliteal artery. Half of these were blunt injuries, and 38 per cent were penetrating. And, there was an interesting category of 19 per cent unknown or other. The data base was limited as there was no information on patient admission physiology, vascular signs or symptoms on admission, extent of injury to the popliteal artery, rationale for fasciotomy, reason for later amputation, and cause of in-hospital or post-hospital discharge deaths.

The authors have compared the results of open versus endovascular repair with a side category of combined repair. As Dr. Butler said, this comparison is compromised by the significant difference in NISS scores between the groups, especially with regard to the significantly higher incidence of associated injuries to the popliteal vein, femoral vein, distal femur, and tibia in the open group.

I have the following four questions: First, is this really the best data base to perform such a comparison? Or should you just have gone to the NTDB or PROOVIT? PROOVIT, in particular, would allow for a similar but more comprehensive retrospective, multicenter review. Second, as I understand your manuscript and presentation, there was an extraordinary 24 percent rate of thromboembolic complications in the endovascular group. Do you attribute this to the fact that endovascular repair was just starting in California in 2007 when you initiated the review of the discharge data base? Is there a possibility that surgeons with limited training in endovascular surgery started to insert stents? Or, frankly, is this the first warning that a metal stent should not be placed in the popliteal artery of a 36 year old man after trauma. Third, one of your most worrisome findings was that patients who needed an endovascular repair followed by an open repair for salvage managed to accrue a hospital bill approaching $450,000. Shouldn't these data be submitted to all the Level I and II centers in California, to all the private health insurers in California, to California Medicaid, California Medi-Cal? And, fourth, when do you plan to initiate the much needed multicenter study to answer the original hypothesis?

I appreciate the opportunity to review this interesting paper and congratulate the authors on one of the first looks at endovascular approaches to this small peripheral artery readily amenable to open repair. Thank you.

Dr. Omar K. Danner (Atlanta, Georgia): Great paper. Great presentation. My question is on the mortality in-patient after the initial operation. You said that the mortality was 10.3 percent versus 2.7 percent. That was statistically significant. But post-discharge it was about four times higher. So just accounting for those in-patient deaths, is there really a difference in the deaths versus some died early, some died late and then others were salvaged but you labeled as both? And should those both actually be included as, you know, as a priori intention to treat as the endovascular group? Thank you.

Dr. Michel B. Aboutanos (Richmond, Virginia): Interesting paper. This is just a question. I know your data is limited, therefore you may not be able to answer this. Do you think that the fact that the fasciotomy rate was much higher in the open versus endovascular because in the endovascular you had no ability do determine if you have concomitant venous injury at the same time and, therefore, you did not go to any prophylactic fasciotomies with this? Just a speculation.

Dr. William J. Butler (San Diego, California): Thank you, Dr. Feliciano, for your comments. You asked if we should have used a different data base and you referenced to the NTDB.

The paper that I quoted at the beginning of my presentation was an NTDB study that compared outcomes following endovascular and open repairs. However, NTDB does not include outcomes beyond the index admission. Our study included initial outcomes and those related to subsequent hospital readmissions in the State of California.

The PROOVIT registry tracks readmissions only if they occur at the hospital where patients were initially treated. The advantage of the OHSPD data base is that it includes all California hospitals and is highly likely to capture subsequent readmissions.

You also asked about thromboembolism. The details of this complication are not available in the OSHPD data base. However, we are concerned that this complication may have been related to the placement of stents in injured arteries prone to thromboembolism. This complication deserves more study. The use of stents in atherosclerotic lesions is not analogous to use in trauma patients who may be at an increased risk of thromboembolism.

You commented on the cost implications of combined approaches. We agree that this is an important issue and deserves further study.

You also commented on the need for a multi-center study. Although PROOVITT is multi-center, it is an observational study. We suspect that further multi-studies based on consensus driven practice guidelines are needed to identify optimal management of these very challenging vascular injuries.

You referenced a 36-year old male trauma patient. I'm 36 years old two weeks ago. And I would tell you that if I roll into your trauma bay with a popliteal artery injury, make a big incision. That's what I want.

Dr. Danner, you referred to mortality during the index admission versus deaths post-discharge. We reviewed the mortality data anticipating this question and found that death was more common after any endovascular management. However, the OHSPD data set does not allow us to determine true causality. This deserve further study.

Dr. Aboutanos, your observation regarding fasciotomy is very important. However, the OSHPD data set does not allow the depth of analysis necessary to answer questions related to use of fasciotomy.

Thank you all for your important comments and questions and I would like to thank the AAST for the privilege of presenting our study.