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Journal

Journal of Vascular Surgery, 73(4)

ISSN

0741-5214

Authors

Sorber, Rebecca
Alshaikh, Husain N
Nejim, Besma
et al.

Publication Date

2021-04-01

DOI

10.1016/j.jvs.2020.08.130

Peer reviewed

HHS Public Access

Author manuscript

J Vasc Surg. Author manuscript; available in PMC 2021 October 01.

Published in final edited form as:

J Vasc Surg. 2021 April ; 73(4): 1361–1367.e1. doi:10.1016/j.jvs.2020.08.130.

Quantifying the risk-adjusted hospital costs of postoperative complications after lower extremity bypass in patients with claudication

Rebecca Sorber, MD[a], **Husain N. Alshaikh, MD**[b], **Besma Nejim, MBChB, MPH**[c], **Christopher J. Abularrage, MD**[a], **James H. Black III, MD**[a], **Mahmoud B. Malas, MD, MHS**[d], **Caitlin W. Hicks, MD, MS**[a,b]

[a]Division of Vascular Surgery and Endovascular Therapy, Johns Hopkins Medical Institutes, Baltimore

[b]The Johns Hopkins Surgery Center for Outcomes Research, The Johns Hopkins School of Medicine, Baltimore

[c]Division of Vascular Surgery, Penn State Health Milton S. Hershey Medical Center, Hershey

[d]Division of Vascular Surgery, University of San Diego, San Diego.

Abstract

Objective: Increasing evidence has shown that the risks associated with surgical revascularization for intermittent claudication outweigh the benefits. The aim of our study was to quantify the cost of care associated with perioperative complications after elective lower extremity bypass (LEB) in patients presenting with intermittent claudication.

Methods: All patients undergoing first-time LEB for claudication in the Healthcare Database (2009–2015) were included. The primary outcome was in-hospital postoperative complications, including major adverse limb events (MALE), major adverse cardiac events (MACE), acute kidney injury, and wound complications. The overall crude hospital costs are reported, and a generalized linear model with log link and inverse Gaussian distribution was used to calculate the predicted hospital costs for specific complications.

Correspondence: Caitlin W. Hicks, MD, MS, Division of Vascular Surgery and Endovascular Therapy, Department of Surgery, The Johns Hopkins University School of Medicine, 600 N Wolfe St, Halsted 668, Baltimore, MD 21287-8611 (chicks11@jhmi.edu).

AUTHOR CONTRIBUTIONS

Conception and design: RS, CA, JB, MM, CH
Analysis and interpretation: RS, HA, BN, MM, CH
Data collection: Not applicable
Writing the article: RS, HA, CH
Critical revision of the article: BN, CA, JB, MM
Final approval of the article: RS, HA, BN, CA, JB, MM, CH
Statistical analysis: HA, BN, CH
Obtained funding: Not applicable
Overall responsibility: CH

Author conflict of interest: none.

Additional material for this article may be found online at www.jvascsurg.org.

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

Results: Overall, 7154 patients had undergone elective LEB for claudication during the study period. The median age was 66 years (interquartile range, 59–73 years), 67.5% were male, and 75.3% were white. Two thirds of patients (61.2%) had Medicare insurance, followed by private insurance (26.9%), Medicaid (7.7%), and other insurance (4.2%). In-hospital complications occurred in 8.5% of patients, including acute kidney injury in 3.0%, MALE in 2.8%, wound complications in 2.3%, and MACE in 1.0%. The overall median crude hospital cost was $11,783 (interquartile range, $8911-$15,767) per patient. The incremental increase in cost associated with a postoperative complication was significant, ranging from $6183 (95% confidence interval, $4604-$7762) for MALE to $10,485 (95% confidence interval, $6529-$14,441) for MACE after risk adjustment.

Conclusions: Postoperative complications after elective LEB for claudication are not uncommon and increase the in-hospital costs by 46% to 78% depending on the complication. Surgical revascularization for claudication should be used sparingly in carefully selected patients.

Keywords

Intermittent claudication; Lower extremity bypass; Postoperative complications; Premier Healthcare Database; Structured exercise therapy

Intermittent claudication is the most common clinical manifestation of symptomatic peripheral artery disease.[1] Its natural history is usually benign, with <5% of patients progressing to chronic limb-threatening ischemia requiring major amputation.[1–3] The consensus-based guidelines for the management of peripheral artery disease have emphasized that surgical intervention for claudication should only be pursued after a failed response to best medical therapy and supervised exercise therapy.[4] More specifically, the Society for Vascular Surgery guidelines state that lower extremity bypass (LEB) can be offered for claudication after a failed trial of medical therapy if a >50% likelihood exists of sustained improvement in function, symptom relief, and bypass patency at 2 years.[2]

Data from the Vascular Quality Initiative revealed that 26% of all LEBs performed from 2009 to 2014 were performed for claudication.[5–7] Although LEB has had reasonable short-term outcomes and long-term patency,[8,9] the long-term benefits and cost-effectiveness of surgery performed for claudication are questionable.[10] In addition, the occurrence of postoperative complications after LEB is not uncommon.[11,12] A recent analysis of data from the National Surgical Quality Improvement Program (NSQIP) reported that postoperative complications occurred in ≤17% of patients undergoing LEB for claudication.[9] These complications, which include renal, cardiac, and limb-based complications, will frequently require intensive care unit admission or additional procedures.[13]

The costs to the healthcare system incurred by postoperative complications after LEB are likely significant.[14,15] However, limited data quantifying the in-hospital costs associated with elective LEB complications in patients with claudication are available. The aim of our study was to quantify the costs of care associated with perioperative complications after LEB performed for claudication, in particular with respect to in-hospital events.

METHODS

Study design.

We performed a retrospective cohort study of data from the Premier Healthcare Database (PHD; Premier Inc, Charlotte, NC). The PHD is a large database of inpatient and hospital-based outpatient data with payer information from all sources (ie, Medicare, Medicaid, and private insurance) that accrues data from >700 U.S. hospitals in academic, nonacademic, government, and community spheres and both urban and rural settings.[16] Within the PHD, 79% of the patients have government insurance (Medicare, Medicaid, managed care). The PHD captures roughly 20% of inpatient discharges in the United States overall. Although the PHD is not surgically focused and cannot be used to assess provider- or hospital-level procedure volumes, its diverse capture, linkage with claims information, and inclusion of Medicare, Medicaid, and private insurance make it a powerful tool to examine the costs associated with purely elective operations.

The diagnoses and procedures within the PHD are based on administrative claims data using International Classification of Diseases, 9th revision (ICD-9), codes. The cost data are self-reported to the PHD by the hospitals, and, as such, the reported costs are determined by each institution's own accounting system.[16] The hospitals that use cost/charge ratios provide the PHD with the charge data, and teams at Premier work with the hospitals to assign Medicare cost/charge ratios to the data provided. All financial data included in the PHD are reviewed and validated against local- and region-specific data before inclusion in the PHD.[16] Some fees, such as professional fees, are not reported by the PHD because these are charge, rather than cost, data and remain proprietary between the institution and payer. This is also true of reimbursement data, which are not available from the PHD.

The study cohort included all adult patients (aged ≥18 years) who had undergone inpatient admission for first-time elective LEB for claudication from July 2009 to March 2015. We used the ICD-9 codes 39.25 and 39.29 to capture LEB procedures. Restricting the cohort to intermittent claudication accounted for 28% of LEB procedures performed for peripheral arterial disease during the study period, with the remainder of patients classified as having chronic limb-threatening ischemia. The diagnosis of claudication was determined from the admitting or principle diagnosis. To restrict the analysis to patients undergoing LEB as the index intervention for claudication, we excluded any patients who had undergone an ipsilateral endovascular intervention before or on the same day as the LEB operation, any patients with a previous admission for ipsilateral LEB, and any patients who had undergone concomitant abdominal aortic aneurysm repair during the same admission for LEB. Finally, all patients with missing data related to sex, race, provider, or cost of hospitalization were excluded from the present study. The institutional review board approved the present study and waived the informed consent requirements given the de-identified data source.

Study outcomes.

The primary outcome of the study was the cost associated with any in-hospital postoperative complication. Postoperative complications included acute kidney injury or new hemodialysis, wound complications, major adverse cardiovascular events (MACE; defined

as myocardial infarction, transient ischemic attack, stroke, or death), and major adverse limb events (MALE; defined as major amputation, operative bypass revision, or lower extremity endovascular intervention). The costs for the hospital stay were computed overall and divided into subcategories (ie, operation room, room and board, supplies, laboratory tests, pharmacy, and other) and are reported as total, fixed, and variable costs for each subcategory. All costs were adjusted for inflation to 2015 U.S. dollars using the Consumer Price Indexes from the U.S. Bureau of Labor Statistics.[17]

Statistical analysis.

We described the study cohort, key hospital characteristics, and frequency of postoperative complications using descriptive statistics. The crude hospital costs were analyzed with a generalized linear model with log link. An inverse Gaussian distribution was then used to calculate the predicted hospital costs overall and for specific complication events. We have also reported the estimated incremental cost increase and relative cost increase for each event. All statistical analyses were performed using Stata, version 14.1 (StataCorp LP, College Station Tex). The data were considered statistically significant at a level of $\alpha \leq .05$.

RESULTS

Study cohort.

Overall, 7154 patients had undergone elective LEB for claudication during the study period (Table I). The median age was 66 years (interquartile range [IQR], 59–73 years), 67.5% were male, and 75.3% were white. Two thirds of the patients (61.2%) had Medicare insurance, followed by private insurance (26.9%), Medicaid (7.7%), and other insurance (4.2%). More than one third of the patients (36.9%) were current smokers, and hypertension (79.2%), hyperlipidemia (59.0%), and coronary artery disease (43.4%) were common. Most procedures had been performed at urban hospitals (87.3%) of medium size (300–599 beds; 52.7%). The geographic distribution of the procedures roughly approximated the population density reported in the census.[15]

Frequency of postoperative complications.

In-hospital complications occurred in 610 patients (8.5%) overall (Table II). Acute kidney injury was the most common complication, occurring in 217 patients (3.0%). Wound complications occurred in 164 patients (2.3%), most related to postoperative bleeding at the surgical site (n = 142; 2.0%). MACE occurred in 1.0% of patients, including 41 acute myocardial infarctions (0.6%), 18 strokes (0.3%), 4 transient ischemic attacks (0.1%), and 18 in-hospital deaths (0.3%). MALE occurred in 2.8% of the patients, including operative bypass revisions in 176 patients (2.5%), lower extremity endovascular interventions in 22 patients (0.3%), and major amputations in 7 patients (0.1%).

Estimated overall hospital costs.

The median crude total hospital cost for elective LEB performed for claudication was $11,783 (IQR, $8911-$15,767), including $5412 (IQR, $3853-$7700) in fixed costs and $6196 (IQR, $4544-$8526) in variable costs (Table III). The largest proportion of hospital costs was attributable to operating room costs (median, $4474; IQR, $3162-$6407),

followed by room and board ($2835; IQR, $1784-$4330) and supply costs ($2153; IQR, $1184-$3576).

Association of postoperative complications with hospital costs.

The estimated in-hospital costs for elective LEB varied significantly for patients with vs without complications (Table IV). Postoperative MACE was associated with an estimated $10,485 increase in hospital costs (95% confidence interval [CI], $6529-$14,441), followed by wound complications ($8984; 95% CI, $6773-$11,195), acute kidney injury ($6719; 95% CI, $4985-$8452), and MALE ($6183; 95% CI, $4603-$7762). The relative increase in hospital costs for any postoperative complication ranged from 46% (MALE) to 78% (MACE) greater than baseline (Table IV) and was substantially greater than the relative cost variation associated with any baseline patient demographic variable (relative increase, 1% −8%), comorbidity (relative increase, 5%−16%), provider region (relative increase, 4% −29%), or year of operation (relative increase, 3%−8%; Supplementary Table, online only).

DISCUSSION

An increasing number of lower extremity revascularizations have been performed for claudication in the United States, despite multiple society recommendations against revascularization as primary management and a lack of apparent benefit in terms of long-term functional outcomes.[2,4,5,10] In the present study, we sought to quantify the costs associated with postoperative complications after elective LEB for claudication. We found an overall in-hospital complication rate of 8.5%, and most complications were acute kidney injury and wound complications. The median in-hospital cost associated with LEB was just <$12,000 and had increased by 46% to 78% if a complication had occurred. Overall, our data have quantified the costs associated with elective LEB and highlighted the high cost burden associated with the development of postoperative complications.

LEB operations, in general, are known to have a high incidence of perioperative complication and readmission rates,[14,15] resulting in an estimated $48.9 million burden in Medicare expenditures annually.[14] Our in-hospital complication rate of 8.5% was comparable to the 7.4% in-hospital major adverse event rate reported in the NSQIP database for patients undergoing LEB for claudication.[11] The individual complications rates in our study were also similar to those reported in the NSQIP, including MALE (2.8% vs 3.2%) and MACE (1.0% vs 1.7%). These complication rates were also consistent across multiple other databases, including analyses of institutional databases[18,19] and the Vascular Quality Initiative.[20] It is encouraging that the major complication rate associated with elective LEB has been consistently <10%. However, the serious nature of the reported adverse cardiac, kidney, and limb events is significant, given that claudication can usually be managed effectively without invasive intervention.[10]

The severity of the complications we have reported is reflected by their associated cost burdens. The baseline crude hospital cost for an uncomplicated LEB procedure reported in the PHD was $11,783, similar to previous reported studies.[21] The increases in cost associated with each complication were significant, especially for MALE ($6183, a 46% relative increase from the baseline cost) and MACE ($10,485, a 78% relative increase from

the baseline cost). Considering that ~40,757 LEBs are performed annually among Medicare beneficiaries in the United States, of which ~26% are performed for claudication,[14] the cumulative cost to Medicare associated with in-hospital MALE and MACE after elective LEB for claudication would be $3.8 million annually. When combined with the previously reported costs of readmissions for posthospitalization complications,[14,22] LEB for claudication is associated with nearly $9 million in unnecessary healthcare costs annually. Together, these data emphasize that surgeons must carefully consider the risks and benefits of revascularization for a pathology that can often be managed medically with good outcomes and amputation-free survival.[3,10]

In addition to the costs associated with in-hospital complications after LEB, we have described the costs associated with individual patient comorbidities. Patients who had undergone LEB with preexisting congestive heart failure and chronic kidney disease were associated with significantly greater LEB costs ($2114 and $1395, respectively) than those without such comorbidities. However, the costs associated with what many surgeons would consider major comorbidities were substantially lower than the costs associated with the development of a postoperative complication. The relative increase in costs for any comorbidity has been, at most, 16%. In contrast, the relative increase in costs for a complication has been as high as 78%. These data suggest that, although major patient comorbidities should clearly be factored into the risk stratification process when offering elective revascularization, the cost implications of a complication pose a much larger problem for the burden of care after LEB. A formal cost-benefit analysis might be helpful to risk stratify patients with claudication for LEB surgery in the future.

When considering methods to decrease the incidence of postoperative complications among patients with claudication, the most obvious answer would be to avoid surgery altogether. The mainstays of treatment of claudication are medical management, smoking cessation, and exercise. Recent investigations comparing the efficacy of revascularization vs supervised exercise therapy for the treatment of intermittent claudication noted no functional or quality of life advantages for patients undergoing endovascular[23] or open[10] revascularization at 18 months and 5 years, respectively. Current tobacco use was prevalent in 36.7% of patients in our study. Active smoking at LEB for claudication has been associated with decreased long-term patency and overall survival,[24] suggesting that elective open revascularization in these patients should receive additional scrutiny. It is concerning that more than one third of the patients in our study were active smokers, highlighting the substantial room for improvement present in the medical management of claudication.[25]

Most of the limitations in our study were related to the administrative nature of the data. The PHD uses ICD-9 codes to identify both diagnoses and procedures, introducing the possibility of coding errors. Some patients with a code indicating claudication might have undergone LEB for nonatherosclerotic etiologies. Also, the PHD is not a surgical- or vascular-focused database and lacks the granularity necessary to understand patients' disease severity, symptoms, bypass configuration, or conduit used. Also, no data are available regarding the use of supervised exercise therapy or other best medical practices before intervention. Finally, we did not have information on the severity of the complications reported. However, the PHD does capture ~20% of all inpatient hospitalizations in the

United States and a representative sample of insurance carriers. The PHD is also unique in its reporting of specific cost data not available from most other national databases. Therefore, although the indications and technical details associated with surgery were not available, our study is unique in its ability to quantify the overall and complication-specific costs associated with LEB for claudication and its complications.

CONCLUSIONS

Postoperative complications after elective LEB for claudication are not uncommon, occurring in 8.5% of patients during the index hospitalization. These complications are a significant source of healthcare expenditure, increasing the costs of the hospital stay by 46% (MALE) and 78% (MACE) greater than baseline. The financial burden associated with postoperative complications supports the notion that LEB should be used sparingly for the treatment of claudication in accordance with established professional society guidelines. Diligent patient selection is warranted to minimize the occurrence of complications and unnecessary healthcare expenditures.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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ARTICLE HIGHLIGHTS

- **Type of Research:** National database retrospective cohort study
- **Key Findings:** Within the Premier Healthcare Database (Premier Inc, Charlotte, NC), an analysis of 7154 lower extremity bypasses performed for claudication yielded an 8.5% postoperative complication rate with an overall median crude hospital cost of $11,783 (interquartile range, $8911-$15,767) per patient. The incremental increase in cost associated with a postoperative complication was significant, ranging from $6183 (95% confidence interval, $4604-$7762) for major adverse limb events to $10,485 (95% confidence interval, $6529-$14,441) for major adverse cardiac events after risk adjustment.
- **Take Home Message:** Complications after elective lower extremity bypass for claudication are not uncommon and are associated with a significant increase in in-hospital costs of 46% to 78%.

Table I.

Baseline patient characteristics (N = 7154; 2009–2015)

Characteristic	Total, No. (%)
Demographics	
Age, years	
Median	66
IQR	59–73
Female sex	2326 (32.5)
Race	
White	5389 (75.3)
Black	822 (11.5)
Other	943 (13.2)
Insurance carrier	
Medicare	4381 (61.2)
Medicaid	553 (7.7)
Private	1921 (26.9)
Other	299 (4.2)
Comorbidity	
Tobacco use	
Never	2446 (34.2)
Previous	2071 (28.9)
Current	2637 (36.9)
Hypertension	5667 (79.2)
Hyperlipidemia	4221 (59.0)
COPD	1783 (24.9)
Diabetes	2507 (35.0)
Previous myocardial infarction	958 (13.4)
Congestive heart failure	417 (5.8)
Coronary artery disease	3104 (43.4)
Chronic kidney disease	575 (8.0)
End-stage renal disease	92 (1.3)
Hospital characteristics	
Location	
Rural	907 (12.7)
Urban	6247 (87.3)
Bed size	
<300	1836 (25.7)
300–599	3769 (52.7)
≥600	1549 (21.7)
Teaching hospital	3269 (45.7)
Region	
New England	257 (3.6)

Characteristic	Total, No. (%)
Mid-Atlantic	665 (9.2)
South Atlantic	2266 (31.7)
East North Central	1021 (14.3)
East South Central	685 (9.6)
West North Central	437 (6.1)
West South Central	864 (12.1)
Mountain	240 (3.6)
Pacific	719 (10.1)

COPD,Chronic obstructive pulmonary disease; *IQR*,interquartile range.

Table II.

Frequency of postoperative complications (2009–2015)

Outcome	Total, No. (%)
LOS, days	
Median	3
IQR	2–4
Any complication	610 (8.5)
Acute kidney injury	217 (3.0)
New dialysis	76 (1.1)
Wound complication	164 (2.3)
Surgical site infection	16 (0.2)
Wound dehiscence	11 (0.2)
Bleeding/hematoma	142 (2.0)
MACE	71 (1.0)
Acute myocardial infarction	41 (0.6)
Transient ischemic attack	4 (0.1)
Stroke	18 (0.3)
Death	18 (0.3)
MALE	203 (2.8)
Major amputation	7 (0.1)
Reoperation	176 (2.5)
Endovascular intervention	22 (0.3)

IQR, Interquartile range; *LOS*, length of stay; *MACE*, major adverse cardiac events; *MALE*, major adverse limb events.

Table III.

Estimated total and subcategories of in-hospital costs (2009–2015)

Cost type	Median USD (IQR)
Total cost	$11,783 ($8911-$15,767)
Total fixed cost	$5412 ($3853-$7700)
Total variable cost	$6196 ($4544-$8526)
Room and board cost	
Total	$2835 ($1784-$4330)
Fixed	$1426 ($831-$2312)
Variable	$1332 ($823-$2118)
Operation room cost	
Total	$4474 ($3162-$6407)
Fixed	$2384 ($1526-$3530)
Variable	$1955 ($1287-$2968)
Supply cost	
Total	$2153 ($1184-$3576)
Fixed	$553 ($221-$1065)
Variable	$1473 ($760-$2614)
Laboratory test cost	
Total	$254 ($136-$492)
Fixed	$109 ($54-$217)
Variable	$134 ($67-$270)
Pharmacy cost	
Total	$559 ($358-$918)
Fixed	$207 ($114-$363)
Variable	$342 ($206-$548)
Other costs	
Total	$444 ($202-$976)
Fixed	$221 ($96-$501)
Variable	$211 ($90-$457)

IQR, Interquartile range; USD, U.S. dollars.

Table IV.

Predicted, incremental, and relative in-hospital costs (USD) associated with postoperative complications (2009–2015)

Complication	Predicted cost, $ (95% CI)	Incremental cost, $ (95% CI)	Relative increase, 95% CI	*P* value
Acute kidney injury				<.001
No	$13,329 ($13,161-$13,496)	-	-	
Yes	$20,048 ($18,327-$21,769)	$6719 ($4985-$8452)	1.50 (1.38–1.64)	
Wound complication				<.001
No	$13,344 ($13,178-$13,510)	-	-	
Yes	$22,328 ($20,121-$24,536)	$8984 ($6773-$11,195)	1.67 (1.51–1.85)	
MALE				<.001
No	$13,396 ($13,225-$13,566)	-	-	
Yes	$19,578 ($18,004-$21,153)	$6183 ($4603-$7762)	1.46 (1.35–1.58)	
MACE				<.001
No	$13,438 ($13,271-$13,606)	-	-	
Yes	$23,923 ($19,973-$27,874)	$10,485 ($6529-$14,441)	1.78 (1.51–2.1)	

CI, Confidence interval; *MACE*, major adverse cardiac events; *MALE*, major adverse limb events; *USD*, U.S. dollars.