From the Society for Vascular Surgery

Risk factors and indications for readmission after lower extremity amputation in the American College of Surgeons National Surgical Quality Improvement Program

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Background: Postoperative readmission, recently identified as a marker of hospital quality in the Affordable Care Act, is associated with increased morbidity, mortality, and health care costs, yet data on readmission after lower extremity amputation (LEA) are limited. We evaluated risk factors for readmission and postdischarge adverse events after LEA in the American College of Surgeons National Surgical Quality Improvement Program (NSQIP).

Methods: All patients undergoing transmetatarsal (TMA), below-knee (BKA), or above-knee amputation (AKA) in the 2011-2012 NSQIP were identified. Independent predischarge predictors of 30-day readmission were determined by multivariable logistic regression. Readmission indication and reinterventions, available in the 2012 NSQIP only, were also evaluated.

Results: We identified 5732 patients undergoing amputation (TMA, 12%; BKA, 51%; AKA, 37%). Readmission rate was 18%. Postdischarge mortality rate was 5% (TMA, 2%; BKA, 3%; AKA, 8%; $P < .001$). Overall complication rate was 43% (in-hospital, 32%; postdischarge, 11%). Reoperation was for wound-related complication or additional amputation in 79% of cases. Independent predictors of readmission included chronic nursing home residence (odds ratio [OR], 1.3; 95% confidence interval [CI], 1.0-1.7), nonelective surgery (OR, 1.4; 95% CI, 1.1-1.7), prior revascularization/amputation (OR, 1.4; 95% CI, 1.1-1.7), preoperative congestive heart failure (OR, 1.7; 95% CI, 1.2-2.4), and preoperative dialysis (OR, 1.5; 95% CI, 1.2-1.9). Guillotine amputation (OR, 0.6; 95% CI, 0.4-0.9) and non-home discharge (OR, 0.7; 95% CI, 0.6-1.0) were protective of readmission. Wound-related complications accounted for 49% of readmissions.

Conclusions: Postdischarge morbidity, mortality, and readmission are common after LEA. Closer follow-up of high-risk patients, optimization of medical comorbidities, and aggressive management of wound infection may play a role in decreasing readmission and postdischarge adverse events. (J Vasc Surg 2014;60:1315-24.)

With internal reports from the Centers for Medicare and Medicaid Services (CMS) estimating potentially preventable hospital readmission costs in the billions of dollars,[1] hospital readmission has become a significant area of interest for both policy makers and clinicians. As we are now in the midst of the implementation of the Affordable Care Act, CMS is rolling out the Hospital Readmission Reduction Program. This program implements a payment algorithm by which hospital reimbursement will be partially based on risk-adjusted 30-day readmission rates.[2] According to these recommendations, hospitals with high risk-adjusted rehospitalization rates will receive lower average per-case payments. This has led to increased interest in studying rehospitalization rates and contributing factors, as indicated by a nearly threefold increase (509 to 1326) in "readmission"-related scholarly articles on www.pubmed.gov since 2007.

Vascular surgery, in particular, has come to the forefront of readmission investigations related to a 2009 *New England Journal of Medicine* study whereby 24% of Medicare beneficiaries operated on for peripheral vascular disease were readmitted, third highest of any diagnosis-related group.[3] Accordingly, recent studies have used data from individual institutions as well as from regional and national sources to identify the incidence of and risk factors for readmission after either open or endovascular lower extremity revascularization.[4-7] Thus, whereas these studies and others comparing reintervention rates after lower extremity revascularization have been common,[8,9] lower extremity amputation (LEA) has not been the subject of similar research.

Despite our growing armamentarium for the treatment of lower extremity arterial disease and recent improvements in limb salvage rates,[10] LEA is still frequently performed, with an estimated two million Americans

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currently living with the loss of a limb.[11] Two recent studies have demonstrated the significant commitment of long-term health care resources to patients after LEA, with most of these patients undergoing multiple rehospitalizations during a period of months to years.[12,13] Yet, despite these inquiries into the long-term resource utilization of patients after LEA, perioperative (≤30-day) readmission has not been studied in detail. We now aim to use the American College of Surgeons National Surgery Quality Improvement Program (NSQIP) database to study the incidence of and risk factors for readmission in patients undergoing LEA.

METHODS

Data source. We used data from the 2011 and 2012 NSQIP, a national, prospectively collected clinical database including more than 300 institutions. Details of data collection and quality control have been previously described.[14,15] In 2011, the NSQIP introduced a variable for readmission within 30 days of surgery to any hospital, including non-NSQIP hospitals, as determined by medical record review and direct patient contact. For this reason, analysis was restricted to 2011 and 2012 only. The accuracy of NSQIP readmission data was compared with that of physician chart review and administrative data and found to be excellent.[16] Whereas the NSQIP began capture of 30-day readmission in 2011, the indication for readmission only became available in the 2012 NSQIP. Thus, readmission indication is available for 2012 only. As this study contained only de-identified data without any protected health information, the study is not considered human research and therefore not subject to Institutional Review Board approval.

Patients. Patients undergoing major LEA—above-knee amputation (AKA), below-knee amputation (BKA), or transmetatarsal amputation (TMA)—were identified by query of the 2011 and 2012 NSQIP Participant User Files by the following Current Procedural Terminology codes: 27590, 27591, 27592, 27596, 27880, 27881, 27882, and 28805. Patients admitted to an NSQIP-participating institution for an index trauma are specifically excluded from the database in the context of that admission. Baseline patient demographics, comorbidities, operative details, and postoperative course were extracted from the database. Patients not at risk for readmission within 30 days of index amputation due to death during index admission or hospital stay longer than 30 days were excluded from analysis.

Outcomes. Our primary outcome measure was overall readmission to any hospital within 30 days of index amputation. Readmissions for 2012 were further categorized as planned vs unplanned and related to the index procedure or unrelated to the index procedure. Planned readmissions were determined by whether the readmission was planned at the time of the index amputation. Readmissions were deemed related to the primary procedure if considered related by the NSQIP reviewer. Data regarding time to readmission, multiple readmissions, readmission indication, and reinterventions occurring on readmission were also noted for 2012 when these parameters were introduced to the NSQIP database. Secondary outcome measures included overall 30-day morbidity and mortality stratified as either before or after discharge.

Measures and terms. Whereas definitions for all NSQIP terms may be found in the NSQIP user guide, this study also used newly created terms defined here. Any wound complication refers to a composite variable inclusive of any NSQIP-defined surgical site infection (SSI) including superficial SSI, deep SSI, organ space SSI, and dehiscence.

Statistical analysis. All analyses were conducted with IBM SPSS Statistics version 21.0.0 for Macintosh (IBM Corp, Armonk, NY). Categorical variables were analyzed by the χ^2 or Fisher exact test where appropriate. Continuous variables were compared by two-tailed independent samples *t*-test or analysis of variance. Cases missing data for any given parameter were eliminated from consideration for the purposes of bivariate analysis. Multiple logistic regression was performed to determine independent predictors of readmission. All variables with a P value $< .10$ on bivariate analysis were included in the model. Models were then constructed by two methods; (1) one in which any cases missing data for a candidate predictor were excluded, and (2) one in which any cases missing data had the missing parameter set to the reference group for that parameter. Method A uses only cases with complete data for candidate predictors at the cost of limited sample size. Method B maximizes sample size but produces conservative estimates. Clinical judgment was used to eliminate redundant variables such as emergent case status, which was largely represented by elective case status, a more informative variable in this context. Similarly, American Society of Anesthesiologists (ASA) class was eliminated as it serves as a proxy for other comorbidities represented in the model. Length of stay was eliminated from consideration related to the inherent bias associated with length of stay as collected by the NSQIP. As the NSQIP follow-up period is 30 days from the date of surgery, increased length of stay decreases the time at risk for readmission. Backward stepwise elimination was used to determine final independent predictors with variables eliminated for P value $> .05$. Model discrimination was assessed by C statistics, with a C statistic of 1.0 denoting perfect predictive power and a C statistic of .5 denoting prediction equivalent to random chance. Hosmer-Lemeshow test was used to assess model calibration. Spearman ρ was used to assess the correlation of predicted readmission probability between the two model methods. Throughout all analyses, statistical significance was determined by a criterion of $P < .05$.

RESULTS

Demographics and clinical details. Overall, 6571 patients underwent LEA in the 2011-2012 NSQIP: 2486 AKA (38%), 3310 BKA (50%), 775 TMA (12%). Exclusions were made for patients not at risk for 30-day readmission at the time of discharge (death on index admission, n = 298 [5%], or in the hospital at 30 days, n = 269 [4%]) and those for whom readmission data were unavailable

Table I. Demographic characteristics and comorbidities of lower extremity amputation (LEA) patients undergoing readmission analysis in the 2011-2012 National Surgical Quality Improvement Program (NSQIP)

	All, *No. (%)*	*TMA,* *No. (%)*	*BKA,* *No. (%)*	*AKA,* *No. (%)*	P *value*
No.	5732 (100)	700 (12)	2909 (51)	2123 (37)	—
Mean age ± SD, years	66.9 ± 13.6	63.6 ± 13.2	64.5 ± 13.3	70.9 ± 13.2	<.001
Male	3650 (64)	494 (71)	1952 (67)	1204 (57)	<.001
Race					.001
White	3562 (65)	410 (62)	1849 (67)	1303 (64)	
Black	1535 (28)	186 (28)	735 (27)	614 (30)	
Asian	89 (2)	11 (2)	36 (1)	42 (2)	
Native American	31 (1)	5 (1)	20 (1)	6 (0)	
Native Hawaiian/Pacific Islander	33 (1)	6 (1)	20 (1)	7 (0)	
Chronic nursing home residence	1035 (18)	61 (9)	376 (13)	598 (28)	<.001
Dependent functional status	2296 (40)	173 (25)	988 (34)	1135 (54)	<.001
Diabetes mellitus	3663 (64)	526 (75)	2054 (71)	1083 (51)	<.001
Smoker within last year	1535 (27)	163 (23)	789 (27)	583 (28)	.081
Chronic obstructive pulmonary disease	657 (12)	49 (7)	305 (11)	303 (14)	<.001
Congestive heart failure within 30 days	371 (7)	39 (6)	194 (7)	138 (7)	.569
History of myocardial infarction last 6 months	107 (4)	12 (3)	59 (4)	36 (4)	.414
History of prior percutaneous coronary intervention	461 (17)	68 (17)	245 (18)	148 (15)	.102
History of prior cardiac surgery	599 (21)	76 (19)	312 (23)	211 (21)	.229
History of revascularization or amputation	1691 (61)	249 (62)	837 (61)	605 (60)	.604
Rest pain/gangrene	1676 (60)	232 (58)	837 (61)	607 (60)	.576
Preoperative open wound	3971 (69)	512 (73)	2073 (71)	1386 (65)	<.001
Dialysis dependence	1062 (19)	126 (18)	609 (21)	327 (15)	<.001
Preoperative sepsis					<.001
SIRS	713 (12)	43 (6)	352 (12)	318 (15)	
Sepsis	731 (13)	407 (14)	407 (14)	213 (10)	
Septic shock	111 (2)	62 (2)	62 (2)	42 (2)	
ASA class ≥4	2314 (40)	187 (27)	1117 (38)	1010 (48)	<.001
BMI ≥30 kg/m^2	1750 (32)	259 (38)	1013 (36)	478 (23)	<.001

AKA, Above-knee amputation; *ASA,* American Society of Anesthesiologists; *BKA,* below-knee amputation; *BMI,* body mass index; *SD,* standard deviation; *SIRS,* systemic inflammatory response syndrome; *TMA,* transmetatarsal amputation.
All percentages reflect valid denominator given missing data.

(n = 272 [4%]). The remaining 5732 patients formed the basis for our study. Comorbidities are outlined in Table I, which demonstrates an increasing burden of comorbid illness with proximal amputation. Operative and postoperative course are discussed with readmission analysis. Discharge was to home in 27% of cases, with the remainder discharged to skilled or unskilled facilities, although discharge to home varied by amputation level (home discharge: TMA 54%, BKA 23%, AKA 23%; $P < .001$).

Morbidity and mortality. The 30-day morbidity and mortality stratified by amputation level and predischarge and postdischarge occurrence are displayed in Table II. For those patients who died within 30 days of surgery but after hospital discharge (n = 266), mean days from discharge until death were 10.9 (standard deviation [SD] ± 7.0). As seen in Table II, the incidence of NSQIP-defined postdischarge adverse events varied by amputation level. Mortality increased with proximal amputation, as did several infectious complications including sepsis, pneumonia, and urinary tract infection. The proportion of patients with multiple NSQIP-defined complications also varied by amputation level, both before and after discharge.

Morbidity and mortality are presented stratified by readmission status and predischarge and postdischarge occurrence in Table III. Temporal distribution of complications varied according to the specific complication. SSIs were more than four times more likely to occur after discharge than before discharge (5% vs 1%), although all other NSQIP-documented complications occurred more frequently before discharge. Specifically, individual postdischarge wound complications were documented as occurring at a mean of 12 to 15 days (SD ± 6) after discharge from the acute care setting.

Bivariate analysis—readmission. Overall readmission rate was 18%. Mean days from discharge to readmission were 11 (SD ± 7). Three percent of readmitted patients (n = 16 of 465; 2012 only) were readmitted a second time. Factors associated with readmission on bivariate analysis were primarily patient related (Table IV). Operative details are listed in Table V, with elective surgery and guillotine amputation showing a protective effect from readmission. Further investigation showed that guillotine amputation was associated with a decreased incidence of postdischarge wound infection (2% vs 5%; $P = .002$). New dialysis dependence and unplanned reintubation on index admission were the lone predischarge complications to predict readmission (Table III). Given the expectation that many guillotine amputations may have a planned return to the operating room for wound revision, we evaluated the risk of readmission after reoperation

Table II. Overall, predischarge, and postdischarge[a] adverse events by amputation level in patients undergoing readmission analysis in the 2011-2012 National Surgical Quality Improvement Program (NSQIP)

	TMA, No. (%)	*BKA, No. (%)*	*AKA, No. (%)*	P *value*
Mean length of stay ± SD, days	8.2 ± 6.6	7.5 ± 5.0	6.7 ± 4.8	.001
Readmission	119 (17)	527 (18)	369 (17)	.694
Any complication	270 (39)	1271 (44)	905 (43)	.049
Predischarge	170 (24)	952 (33)	699 (33)	<.001
Postdischarge	65 (9)	320 (11)	227 (11)	.419
Any wound complication	84 (12)	233 (8)	142 (7)	<.001
Predischarge	13 (2)	29 (1)	22 (2)	.137
Postdischarge	31 (4)	163 (6)	87 (4)	.042
Postdischarge mortality	11 (2)	87 (3)	168 (8)	<.001
Myocardial infarction	5 (1)	45 (2)	28 (1)	.228
Predischarge	4 (1)	32 (1)	15 (1)	.215
Postdischarge	1 (0)	13 (0)	13 (1)	.280
New dialysis dependence	10 (1)	34 (1)	15 (1)	.148
Predischarge	9 (1)	29 (1)	12 (1)	.121
Postdischarge	1 (0)	5 (0)	3 (0)	.959
Sepsis	31 (4)	142 (5)	155 (7)	<.001
Predischarge	20 (3)	82 (3)	80 (4)	.145
Postdischarge	11 (2)	60 (2)	75 (4)	.001
Pneumonia	13 (2)	82 (3)	78 (4)	.034
Predischarge	8 (1)	38 (1)	35 (2)	.484
Postdischarge	3 (0)	25 (1)	29 (1)	.055
Urinary tract infection	8 (1)	108 (4)	107 (5)	<.001
Predischarge	3 (0)	38 (1)	45 (2)	.003
Postdischarge	2 (0)	23 (1)	29 (1)	.018
Any return to operating room[b]	110 (16)	324 (11)	118 (6)	<.001
Unplanned predischarge reoperation[c]	28 (9)	62 (4)	25 (2)	<.001
Unplanned postdischarge reoperation[c]	21 (7)	76 (5)	33 (3)	.010
Any reoperation, guillotine only	N/A	63 (16)	5 (5)	.003
Any reoperation, non-guillotine only	N/A	261 (10)	113 (6)	<.001
Multiple complications	55 (8)	304 (11)	264 (12)	.002
Predischarge	23 (3)	147 (5)	124 (6)	.028
Postdischarge	8 (1)	64 (2)	73 (3)	.001

AKA, Above-knee amputation; *BKA,* below-knee amputation; *N/A,* not applicable; *SD,* standard deviation; *TMA,* transmetatarsal amputation.
[a]Predischarge and postdischarge distinction is not applied when exact date of the event is unknown.
[b]2011 and 2012 patients.
[c]2012 patients only.

independently for guillotine and non-guillotine amputation patients (Table III).

Multivariable analysis—readmission. Independent predictors of readmission as determined through the model techniques outlined in the Methods section are shown in Fig 1. Predictors were generally patient related but also included nonelective surgery, non-home discharge, and postoperative new dialysis dependence. Non-home discharge was associated with a higher baseline comorbidity burden (home discharge ASA class 4, 28%; non-home discharge ASA class 4, 45%; $P < .001$) and increased incidence of predischarge complications (home discharge, 23%; non-home discharge, 35%; $P < .001$). The model depicted in Fig 1, *A*, excluding any patient with missing data, included a sample size of 2712, of which 480 were readmitted. The model in Fig 1, *B*, included all patients. The readmission rate of 18% (n = 480 of 2712) for the patients in the exclusionary model did not differ from the overall readmission rate ($P = 1.000$), also 18%, suggesting that these patients were a representative sample with respect to readmission. Model discrimination is as shown by the C statistics demonstrated in the figure. The Hosmer-Lemeshow test for each model was nonsignificant. For those patients included in both models (n = 2712), the Spearman ρ correlating predicted probability of readmission was .836.

Reoperation details—2012 only. In the 2012 NSQIP, 115 patients (n = 115 of 2874; 4%) underwent 128 predischarge reoperations on their index admission. Approximately 70% of these patients returned to the operating room for either additional amputation (n = 54 of 115; 47%) or wound-related procedures (n = 28 of 115; 24%), including débridement, incision and drainage, and revision. An additional 11% underwent either open or endovascular revascularization (n = 13 of 115). In the 2012 NSQIP, 130 patients (n = 130 of 2874; 5%) underwent 150 reoperations after discharge. One in four readmitted patients (n = 112 of 465) had a postdischarge return to the operating room. Similar to predischarge reoperation, wound-related procedures (n = 50 of 130; 38%) and additional amputations (n = 61 of 130; 47%) accounted for the majority of postdischarge reoperations.

Table III. Overall, predischarge, and postdischarge[a] adverse events by readmission status in lower extremity amputation (LEA) patients who underwent readmission analysis in the 2011-2012 National Surgical Quality Improvement Program (*NSQIP*)

	Overall, No. (%)	*Readmitted, No. (%)*	*Not readmitted, No. (%)*	P *value*
No.	5732 (100)	1015 (18)	4717 (82)	—
Mean length of postoperative stay ± SD, days	7.3 ± 5.2	6.8 ± 4.4	7.4 ± 5.4	<.001
Any NSQIP complication	2446 (43)	724 (71)	1722 (37)	<.001
Predischarge	1821 (32)	340 (34)	1481 (31)	.194
Postdischarge	612 (11)	440 (43)	172 (4)	<.001
Any wound complication	459 (8)	248 (24)	211 (5)	<.001
Predischarge	64 (1)	11 (1)	53 (1)	1.000
Postdischarge	281 (5)	180 (18)	101 (2)	<.001
Postdischarge mortality	266 (5)	96 (10)	170 (4)	<.001
Myocardial infarction	78 (1)	33 (3)	45 (1)	<.001
Predischarge	51 (1)	9 (1)	42 (1)	1.000
Postdischarge	27 (1)	24 (2)	3 (0)	<.001
New dialysis dependence	59 (1)	24 (2)	35 (1)	<.001
Predischarge	50 (1)	15 (2)	35 (1)	.038
Postdischarge	9 (0)	9 (1)	0 (0)	<.001
Sepsis	328 (6)	162 (16)	166 (4)	<.001
Predischarge	182 (3)	33 (3)	149 (3)	.844
Postdischarge	146 (3)	129 (13)	17 (0)	<.001
Pneumonia	173 (3)	78 (8)	95 (2)	<.001
Predischarge	81 (1)	18 (2)	63 (1)	.304
Postdischarge	57 (1)	51 (5)	6 (0)	<.001
Unplanned reintubation	120 (2)	59 (6)	61 (1)	<.001
Predischarge	75 (1)	22 (2)	53 (1)	.014
Postdischarge	45 (1)	37 (4)	8 (0)	<.001
Urinary tract infection	223 (4)	89 (9)	134 (3)	<.001
Predischarge	86 (2)	20 (2)	66 (1)	.199
Postdischarge	54 (1)	34 (3)	20 (0)	<.001
Any return to operating room[b]	570 (18)	310 (48)	260 (10)	<.001
Unplanned predischarge reoperation[c]	115 (4)	22 (5)	93 (4)	.367
Unplanned postdischarge reoperation[c]	130 (5)	112 (24)	18 (1)	<.001
Unplanned predischarge reoperation (nonguillotine only)[c]	67 (3)	14 (4)	53 (3)	.413

SD, Standard deviation.
[a]Predischarge and postdischarge distinction is not applied when exact date of the event is unknown.
[b]2011 and 2012 patients.
[c]2012 patients only.

Revascularization was rare in the postdischarge setting (n = 3 of 150; 2%).

Readmission indication—2012 only. In the 2012 NSQIP, 465 patients were readmitted, of which 451 readmissions (97%) were unplanned. Of the unplanned readmissions, half (n = 227 of 451) were considered related to the index amputation. TMA patients had the highest proportion of related readmissions (65%) compared with BKA (49%) and AKA (49%) ($P = .219$). The readmission indications given by the NSQIP for the unplanned, related readmissions (n = 227) are presented in Fig 2. The non-NSQIP-defined wound-related indications include wound infections not meeting NSQIP diagnostic criteria for infection as well as other noninfectious wound complications, such as nonhealing wound and hematoma. Including both NSQIP-defined and non-NSQIP-defined wound complications, these accounted for half of all readmissions (49%). Those patients readmitted with peripheral vascular disease complications include indications such as lower extremity ulcer, gangrene, and cellulitis. Readmission indication varied by amputation level. The proportion of readmitted patients readmitted for non-wound-related infectious indication increased with proximal amputation (TMA, 14%; BKA, 20%; AKA, 35%; $P = .020$). Although not reaching statistical significance, a greater proportion of patients were readmitted for a wound-related indication with distal amputation (TMA, 62%; BKA, 54%; AKA, 44%; $P = .197$). Patients readmitted for wound complications were more likely to undergo additional amputation than were patients readmitted for other indications (33% vs 6%; $P < .001$). Peripheral vascular disease readmissions decreased with proximal amputation (TMA, 62%; BKA, 54%; AKA, 44%; $P = .222$). Readmission indications for the unplanned, unrelated readmissions are unavailable in the NSQIP database.

DISCUSSION

This study represents the first investigation of a national, multicenter, prospective clinical database to evaluate risk factors for readmission after LEA. Readmission after LEA is extremely common, with nearly one in five patients undergoing LEA in the 2011-2012 NSQIP

Table IV. Bivariate comparison of preoperative characteristics for readmitted and non-readmitted lower extremity amputation (LEA) patients in the 2011-2012 National Surgical Quality Improvement Program (NSQIP)

	Overall, No. (%)	*Readmitted, No. (%)*	*Not readmitted, No. (%)*	P *value*
No.	5732 (100)	1015 (18)	4717 (82)	—
Mean age ± SD, years	67.7 ± 13.6	67.4 ± 13.8	66.7 ± 13.6	.135
Male	3650 (64)	634 (63)	3016 (64)	.368
Race				.007
White	3562 (65)	637 (65)	2925 (65)	
Black	1535 (28)	299 (30)	1236 (28)	
Asian	89 (2)	11 (1)	78 (2)	
Native American	31 (1)	6 (1)	25 (1)	
Native Hawaiian/Pacific Islander	33 (1)	5 (1)	28 (1)	
Chronic nursing home residence	1035 (18)	219 (22)	816 (17)	.001
Dependent functional status	2296 (40)	458 (46)	1838 (39)	<.001
Diabetes mellitus	3663 (64)	666 (66)	2997 (64)	.221
Smoker within last year	1535 (27)	260 (26)	1275 (27)	.369
Chronic obstructive pulmonary disease	657 (12)	138 (14)	519 (11)	.022
Congestive heart failure within 30 days	371 (7)	92 (9)	279 (6)	<.001
History of myocardial infarction last 6 months	107 (4)	18 (4)	89 (4)	.898
History of prior percutaneous coronary intervention	461 (17)	92 (19)	369 (16)	.183
History of prior cardiac surgery	599 (21)	120 (24)	479 (21)	.117
History of revascularization or amputation	1691 (61)	332 (67)	1359 (59)	.002
Rest pain/gangrene	1676 (60)	329 (66)	1347 (59)	.002
Preoperative open wound	3971 (69)	709 (70)	3262 (69)	.680
Dialysis dependence	1062 (19)	256 (25)	806 (17)	<.001
Preoperative sepsis				.158
SIRS	713 (12)	147 (15)	566 (12)	
Sepsis	731 (13)	131 (13)	600 (13)	
Septic shock	111 (2)	21 (2)	90 (2)	
ASA class ≥4	2314 (40)	475 (47)	1839 (39)	<.001
BMI ≥30 kg/m^2	1750 (32)	304 (31)	1446 (32)	.452

ASA, American Society of Anesthesiologists; *BMI,* body mass index; *SD,* standard deviation; *SIRS,* systemic inflammatory response syndrome.
All percentages reflect valid denominator given missing data.

Table V. Operative details for lower extremity amputation (LEA) patients who underwent readmission analysis in the 2011-2012 National Surgical Quality Improvement Program (NSQIP)

	Overall, No. (%)	*Readmitted, No. (%)*	*Not readmitted, No. (%)*	P *value*
No.	5732 (100)	1015 (18)	4717 (82)	—
Mean OR time ± SD, minutes	66 ± 40	66 ± 35	66 ± 42	.616
Amputation level				.694
TMA	700 (12)	119 (12)	581 (12)	
BKA	2909 (51)	527 (52)	2382 (51)	
AKA	2123 (37)	369 (36)	1754 (37)	
Guillotine amputation	495 (10)	58 (7)	437 (11)	<.001
Emergency surgery	716 (13)	110 (11)	606 (13)	.084
Elective surgery	2044 (36)	318 (32)	1726 (37)	.002

AKA, Above-knee amputation; *BKA,* below-knee amputation; *OR,* operating room; *SD,* standard deviation; *TMA,* transmetatarsal amputation.

readmitted. Independent risk factors for readmission in the NSQIP cohort were primarily patient related, although nonelective surgery, non-home discharge, and postoperative dialysis dependence also predicted readmission (Fig 1). Both methods of logistic regression model construction produced similar results. Readmissions were unplanned in most cases (97%), although approximately half of unplanned readmissions were deemed unrelated to the index amputation. Of patients with unplanned, related readmissions, half were related to wound complications. Highlighting the importance of wound management in these patients, reoperations, both before and after discharge, were related to wound issues in approximately a third of patients and included additional amputation in approximately half. Finally, readmitted patients represent an extremely high-risk population as they demonstrated a mortality rate two and a half times that of non-readmitted patients (10% vs 4%).

Whereas prior studies on readmission after LEA have focused on long-term resource utilization, our study is the first to evaluate the incidence of perioperative (30-day) readmission and its risk factors. Feinglass et al[12]

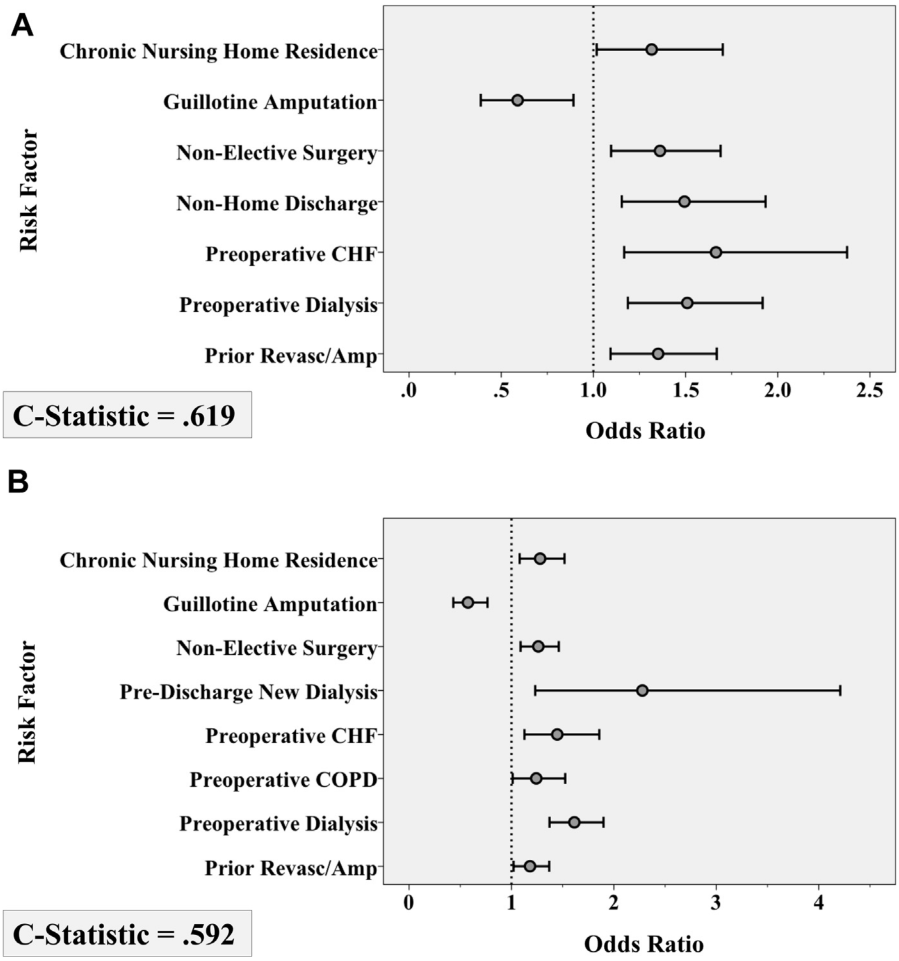

Fig 1. A, Independent predictors of readmission for lower extremity amputation (LEA) patients in the 2011-2012 National Surgical Quality Improvement Program (NSQIP); missing variables excluded. **B,** Independent predictors of readmission for LEA patients in the 2011-2012 NSQIP; missing variables set to reference group. *CHF,* Congestive heart failure; *COPD,* chronic obstructive pulmonary disease.

reviewed the cumulative risk of readmission for patients undergoing LEA in the Department of Veterans Affairs NSQIP system in the early 1990s, showing that more than 70% of patients were readmitted during a median follow-up period of 32 months. Similarly, Henry et al[13] reported on long-term resource utilization after LEA at two tertiary care centers, yet this study also reported a 30-day readmission rate of 20.1% (n = 73 of 364). This rate of readmission is similar to the rate found in the NSQIP cohort (19%), showing that the issue of readmission after LEA is relevant to tertiary referral centers as well as to others.

Given the chronic and largely nonmodifiable nature of preoperative nursing home residence, congestive heart failure, chronic obstructive pulmonary disease, and dialysis dependence, quality improvement measures focused on these patient-related readmission risk factors are likely to be limited. Although we may hope to medically optimize these patients preoperatively through diuresis and medication management, substantive improvement in their baseline comorbidity profile is often not feasible in the preoperative period. Non-home discharge, also a predictor of readmission, was associated with a higher burden of preoperative comorbid illness and predischarge complications. Robust primary care management of these complex patients with early referral to vascular surgeons may limit the proportion of amputations performed under emergent circumstances, which could also play a role in mitigating readmissions by allowing optimization.

With few patient-related risk factors for readmission conducive to preoperative modification, we look to the indication for readmission and interventions performed on readmission for insight into how to address this issue. Approximately half of patients were readmitted for wound-related complications, and one quarter of readmitted patients returned to the operating room, most for wound-related procedures or additional amputations. In fact, patients readmitted for wound complications were seven times more likely to undergo additional amputation

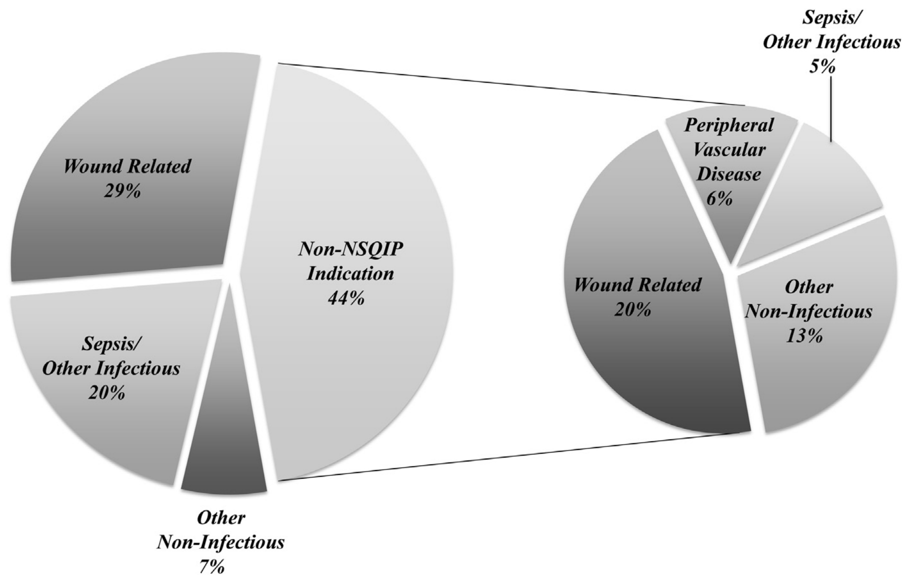

Fig 2. Unplanned related readmission indication among lower extremity amputation (LEA) patients in the 2012 National Surgical Quality Improvement Program (*NSQIP*) cohort.

than were patients readmitted for other reasons. This, in conjunction with a trend toward increasing wound complications with distal amputation, may suggest that surgeons attempting to leave their patients with maximum limb function through a limited amputation could be susceptible to higher readmission rates. As the wound complications and the need for reoperation are likely to relate to a number of patient and operative factors, these present several opportunities for quality improvement. Avoidance of reoperation was the focus of a 2013 study by O'Brien et al[17] that evaluated risk factors for early failure of LEA as indicated by a return to the operating room on index admission. Using the 2005-2010 NSQIP, O'Brien et al showed active tobacco use (odds ratio [OR], 1.18; 95% confidence interval [CI], 1.00-1.38) and intraoperative surgical trainee participation (OR, 1.37; 95% CI, 1.20-1.57) to increase reoperation risk, whereas locoregional anesthesia (OR, 0.75; 95% CI, 0.63-0.89) and operating room time longer than 40 minutes were found to be protective.

By use of the risk factors for reoperation elucidated by O'Brien et al, tangible steps to decrease the need for reoperation, and consequently readmission, are evident. A recent meta-analysis on the benefit of preoperative smoking cessation found a 40% decrease in postoperative complications in patients who discontinued tobacco use preoperatively.[18] Routine use of proactive smoking cessation strategies, such as in-clinic enrollment in smoking cessation programs during preoperative consultation, may improve our patients' success in this regard.[19,20] Intraoperatively, the use of locoregional anesthesia, when possible, avoids the physiologic stress of general anesthesia and may play a role in preventing certain systemic postoperative complications. Finally, whereas careful supervision of surgical trainees and a deliberate technical approach may also aid in the avoidance of reoperation and rehospitalization, it is difficult to draw conclusions about the impact of trainee participation on postoperative outcomes with use of the NSQIP database, given the difficulty in eliminating hidden confounders related to the selection of intraoperative assistants.

In further evaluation of the indication for readmission and the role it may play in readmission avoidance, readmission indication was not similarly distributed across amputation level given, probably related to baseline differences in health status of the patients undergoing these procedures. Patients receiving an AKA compared with a TMA in the NSQIP cohort were nearly two times more likely to be ASA class 4 or higher (Table I). Accordingly, AKA patients were more likely than BKA or TMA patients to be readmitted for non-wound-related infectious complications, such as pneumonia, urinary tract infection, and sepsis. This is in contrast to readmissions for wound complications or complications of peripheral vascular disease, which showed trends toward an increase in incidence with distal amputation.

Whereas the particular care needs of LEA patients may vary by amputation level, a preponderance of postdischarge wound complications was seen for amputations at all levels. Henry et al reported similar results at their institutions, with 52.8% of 30-day readmissions taking place for issues related to amputation and peripheral arterial disease. Interestingly, guillotine amputations were seen to have decreased readmission rates relative to non-guillotine amputations, which may be attributable to a 2.5-fold increase in SSI for non-guillotine amputations. However, guillotine amputations, whether later revised in the operating room or allowed to heal secondarily with a negative pressure dressing, often dramatically delay patients' return to function, and as such, this approach must be weighed carefully. A 2011 report by Hasanadka et al[21] that reviewed the NSQIP for risk factors of SSI found elevated preoperative international normalized ratio and smoking status to be the lone modifiable risk factors for wound infection. These findings further emphasize the critical importance of preoperative smoking cessation while also highlighting the necessity for excellent intraoperative hemostasis to avoid hematoma in this population already at high risk for SSI.

Any discussion of readmission necessarily involves assessment of the appropriateness of hospital length of stay as this is thought to provide a counterbalance to the incidence of readmission. In the NSQIP cohort, increased length of stay was correlated with a decreased risk of readmission (Table III). However, given that readmissions occurred at a mean of 11 days (SD ± 7) after discharge and NSQIP follow-up ends at 30 days after surgery, a longer length of stay shortens the postdischarge follow-up for these patients, thus resulting in a decreased likelihood of readmission. For this reason, length of stay was excluded from our multivariable model. Of note, Medicare readmission penalties are assessed for readmission within 30 days of hospital discharge, whereas the NSQIP follows patients only for 30 days after their index operation.[2,15] Thus, this data set is unable to provide accurate estimates about the effect of hospital stay duration on readmission risk. However, as noted in the Results section, postdischarge wound infections were diagnosed, on average, more than a week after leaving the hospital, and postdischarge mortality occurred approximately 10 days after discharge. Although this certainly argues for close postoperative follow-up, it is unclear whether marginal increases in length of stay would provide a benefit with respect to the development of these complications.

The findings of this study must be interpreted in the context of the study design. The NSQIP database provides data de-identified at the patient, institutional, and regional levels, which precludes the investigation of institutional and regional variation in readmission. Future studies using alternative data sources may provide valuable insight through the identification of high-performing centers and their best practices. The database also does not include information such as insurance type or median zip code income to assess the impact of socioeconomic factors on readmission. However, as a prospectively collected, multicenter, clinical database whose methodology includes direct patient contact within 30 days, the NSQIP database has the particular strength of capturing readmissions to both the operating institution and others. Whereas the NSQIP database did collect readmission indication in 2012, it did so only for readmissions deemed related to the index procedure, approximately half of unplanned readmissions. As the relationship of certain systemic complications to the index procedure is highly subjective, future iterations of the NSQIP may consider including readmission indication for all readmitted patients.

CONCLUSIONS

This study represents the first and largest report from a multicenter clinical database on the incidence of and risk factors for readmission after LEA. With one in five patients rehospitalized after LEA, we have shown readmission to be common, and given its association with a twofold increase in mortality, we have also shown readmission to be incredibly costly to our patients. Risk factors for readmission include patient characteristics as well as the occurrence of reoperation on index admission. Whereas indications for readmission require further study, we have shown that a majority of readmissions are related to wound complications. Strategies to mitigate postoperative readmission should place particular attention on preoperative optimization of comorbid illness with an emphasis on smoking cessation and intraoperative factors to prevent both wound complications and reoperation.

AUTHOR CONTRIBUTIONS

Conception and design: MS, TC
Analysis and interpretation: MS, TC, JQ, RL, MF, JM, DB, JD
Data collection: TC, JQ, JD, JM
Writing the article: TC
Critical revision of the article: MS, TC, JQ, RL, MF, JM, DB, JD
Final approval of the article: MS, TC, JQ, RL, MF, JM, DB, JD
Statistical analysis: TC
Obtained funding: MS, TC
Overall responsibility: TC

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