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Assessment of Risk Factors Correlated with Outcomes of Traumatic Lower Extremity Soft Tissue Reconstruction

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Background: Identifying risk factors for traumatic lower extremity reconstruction outcomes has been limited by sample size. We evaluated patient and procedural characteristics associated with reconstruction outcomes using data from almost four million patients.

Methods: The National Trauma Data Bank (2015–2018) was queried for lower extremity reconstructions. Univariable and multivariable analyses determined associations with inpatient outcomes.

Results: There were 4675 patients with lower extremity reconstructions: local flaps (77%), free flaps (19.2%), or both (3.8%). Flaps were most commonly local fasciocutaneous (55.1%). Major injuries in reconstructed extremities were fractures (56.2%), vascular injuries (11.8%), and mangled limbs (2.9%). Ipsilateral procedures prereconstruction included vascular interventions (6%), amputations (5.6%), and fasciotomies (4.3%). Postoperative surgical site infection and amputation occurred in 2% and 2.6%, respectively. Among survivors (99%), mean total length of stay (LOS) was 23.2 ± 21.1 days and 46.8% were discharged to rehab. On multivariable analysis, vascular interventions prereconstruction were associated with increased infection [odds ratio (OR) 1.99, 95% confidence interval (CI) 1.05–3.79, $P = 0.04$], amputation (OR 4.38, 95% CI 2.56–7.47, $P < 0.001$), prolonged LOS (OR 1.59, 95% CI 1.14–2.22, $P = 0.01$), and discharge to rehab (OR 1.49, 95% CI 1.07–2.07, $P = 0.02$). Free flaps were associated with prolonged LOS (OR 2.08, 95% CI 1.74–2.49, $P < 0.001$).

Conclusions: Prereconstruction vascular interventions were associated with higher incidences of adverse outcomes. Free flaps correlated with longer LOS, but otherwise similar outcomes. Investigating reasons for increased complication and healthcare utilization likelihood among these subgroups is warranted. *(Plast Reconstr Surg Glob Open 2023; 11:e4961; doi: 10.1097/GOX.0000000000004961; Published online 26 April 2023.)*

INTRODUCTION

Lower extremities are the most commonly injured body region, occurring in over 40% of trauma patients in North America.[1] Salvaging limbs with extensive soft tissue damage may require reconstruction with pedicled or free flaps.[2] Complications of traumatic lower extremity soft tissue reconstruction include flap infection and failure, often requiring amputation.[2] Poor outcomes may be due to vascular injuries and flap type.[2–4] Whether risk factors for flap complications in other body regions, including older age, bleeding disorders, tobacco use, gender, and obesity, exhibit similar associations with flap outcomes after traumatic lower extremity soft tissue reconstruction is unclear.[5–9]

Analysis of patient comorbidities, injury characteristics, and hospital factors associated with traumatic lower extremity soft tissue reconstruction outcomes is limited. Previous studies were small, single-center series, infrequently risk-adjusted, and broadly included upper and lower extremities.[2–4] Improved understanding of risk

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factors for infection and amputation may guide surgeons in counseling patients and determining appropriate reconstruction candidates.

The American College of Surgeons National Trauma Data Bank (NTDB) is the largest multicenter registry of trauma patients in North America and documents performance of lower extremity soft tissue reconstruction. Among patients treated with lower extremity soft tissue reconstruction, the NTDB provides granular details regarding medical history, injuries, vital signs on presentation, subsequent in-hospital interventions, and complications. Our aim was to evaluate whether patient, hospital, and procedural characteristics are associated with worse outcomes. Our primary outcomes were surgical site infection (SSI) and amputation. Secondary outcomes were prolonged length of stay (LOS) and discharge to home versus rehabilitation facilities.

Takeaways

Question: Which patient and procedural characteristics are associated with worse traumatic lower extremity soft tissue reconstruction outcomes?

Findings: In a retrospective analysis of the largest North American trauma registry, there were 4675 patients with lower extremity reconstructions: local flaps (77%), free flaps (19.2%), or both (3.8%). Vascular interventions before reconstruction were independently associated with increased surgical site infection, amputation, length of stay, and discharge to rehab. Free flaps were associated with prolonged length of stay.

Meaning: In the largest multicenter study of patients undergoing traumatic lower extremity soft tissue reconstruction, risk factors for adverse outcomes and healthcare utilization were identified, which surgeons should consider.

METHODS

The The American College of Surgeons NTDB was queried from January 1, 2015 to December 31, 2018. This registry provides demographics, comorbidities, procedural details, and inpatient outcomes for patients presenting after trauma to over 700 academic and nonacademic medical centers in North America.[1] Clinical abstractors prospectively collected these data. The Boston University institutional review board approved and classified this study as “non-human” subjects research. Patient consent was not required.

Patient Selection

Among 3,924,126 records, we included records for patients who underwent lower extremity soft tissue reconstruction with local or free fasciocutaneous or muscle flaps (n = 4675). We used International Classification of Diseases, 10th Revision, Procedure Coding System (ICD-10-PCS) codes, implemented on October 1, 2015, to identify lower extremity reconstructions (Table 1).[10] Previous ICD coding system versions did not specify laterality and, therefore, were not used. We excluded patients without ICD-10 codes for lower extremity soft tissue reconstruction with local or free fasciocutaneous or muscle flaps (n = 3,923,583). Given differences in comorbidities, anatomy, physiology, and trauma evaluation approach between pediatric and adult patients, we excluded pediatric patients aged younger than 18 years (n = 543).

Covariates

Covariates evaluated were patient demographics, including age, sex, race, primary payer (private, public, self-pay); baseline comorbidities, including obesity (body mass index ≥30), functional dependence (partial or complete dependence upon caretakers or equipment to conduct some or all activities of daily living), any anticoagulant use or bleeding disorder, active smoking, chronic obstructive pulmonary disease, diabetes, chronic renal failure, congestive heart failure, hypertension, coronary artery disease, peripheral arterial disease, substance use disorder; hospital characteristics, including ACS-designated trauma level (level 1 to 3 in order of higher to lower hospital capacity to manage trauma[11]); and trauma characteristics, including mechanism of injury (blunt, stab wound, firearm), transfer from outside acute care facility status, and initial vital signs and total Glasgow Coma Scale score.[12]

Baseline injury characteristics evaluated were total Injury Severity Score (ISS; determined based on the three most severe injuries in three body regions, with a score more than 15 corresponding to major trauma[13]), as well as injury type and severity identified using Abbreviated Injury Scale codes (Table 1). Injuries queried were those to the head, spine, abdomen, and pelvis [any type (soft tissue, vascular, nerve, skeletal)]. Abbreviated Injury Scale grade severity is classified as minor, moderate, serious, severe, critical, or maximal based on global consensus.[14]

Lower extremity reconstruction procedural details included flap type (local, free), reconstruction location (hip, upper leg, lower leg, foot), tissue utilized for reconstruction (fasciocutaneous, muscle), and time from presentation to reconstruction. Ipsilateral leg injuries diagnosed on admission, identified using ICD-10-Clinical Modification codes, included fracture (closed, Gustilo I–II, Gustilo III[15]), vascular injury, and mangled limb (Table 1). Ipsilateral leg procedures before reconstruction, identified using ICD-10-PCS codes and NTDB documentation of procedure timing relative to presentation, included suprainguinal and infrainguinal open vascular operations (endarterectomy, bypass, or repair, including suture- or patch-repair) or endovascular interventions; fasciotomy; and amputation (above or below knee, foot/toe) (Table 1). Other procedural characteristics evaluated included blood transfusions less than 4 hours of hospital arrival; therapeutic embolization or operation less than 24 hours of hospital arrival for hemorrhagic control (laparotomy, thoracotomy, extremity, neck, other skin/soft tissue); and venothromboembolism prophylaxis use.

Inpatient outcomes included NTDB indicators of SSI, prolonged total LOS among survivors [greater than

Table 1. Diagnosis and Procedure Codes

Diagnosis or Procedure	Code Type	Code
Lower extremity reconstruction	ICD-10-PCS	Lower extremity reconstruction codes beginning with 0KRN, 0KXN, 0KRQ, 0KRS, 0KXQ, 0KXS, 0HXH, 0HXK, 0JRL, 0JRN, 0JXL, 0JXN, 0KRV, 0KXV, 0HXM, 0JRQ, 0JXQ, 0KRP, 0KXP, 0KRR, 0KRT, 0KXR, 0KXT, 0HXJ, 0HXL, 0JRM, 0JRP, 0JXM, 0JXP, 0KRW, 0KXW, 0JRR, 0JXR
Head injury	AIS 2005	Codes 100099 to 161013
Spinal injury	AIS 2005	Codes 600099 to 650699
Abdominal injury	AIS 2005	Codes 500099 to 545699
Pelvic injury	AIS 2005	Codes 856100 to 856272
Leg fracture	ICD-10-CM	Codes beginning with S72 and S82
Leg vascular injury	ICD-10-CM	Codes beginning with S75 and S85
Mangled leg	ICD-10-CM	Codes beginning with S78 and S88
Leg amputation	ICD-10-PCS	Leg amputation codes beginning with 0Y6
Endovascular intervention	ICD-10-PCS	All suprainguinal and infrainguinal endovascular intervention codes beginning with 047, 04C, 04V, and 047
Any open suprainguinal operation	ICD-10-PCS	All open suprainguinal bypass, endarterectomy, and repair codes beginning with 04R, 041, 031, 04C, 04S, 04U, and 04Q
Any open infrainguinal operation	ICD-10-PCS	All open infrainguinal bypass, endarterectomy, and repair codes beginning with 041, 04R, 04C, 04Q, 04U, and 04S
Lower extremity fasciotomy	ICD-10-PCS	All fasciotomy codes beginning with 0J8

AIS 2005, Acute Injury Scale, 2005 update; ICD-10-CM, International Classification of Diseases, Tenth Revision, Clinical Modification.

the median LOS (17.7 days) as described previously[16,17]], discharge to rehabilitation facilities versus home as an indirect measure of functional outcome,[18] and mortality. Ipsilateral amputation after reconstruction was determined using ICD-10-PCS codes and time-to-procedure variables.

Statistical Analysis

Covariates and outcomes were reported as categorical variables, n (%), or continuous variables, mean ± standard deviation and median with interquartile range, as appropriate. Multivariable logistic regression evaluated factors independently associated with outcomes. The models included variables found to be statistically different in unadjusted analyses (using a P value < 0.5). Backward elimination at the 0.5 level reduced the models. The relationships were expressed as adjusted odds ratios (ORs) with corresponding 95% confidence intervals (CI). A P value less than 0.05 was set as statistically significant. All analyses were performed using SAS 9.4 (SAS Institute Inc, Cary, N.C.).

RESULTS

Demographics and Comorbidities

We identified 4675 patients who underwent traumatic lower extremity soft tissue reconstruction. Overall, mean age was 43.4 ± 17 years and most patients were men (74%), White (66.7%), and received public insurance or were uninsured (51.8%) (Table 2). Approximately one third were obese (35.2%) and over a quarter were active smokers (28.2%). Most patients presented to level-1 trauma centers (73.4%) after blunt injuries (86.9%) with an average total ISS of 14.4 ± 10.5, indicating minor trauma. Concurrent at least moderate Abbreviated Injury Scale severity injuries to the head, spine, abdomen, or pelvis were 14% or less.

Characteristics of Ipsilateral Extremity Injuries and Interventions before Reconstruction

Extremity injuries ipsilateral to the reconstruction included leg fractures [closed (22.5%), Gustilo I–II (20.8%), and Gustilo I–II (12.9%)], vascular injuries (11.8%), and mangled limbs (2.9%) (Table 2). Ipsilateral vascular injuries resulting in intervention occurred in 6%. Open infrainguinal vascular operations were most common (5.3%), followed by endovascular interventions (0.9%) and open suprainguinal operations (0.2%). Ipsilateral leg fasciotomy and surgical amputation occurred in 4.3% and 5.9%, respectively. The most common amputation was below-knee (3.6%).

Procedural Details and Inpatient Outcomes

Mean time to reconstruction after presentation was 9.3 ± 10.6 days (Table 3). Lower extremity reconstructions were only local flaps in 77%, only free flaps in 19.2%, or both in 3.8%. Local flaps were more commonly fasciocutaneous than muscle (73.7% versus 26.3%, respectively). Free flaps were more commonly fasciocutaneous than muscle (84.5% versus 15.5%, respectively). Skin grafts were used in 44.8%. Lower legs were the most common region reconstructed (71.9%), followed by upper legs (29.6%), feet (15.1%), and hips (0.7%). Outcomes (Table 4) were SSI (2%), ipsilateral amputation after reconstruction (2.6%) with below-knee amputation being the most common (1.4%), discharge to a rehabilitation facility rather than home (46.8%), and death (1%). The average LOS among survivors was 23.2 ± 21.1 days.

Multivariable Analysis of Inpatient Outcomes

On multivariable analysis, increased SSI was associated with fasciotomy (OR 2.53, 95% CI 1.23–5.19, P = 0.01), vascular intervention before reconstruction (OR 1.99, 95% CI 1.05–3.79, P = 0.04), non-White race (OR 1.59, 95%

Table 2. Baseline Characteristics of Patients Undergoing Lower Extremity Reconstruction

Characteristic	Overall (N = 4675)
Age, y (mean ± SD)	43.4 ± 17
Men	3458 (74%)
White	3119 (66.7%)
Primary payer	
Private/commercial	2170 (46.4%)
Public	1833 (39.2%)
Uninsured	587 (12.6%)
Obese	1644 (35.2%)
Functional dependence	94 (2%)
Anticoagulant use/bleeding disorder	169 (3.6%)
Active smoking	1319 (28.2%)
Chronic obstructive pulmonary disease	192 (4.1%)
Diabetes	448 (9.6%)
Chronic renal failure	25 (0.5%)
Congestive heart failure	63 (1.3%)
Hypertension	997 (21.3%)
Coronary artery disease	29 (0.6%)
Peripheral arterial disease	22 (0.5%)
Substance use disorder	494 (10.6%)
Level I trauma center	3431 (73.4%)
Blunt injury	4061 (86.9%)
Stab injury	103 (2.2%)
Firearm injury	398 (8.5%)
Transferred from outside facility	1055 (22.6%)
Initial systolic blood pressure, mm Hg (mean ± SD)	129.7 ± 28.2
Initial total Glasgow Coma Scale (mean ± SD)	13.5 ± 3.5
Total Injury Severity Score (mean ± SD)	14.4 ± 10.5
Concurrent at least moderate head injury	635 (13.6%)
Concurrent at least moderate spinal injury	636 (13.6%)
Concurrent at least moderate abdominal injury	525 (11.2%)
Concurrent at least moderate pelvic injury	552 (11.8%)
Ipsilateral closed leg fracture	1053 (22.5%)
Ipsilateral Gustilo I–II leg fracture	974 (20.8%)
Ipsilateral Gustilo I–II leg fracture	605 (12.9%)
Ipsilateral leg vascular injury	551 (11.8%)
Ipsilateral mangled leg	134 (2.9%)
Ipsilateral any endo- or open vascular intervention before reconstruction	281 (6.0%)
Ipsilateral any endovascular intervention before reconstruction	44 (0.9%)
Ipsilateral any open vascular intervention before reconstruction	253 (5.4%)
Ipsilateral any open suprainguinal vascular intervention before reconstruction	11 (0.2%)
Ipsilateral any open infrainguinal vascular intervention before reconstruction	247 (5.3%)
Ipsilateral leg fasciotomy before reconstruction	201 (4.3%)
Ipsilateral any level leg amputation before reconstruction	262 (5.6%)
Highest level ipsilateral leg amputation	
Ipsilateral above knee amputation	63 (1.3%)
Ipsilateral below knee amputation	169 (3.6%)
Ipsilateral minor amputation	46 (1.0%)
Angiography with embolization for hemorrhage control	107 (2.3%)
Surgery within 24h for hemorrhage control	715 (15.3%)
Blood transfusion within 4h, units (mean ± SD)	2.8 ± 45.6
Venothromboembolism prophylaxis	4053 (86.7%)

Table 3. Procedural Details of Traumatic Lower Extremity Reconstruction

Characteristic	Overall (N = 4675)
Time to reconstruction, days (mean ± SD)	9.3 ± 10.6
Time to reconstruction, days (median [IQR])	6.5 [2.8–12.1]
Flap type	
Only local flap	3600 (77.0%)
Only free flap	897 (19.2%)
Both local and free flaps	178 (3.8%)
Flap tissue	
Local fasciocutaneous flap	2576 (55.1%)
Free fasciocutaneous flap	917 (19.6%)
Local muscle flap	1446 (30.9%)
Free muscle flap	168 (3.6%)
Flap location	
Hip reconstruction	32 (0.7%)
Upper leg reconstruction	1384 (29.6%)
Lower leg reconstruction	3362 (71.9%)
Foot reconstruction	705 (15.1%)
Skin grafts	2093 (44.8%)

IQR, Interquartile range.

Table 4. Inpatient Outcomes among Patients Undergoing Traumatic Lower Extremity Reconstruction

Characteristic	Overall (N = 4675)
Surgical site infection	92 (2.0%)
Unplanned return to the operating room	240 (5.1%)
Ipsilateral amputation after reconstruction	123 (2.6%)
Ipsilateral above knee amputation after reconstruction	49 (1.0%)
Ipsilateral below knee amputation after reconstruction	66 (1.4%)
Ipsilateral minor amputation after reconstruction	18 (0.4%)
Total length of stay among survivors, days (mean ± SD)	23.2 ± 21.1
Total length of stay among survivors, days (median [IQR])	17.7 [10–29.9]
Discharge to rehabilitation facility	2187 (46.8%)
Inpatient death	46 (1.0%)

CI 1.03–2.5, $P = 0.03$), and higher ISS (OR 1.02, 95% CI 1.01–1.04, $P = 0.01$) (Table 5).

Increased amputation after reconstruction was associated with vascular intervention before reconstruction (OR 4.38, 95% CI 2.56–7.47, $P < 0.001$), foot reconstruction (OR 3.96, 95% CI 2.37–6.62, $P < 0.001$), stab trauma (OR 3.17, 95% CI 1.04–9.68, $P = 0.04$), lower leg reconstruction (OR 3.03, 95% CI 1.68–5.45, $P < 0.001$), mangled leg trauma (OR 3.01, 95% CI 1.41–6.42, $P = 0.01$), hemorrhagic control surgery (OR 2.50, 95% CI 1.5–4.14, $P < 0.001$), diabetes (OR 2.11, 95% CI 1.21–3.68, $P = 0.01$), and higher ISS (OR 1.02, 95% CI 1.01–1.04, $P = 0.01$) (Table 6).

Prolonged LOS was associated with hip reconstruction (OR 3.45, 95% CI 1.06–11.21, $P = 0.04$), hemorrhagic control surgery (OR 2.13, 95% CI 1.64–2.78, $P < 0.001$), free flaps (OR 2.08, 95% CI 1.74–2.49, $P < 0.001$), upper leg reconstruction (OR 2.04, 95% CI 1.64–2.54, $P < 0.001$), lower leg reconstruction (OR 1.89, 95% CI 1.47–2.44, $P <$

Table 5. Multivariable Analysis of SSI among All Patients Undergoing Traumatic Lower Extremity Reconstruction

	OR	95% CI	P
Ipsilateral fasciotomy before reconstruction	2.53	1.23–5.19	**0.01**
Ipsilateral vascular intervention before reconstruction	1.99	1.05–3.79	**0.04**
Total Injury Severity Score, unit	1.02	1.01–1.04	**0.01**
White race	0.63	0.4–0.97	**0.03**
Hip level reconstruction	2.83	0.63–12.71	0.18
Venothromboembolism prophylaxis	2.15	0.67–6.9	0.20
Free flap	1.25	0.77–2.03	0.37

Values in boldface indicate significance at $P < 0.05$.

0.001), foot reconstruction (OR 1.88, 95% CI 1.44–2.45, $P < 0.001$), skin grafts (OR 1.80, 95% CI 1.53–2.11, $P < 0.001$), vascular intervention before reconstruction (OR 1.59, 95% CI 1.14–2.22, $P = 0.01$), closed leg fractures (OR 1.39, 95% CI 1.16–1.68, $P < 0.001$), moderate-to-severe pelvic injury (OR 1.32, 95% CI 1–1.74, $P = 0.047$), Gustilo type I–II fractures (OR 1.30, 95% CI 1.04–1.63, $P = 0.02$), obesity (OR 1.25, 95% CI 1.08–1.46, $P < 0.001$), and higher ISS (OR 1.06, 95% CI 1.05–1.07, $P < 0.001$) (Table 7). Prolonged LOS was less likely with higher Glasgow Coma Scale score (OR 0.92, 95% CI 0.89–0.94, $P < 0.001$), White race (OR 0.81, 95% CI 0.69–0.95, $P = 0.01$), and stab trauma (OR 0.65, 95% CI 0.49–0.87, $P < 0.001$).

Discharge to rehabilitation facilities was associated with mangled leg trauma (OR 2.49, 95% CI 1.51–4.11, $P < 0.001$), bleeding diathesis (OR 20.02, 95% CI 1.25–3.25, $P = 0.004$), closed leg fracture (OR 1.65, 95% CI 1.35–20.01, $P < 0.001$), moderate-to-severe spinal injury (OR 1.63, 95% CI 1.25–2.12, $P < 0.001$), vascular intervention before reconstruction (OR 1.49, 95% CI 10.07–20.07, $P = 0.02$), lower leg reconstruction (OR 1.35, 95% CI 10.09–1.67, $P = 0.01$), Gustilo type I–II fracture (OR 1.30, 95% CI 10.06–1.6, $P = 0.01$), upper leg reconstruction (OR 1.25, 95% CI 10.02–1.53, $P = 0.03$), obesity (OR 1.18, 95% CI 1–1.39, $P = 0.045$), higher ISS (OR 10.07, 95% CI 10.06–10.08, $P < 0.001$), and older age (OR 10.03, 95% CI 10.03–10.04, $P < 0.001$) (Table 8). Discharge to rehabilitation facilities was less likely with higher Glasgow Coma Scale score (OR 0.94, 95% CI 0.91–0.96, $P < 0.001$), interfacility transfer (OR 0.82, 95% CI 0.68–0.99, $P = 0.04$), firearm trauma (OR 0.73, 95% CI 0.53–1, $P = 0.047$), male sex (OR 0.71, 95% CI 0.6–0.85, $P < 0.001$), uninsured status (OR 0.32, 95% CI 0.24–0.41, $P < 0.001$), and level I–II trauma status (OR 0.21, 95% CI 00.05–0.94, $P = 0.04$).

DISCUSSION

In the largest multicenter study of trauma patients undergoing lower extremity soft tissue reconstruction, SSI and ipsilateral amputation were infrequent, occurring in less than 3% of patients, respectively. Prevalence of these complications was less than reported in previous series, partly owing to our larger denominator, shorter follow-up, and inclusion of a broader range of soft tissue trauma severity.[2,4] However, half of surviving patients remained hospitalized for over 2 weeks, and nearly half needed further rehabilitation after discharge. Across all outcomes measured, vascular interventions before reconstruction correlated with higher rates of complications, particularly SSI and amputation, and healthcare utilization. Flap reconstruction types exhibited similar complication risk, but patients with free flaps were more likely to have longer hospital stays.

Vascular interventions before soft tissue reconstruction were independently associated with increased SSI and amputation after reconstruction. Previous smaller series evaluating associations of vascular injuries with reconstruction outcomes demonstrated conflicting results. In a series of 158 traumatic lower extremity fractures treated with soft tissue reconstruction with free (43%) or local flaps, ipsilateral arterial injuries (16.5%) were associated with more amputations, but not with soft tissue infection.[2] Another study of 188 free flaps for traumatic lower extremity reconstruction found that posterior tibial artery injuries (11.5%) were associated with more flap failures and take-backs.[19] An analysis comparing 79 war-related traumatic extremity vascular repairs with subsequent free (43%) or local flap reconstruction (47% in lower extremities) to a cohort of 253 reconstructed extremities without vascular injuries demonstrated no difference in soft tissue infection or amputation.[4] Our multicenter study of

Table 6. Multivariable Analysis of Ipsilateral Amputation after Reconstruction among All Patients Undergoing Traumatic Lower Extremity Reconstruction

	OR	95% CI	P
Ipsilateral vascular intervention before reconstruction	4.38	2.56–7.47	**<0.001**
Foot level reconstruction	3.96	2.37–6.62	**<0.001**
Stab versus blunt trauma	3.17	1.04–9.68	**0.04**
Lower leg level reconstruction	3.03	1.68–5.45	**<0.001**
Ipsilateral mangled leg on presentation	3.01	1.41–6.42	**0.01**
Surgery within 24h for hemorrhagic control	2.50	1.5–4.14	**<0.001**
Diabetes	2.11	1.21–3.68	**0.01**
Total Injury Severity Score, unit	1.02	1.01–1.04	**0.01**
Male sex	1.62	0.96–2.75	0.07
Ipsilateral Gustilo type I–II fracture versus none	1.39	0.88–2.21	0.16
Free flap	1.15	0.73–1.82	0.55
Firearm versus blunt trauma	0.38	0.13–1.1	0.07

Values in boldface indicate significance at $P < 0.05$.

Table 7. Multivariable Analysis of LOS Greater Than the Median among Surviving Patients Undergoing Traumatic Lower Extremity Reconstruction

	OR	95% CI	*P*
Hip level reconstruction	3.45	1.06–11.21	**0.04**
Surgery within 24 hours for hemorrhagic control	2.13	1.64–2.78	**<0.001**
Free flap	2.08	1.74–2.49	**<0.001**
Upper leg level reconstruction	2.04	1.64–2.54	**<0.001**
Lower leg level reconstruction	1.89	1.47–2.44	**<0.001**
Foot level reconstruction	1.88	1.44–2.45	**<0.001**
Skin graft	1.80	1.53–2.11	**<0.001**
Ipsilateral vascular intervention before reconstruction	1.59	1.14–2.22	**0.01**
Ipsilateral closed leg fracture	1.39	1.16–1.68	**<0.001**
At least moderate pelvic injury	1.32	1–1.74	**0.047**
Ipsilateral Gustilo type I–II fracture versus none	1.30	1.04–1.63	**0.02**
Obesity	1.25	1.08–1.46	**<0.001**
Total Injury Severity Score, unit	1.06	1.05–1.07	**<0.001**
Total Glasgow Coma Scale score, unit	0.92	0.89–0.94	**<0.001**
White race	0.81	0.69–0.95	**0.01**
Stab versus blunt trauma	0.65	0.49–0.87	**<0.001**
Angiogram within 24 hours for hemorrhagic control	2.14	0.93–4.95	0.07
At least moderate spinal injury	1.26	0.97–1.62	0.08
Ipsilateral mangled leg on presentation	0.72	0.45–1.15	0.17

Values in boldface indicate significance at $P < 0.05$.

Table 8. Multivariable Analysis of Discharge to Rehabilitation Facility among Surviving Patients Undergoing Traumatic Lower Extremity Reconstruction

	OR	95% CI	*P*
Ipsilateral mangled leg on presentation	2.49	1.51–4.11	**<0.001**
Bleeding disorder/chronic anticoagulation	2.02	1.25–3.25	**0.004**
Ipsilateral closed leg fracture versus none	1.65	1.35–2.01	**<0.001**
At least moderate spinal injury	1.63	1.25–2.12	**<0.001**
Ipsilateral vascular intervention before reconstruction	1.49	1.07–2.07	**0.02**
At least moderate pelvic injury	1.46	1.11–1.93	**0.01**
Lower leg level reconstruction	1.35	1.09–1.67	**0.01**
Ipsilateral Gustilo type I–II fracture versus none	1.30	1.06–1.6	**0.01**
Upper leg reconstruction	1.25	1.02–1.53	**0.03**
Obesity	1.18	1–1.39	**0.045**
Total injury severity score, unit	1.07	1.06–1.08	**<0.001**
Age, y	1.03	1.03–1.04	**<0.001**
Total Glasgow Coma Scale score	0.94	0.91–0.96	**<0.001**
Presented as an interfacility transfer	0.82	0.68–0.99	**0.04**
Firearm versus blunt trauma	0.73	0.53–1	**0.047**
Male sex	0.71	0.6–0.85	**<0.001**
Uninsured versus private insurance	0.32	0.24–0.41	**<0.001**
Level I–II versus Level I trauma center	0.21	0.05–0.94	**0.04**
Coronary artery disease	2.26	0.72–7.06	0.16
Surgery within 24 hours for hemorrhagic control	1.29	0.99–1.67	0.06
Venothromboembolism prophylaxis	1.26	0.94–1.7	0.12
Hypertension	1.24	0.99–1.55	0.06
Diabetes	1.22	0.92–1.61	0.17
Free flap	0.92	0.76–1.1	0.35
Stab versus blunt trauma	0.61	0.33–1.12	0.11

Values in boldface indicate significance at $P < 0.05$.

reconstructed lower extremities after trauma in civilians, however, found that even repaired vascular injuries had weak and moderate associations with SSI and amputation, respectively. Patients with vascular injuries severe enough to warrant repair may have had fewer patent leg vessels or underwent reconstruction using injured vessels.[20] Prior single-center reviews of free flaps for Grade I–II-B and -C injuries demonstrated that decreased vessel runoff and anastomosis to injured recipient vessels were associated with increased total flap failure risk.[21,22] Additionally, redistribution of blood flow after free or local flap reconstruction in extremities with already compromised vasculature may have inhibited wound healing and resulted in incident infection and amputation.[23] Extremity complications may have prolonged LOS and increased utilization of rehabilitation services after discharge among patients with repaired vascular injuries.

We found that local and free flap types for traumatic lower extremity reconstruction were associated with similar risk of SSI and amputation. Prior single-center studies comparing extremity complications between local and free flaps for traumatic extremity reconstruction yielded variable results. A previous series comparing 23 local and 17 free flaps in patients with open tibial or ankle fractures found no significant difference in infection or below-knee amputation within three years.[24] Similarly, a study of 43 local and 180 free flaps found no difference in early complications requiring reintervention.[25] A study comparing 88 rotational and 107 free flaps for primarily open tibial fractures found overall no difference in wound infections or flap loss; however, in the setting of more severe bone injury, rotational flaps were more likely to be associated with wound complications resulting in operative reintervention within 6 months.[26] In our study, reconstruction was performed after a longer period from presentation (mean 9 days versus 7 days in Pollak et al[26]). Local reconstruction after more complete delineation of the zone of injury may explain why we did not observe worse outcomes with this reconstruction technique. Another study of 15 combat-related traumatic lower extremity vascular repairs with subsequent reconstruction (three free flaps) found that five amputations over 16 months were in extremities reconstructed with pedicled flaps.[27] However, the study was not risk-adjusted, nor was it representative of the reconstructive experience in the civilian population.

Free compared with local flaps were more likely to be associated with prolonged LOS. Previous unadjusted analysis of LOS among patients undergoing traumatic extremity reconstruction showed no difference between flap types.[26] However, analysis of matched free and local flap patient cohorts undergoing reconstruction for traumatic and nontraumatic indications demonstrated longer LOS among the free flap cohort.[28] The longer LOS after traumatic-only free flap reconstruction in our risk-adjusted model may relate to postoperative free flap monitoring protocols that were not available in the dataset and could not be adjusted for.[29] We could not distinguish between one- and two-stage pedicled flap reconstruction in the NTDB. The latter requires a second operation to divide the pedicle and may entail a longer LOS than free flap reconstruction. However, two-stage pedicled flap reconstruction is rarely performed.[30] In patients who are candidates for both free and local flap reconstruction, providers may weigh the similar perioperative complication risks against the longer LOS with free flaps which can increase healthcare cost.[26]

Modifiable and nonmodifiable patient and hospital characteristics were associated with traumatic lower extremity reconstruction outcomes. Non-White race had a small correlation with wound infection. Previous single-center studies found no association between race and infection after traumatic extremity reconstruction or operatively treated tibial fractures.[31,32] Increased SSI among non-White patients in our study may relate to inadequate access to preventive care resulting in chronic comorbidities that increased susceptibility to infection.[33] Furthermore, physician bias and misperception of the severity of their minority patients' injuries may have been a factor.[34] Diabetes had a small association with limb loss after reconstruction, which is consistent with findings in prior single-center series of patients undergoing free flaps to traumatic injuries and chronic wounds.[20,35,36] However, in our study, this association persisted even after adjustment for comorbidities and regardless of flap type. While prior meta-analysis demonstrated more complications among patients with lower extremity injuries in general admitted directly to tertiary centers versus transferred to tertiary centers from nontertiary centers, we found that patients transferred to hospitals with higher level trauma accreditation status experienced decreased likelihood of needing rehabilitation after reconstruction.[37] Patients with extremity trauma necessitating reconstruction may exhibit functional benefits from the orthopedic and plastic surgeon collaborative approach to reconstruction available at specialized trauma centers.[38] Although surgeons may not have the opportunity to control patient comorbidities before reconstruction, providers treating patients with lower extremity injuries should increase their efforts to treat diabetes and consider transfer of patients to specialized trauma centers with orthoplastics expertise.

Our study had several limitations. Granular details regarding intervention time relative to injury time, specific blood vessel injuries in reconstructed extremities, Gustilo I–II subcategories, patient candidacy for local versus free flaps, surgeon specialty (eg, trauma, plastic, orthopedic surgery), use of multidisciplinary orthoplastic approach to care, flap construction (eg, preoperative vascular imaging, defect size to be covered, specific donor muscle used, skin graft donor site, free flap target vessels, and anastomosis technique), flap monitoring, negative pressure wound therapy, or postoperative antiplatelet or therapeutic anticoagulation use—all of which may affect reconstruction outcomes—could not be determined retrospectively.[39] Given the lack of hospital or surgeon identifiers in the NTDB, inter-facility or -surgeon variation in approach to reconstruction could not be adjusted for. Flap-specific outcomes (eg, flap necrosis, sensory deficits, performance of salvage procedures on the flap) and functional outcomes (eg, ambulatory status) were not available. SSI and amputation may have presented late in our study population; however, the database did not capture readmissions or long-term complications after the index hospitalization. Despite the limitations, our study identified independent risk factors for complications that may guide physicians considering offering lower extremity soft-tissue reconstruction. Further prospective analysis is warranted to determine whether high-risk groups benefit from lower extremity reconstruction compared with amputation and prosthesis.

CONCLUSIONS

Traumatic lower extremity soft tissue reconstructions in the NTDB were most frequently local flaps with favorable outcomes. However, vascular intervention before reconstruction was associated with higher incidence of SSI, amputation, prolonged LOS, and discharge to rehabilitation facilities. Patients requiring vascular interventions may have experienced more severe trauma predisposing to complications. Free flap reconstruction correlated with longer hospital stay. Patient factors, including race and diabetes, were associated with poorer outcomes and may be considered in risk-benefit analysis. Future studies evaluating lower extremity reconstruction outcomes should clarify why high-risk cohorts identified in this study are at increased risk of complications and healthcare utilization.

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DISCLOSURE

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