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Limb Salvage Does Not Predict Functional Limb Outcome after Revascularization for Traumatic Acute Limb Ischemia

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Background: Traumatic vascular injury leading to acute limb ischemia (ALI) is an uncommon problem with a potential for high morbidity. We describe a contemporary series of patients with traumatic ALI managed primarily by vascular surgeons at a tertiary referral center and review factors associated with limb salvage and functional limb outcomes.

Methods: We conducted a single institution, retrospective review of all patients requiring revascularization for upper extremity (UE) and lower extremity (LE) ALI secondary to trauma from 2013 to 2016. Demographic data, transfer timing, injury severity score (ISS), Rutherford classification (RC), preoperative imaging, level of occlusion, procedural information, fasciotomy characteristics, and discharge disposition were reviewed. Outcome measures included limb salvage and functional limb outcomes.

Results: We identified 68 patients with traumatic ALI requiring revascularization. The majority of patients had moderate ISS scores, were RC 2a or 2b on presentation (65%), were transferred from another institution (53%), and underwent preoperative imaging (62%) with expeditious time to operation (median 4.5 hr). The most common location of vascular injury for UE was axillary-brachial (88%) and for LE was femoral-popliteal (69%). Open vascular procedures dominated the treatment strategy, and the median number of operations was 3. Fasciotomy was performed in 25% of UE and 58% of LE injuries. Shunts were utilized in only 2 patients. Overall LS was 94% for UE and 78% for LE. The median length of stay (LOS) was 11 days, with 25% of patients discharged to a skilled nursing facility. Follow-up was obtained for 59% of patients. For UE injuries, 57% of patients had no or minimal functional deficits, while 33% had major functional deficits and 10% underwent amputation. For LE injuries, 68% of patients had no or minimal functional deficits, while 6% had major functional deficits, and 26% had undergone amputation. Rutherford class and the number of operations performed were independent predictors of amputation and functional limb at follow-up in our logistic regression model ($P < 0.05$).

Conclusions: Revascularization for traumatic ALI yields high limb salvage rates in patients with RC 1 and 2 ischemia and patients with UE injuries. However, limb salvage does not necessarily equate to good functional outcomes. This signifies the complex nature of injuries in this patient population, especially when multiple operations are required.

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Declarations of interest: None.

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INTRODUCTION

Traumatic acute limb ischemia (ALI) is an uncommon phenomenon with a high potential for significant morbidity and mortality. Historically, approximately 2% of all trauma admissions have involved vascular injury.[1,2] An even smaller number will be candidates for revascularization: Recent data from the American Association for the Surgery of Trauma PROOVIT registry identified only 266 operative vascular injuries distributed to 14 major trauma centers over a period of nearly 2 years.[3] Scholarship of this patient population often requires many years of patient data collection or a large database review and has historically focused on limb salvage as a surrogate for functional outcome. Recent efforts—particularly in the military literature—have emphasized the utility of patient-centered functional outcomes.[4] Based on our high-volume experience at a large tertiary referral center, we present a unique, 3-year snapshot of patient-centered traumatic ALI outcomes in the endovascular era.

An important subtext to this effort is the ever-increasing role of the vascular surgeon as the sole operator available to provide extremity revascularization at a given institution. In our series, vascular reconstruction or repair was performed by vascular surgeons in all cases. Within this context, the purpose of this study was to analyze limb salvage and its relation to functional outcomes in a series of civilian patients with traumatic ALI requiring revascularization.

MATERIAL AND METHODS

Harborview Medical Center serves as the only level I trauma center for a five-state region encompassing a large geographic region of the Pacific Northwest and Rocky Mountain West (WA, AL, MT, ID, WY). Trauma admissions average 6,000 per year, with 38% having an Injury Severity Score IISS) greater than 15.[5] Long transport times and wide variations in disposition pose a significant challenge for initial management and follow-up. In our series, 53% of patients were transferred from an outside facility, with median transport time of approximately 3 hr and a median time to the operating room of 4.5 hr.

We conducted a retrospective review of all patients requiring revascularization for lower extremity (LE) and upper extremity (UE) trauma-related ALI at a single institution from 2013 to 2016. ALI was defined as hard signs of vascular injury, reduced ABI with an injury demonstrated on noninvasive imaging and pulse deficit with clinical evidence of ALI on physical exam. Interventions included traditional open surgical techniques, endovascular repair, and combination procedures. Our analysis included patient demographics, transfer timing, ISS, Rutherford classification (RC), preoperative imaging, level of occlusion, operative timing, procedural information, fasciotomy characteristics, and discharge disposition. Our study was approved by the University of Washington Institutional Review Board and adhered to established institutional policies.

All patients were treated at a level I trauma center with a tertiary referral base covering a large geographic region. Revascularization was performed by vascular surgeons in every case. Patients with isolated vascular injuries were primarily managed by a vascular surgery service postoperatively. Those with multisystem trauma were routinely managed in a multidisciplinary fashion, involving trauma surgery, orthopedic surgery, plastic surgery, rehabilitation medicine, and podiatry, depending on the extent of injury. Our policy for patients treated via open, endovascular, and hybrid approaches involved prescription of daily aspirin once safe from a hemorrhage standpoint. On discharge, standard postoperative follow-up and graft or stent surveillance were arranged at the treating institution.

Outcome measures included limb salvage during the index hospitalization, length of hospitalization, discharge disposition, and functional status at outpatient follow-up. Limb function was evaluated by review of the electronic medical record by 2 independent reviewers. Patients were stratified into 3 categories: minimal/no function deficits, major functional deficits, or amputation. Patients were considered as having major functional deficits if they were unable to walk independently and unassisted by a mechanical device (e.g., using a walker, cane, or wheelchair).

Continuous variables were expressed in terms of median and interquartile range (IQR) while categorical variables were expressed in percentages. Multivariate logistic and linear regression analyses were performed to correlate variables with primary and secondary outcomes as listed earlier after correcting for patient age and sex. All statistical analyses were performed using JMP 12.0 software (SAS International Inc., Cary NC), and a P value < 0.05 was considered statistically significant.

RESULTS

We identified 68 patients with traumatic ALI requiring revascularization (Table I). The majority of our patients were male, with an average age of

Table I. Patient demographics and injury pattern

	Upper (n = 32)	Lower (n = 36)
Median age in years (IQR)	36 (29–60)	46 (28–62)
Male (%)	81	84
Median ISS (IQR)	13 (9–24)	13 (10–25)
Transferred from another hospital (%)	58	51
Median transfer time in hours (IQR)	2.7 (0.7–9.2)	3.2 (1.5–13.6)
Median time to operating room in hours (IQR)	4.5 (1.9–8.7)	4.5 (2.4–7.0)
Preoperative CT (%)	55	68
Rutherford Classification		
1 (%)	35	19
2a (%)	23	27
2b (%)	39	41
3 (%)	3	14
Venous injury (%)	25	17
Level of injury		
Aortoiliac (%)		3
Femoral-popliteal (%)		69
Tibial (%)		11
Aorto-subclavian (%)	6	
Axillary-brachial (%)	88	
Multilevel (%)	6	17

IQR, Interquartile range; CT, Computed tomography.

36. Sixty-two percent of our patients suffered blunt injury, while 38% suffered penetrating injuries, with a nearly equal distribution of UE and LE involvement. The majority of patients were transferred from another institution (53%), over distances ranging from 4 to 517 miles. Modes of transportation included ground, fixed-wing, and helicopter transport. Median transfer time in hours was 2.7 (0.7–9.2) for UE and 3.2 (1.5–13.6) for LE injuries. Due to the wide variation in transport times, we did not stratify transfer versus nontransfer patients.

On presentation, the majority of our cohort had moderate ISS scores (median 13, range 9–25), and RC 2 (65%), with a median time to operation of 4.5 hr. RC 1 patients represented 26%, and RC 3 patients represented 9% of our cohort. Most UE vascular injuries occurred in the axillary-brachial region (88%), with 6% aorto-subclavian and 6% multilevel. Of LE vascular injuries, 69% were femoral-popliteal, 11% tibial, 3% aortoiliac, and 17% multilevel. Concomitant venous injury was found in 25% of UE and 17% of LE patients (Table I).

As seen in Table II, in both groups, open revascularization predominated (84% UE, 69% LE). The most common method of revascularization was primary repair, representing 44% of UE patients and 39% of LE patients. Arterial reconstruction with bypass was performed with autologous conduit whenever possible, and overall represented 31% of UE and 22% of LE reconstructions. Stents were used relatively infrequently, representing only 3% of UE operations and 8% of LE patients in our series. Stents were not used in any of our hybrid cases, and these were primarily diagnostic or converted to open operations.

The median number of operations was 3, with a range of 1–8. Sequential fasciotomy washouts, operative wound vac changes, debridement, and closure were all included in this number. Concomitant venous injury was treated with ligation in the majority of cases. Temporary arterial shunts were used in two patients, both with severe multisystem injury requiring a staged approach to revascularization. Fasciotomies were required in 25% of UE and 58% of LE injuries (Table II). Amputation was required in 18% of patients during the index hospitalization, with only one undergoing primary amputation. Overall limb salvage (LS) rate was 94% for UE and 78% for LE (Table II). Rutherford class and the number of operations performed were independent predictors of amputation and functional limb at follow-up in our logistic regression model ($P < 0.05$).

Consistent with overall injury severity, median LOS was 11 days, with 25% of patients being discharged to a skilled nursing facility. Only 2 of 68 patients died, both as a result of severe multisystem trauma. Overall rate of follow-up was 59%. This cohort was divided into UE and LE revascularization. In the UE cohort, 33% had major functional deficits and 10% had undergone amputation. In the LE cohort, 6% had major functional deficits and 26% had undergone amputation.

DISCUSSION

Changes in treatment paradigms with the advent of increasing endovascular techniques in vascular trauma underscore the need for more contemporary data incorporating multiple treatment modalities.[2] Our 4-year study cohort of 68 patients represents a robust sample size over a short period of time. Encompassing patients treated from 2013 to 2016, it also provides a timely snapshot of current treatment paradigms in the endovascular era.

Amputation rates were low, despite evidence suggesting prolonged ischemic times in this cohort. Our UE limb salvage rate of 94% is consistent with contemporary series, which have demonstrated

Table II. Operative details and limb salvage

	Upper ($n = 32$)	Lower ($n = 36$)
Median number of operations performed (IQR)	3 (2–4)	3 (3–5)
Rutherford 1	2 (1–3)	3 (1–4)
Rutherford 2a	3 (2–4)	4 (3–6)
Rutherford 2b	3 (1–7)	4 (3–8)
Rutherford 3	3 (3–3)	3 (2–5)
Type of procedure		
Open (%)	84	69
Bypass	31	22
Primary repair	44	39
Ligation	9	8
Endovascular (%)	9	17
Stented	3	8
Hybrid (%)	6	14
Fasciotomy (%)	25	58
Limb salvage overall (%)	94	78
LS for Rutherford 1 (%)	100	100
LS for Rutherford 2a (%)	100	80
LS for Rutherford 2b (%)	92	80
LS for Rutherford 3 (%)	0	40

IQR, Interquartile range; ISS, Injury severity score; LS, Limb salvage.

consistently high rates ranging from 94 to 98%.[6–8] Similarly, the 78% lower extremity limb salvage rate we demonstrate is comparable to the modern experience. In a 10-year, single institution series, Liang et al. reported 87 LE vascular injuries requiring revascularization. Limb salvage rate was 83%.[9] Our data also suggests long ischemic times. Although Rutherford ALI classification was not specifically developed for trauma patients, it remains a commonly understood and standardized barometer for the severity of ischemic changes on presentation. The majority of our patients presented with Rutherford Class 2 ischemia, including 68% of lower extremity injuries. This trend is further reflected in our relatively high lower extremity fasciotomy rate of 58%. In contrast, Franz et al. reported a 38% lower extremity fasciotomy rate for operative arterial injuries in patients presenting to an urban level I trauma center.[10] Even though their study was directed toward popliteal artery injuries specifically—which suggests significant risk for limb ischemia—Mullenix et al.[11] reported an overall fasciotomy rate of 49% in a review of the National Trauma Data Bank. How do we explain these differences? One surprising factor in our data was the relatively small volume of patients (2) with intravascular shunts. Coupled with the high proportion of transfers and wide variation in practice in our region, prolonged ischemia time due to inability or reluctance to shunt may have contributed to longer ischemic times and higher fasciotomy rates in our series. Based on our experience, we argue for a lower threshold for immediate, ''damage control'' revascularization via shunt at the initial point of evaluation.

Consistent with historical data regarding traumatic extremity arterial injury, in our study, open surgical repair represented the mainstay of treatment. Only 17% of LE injuries and 9% of UE injuries were treated with primary endovascular procedures. Hybrid approaches represented 14% and 6% of operations, respectively. In an 8-year review of the NTDB ending in 2010, Branco et al. showed that the vast majority of extremity arterial injuries in this period were treated with traditional open repair. However, there was a significant trend toward increasing endovascular intervention for treatment of iliac artery injuries, and patients treated with endovascular means had improved in-hospital mortality rates.[2] Clearly, endovascular treatment for extremity arterial trauma is a viable option.

Our 59% rate of follow-up is consistent with prior studies of revascularization for traumatic injuries.[8,12]

In most modern series, outcome measures during follow-up have frequently centered on limb salvage or graft patency. Long-term functional status after revascularization for traumatic ALI has been less extensively studied. A notable exception is the work done by Frech and colleagues for UE injuries. Their study used the DASH questionnaire, a 30-question survey given to patients postoperatively, to identify factors influencing decreased functional status. Patients with associated nerve injury had a worsened functional status.[8]

There are a number of limitations to our study. Our data were collected in a retrospective fashion from patient charts, which may have contained incomplete, inaccurate, or missing details. Documentation of physical exam findings, for example, may vary with different physicians. Operative reports may leave out important details about the appearance of tissues and presence of vein injury. Second, as discussed previously, traumatic vascular injury often involves concomitant nerve injury, which makes the initial physical exam difficult to interpret and Rutherford ALI classification an imperfect measure of ischemia in this setting. Third, the sheer size of our catchment area presents a unique set of challenges. Long transport times coupled with a low rate of prearrival intravascular shunting may have had an adverse effect on ischemia time and patient outcomes. Furthermore, wide variations in geographic distance between our center and our patient's homes likely contributed to a lower rate of follow-up and limit our ability to assess long-term rehabilitation.

CONCLUSION

Prompt revascularization for traumatic acute limb ischemia results in high limb salvage rates in patients with upper extremity injuries and lower extremity Rutherford Class 1 and 2 ischemia. Yet good functional outcomes—particularly in the upper extremity—are clearly harder to achieve. Our findings underscore the complexity of these rare but morbid injuries and emphasize the need for close follow-up and timely revascularization.

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