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Contemporary Outcomes of Civilian Lower Extremity Arterial Trauma

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Abstract

Objectives—Lower extremity arterial injury may result in limb loss following blunt or penetrating trauma. The purpose of this study is to examine outcomes of civilian lower extremity arterial trauma and predictors of delayed amputation (DA).

Methods—The records of patients presenting to a major level I trauma center from 2004-2014 with infrainguinal arterial injury were identified from a prospective institutional trauma registry and outcomes were reviewed. Standard statistical methods were used for data analysis.

Results—149 patients were identified (mean age 33±14, 86% male); 46% presented with blunt trauma. 19(13%) had common femoral (CFA), 26(17%) superficial femoral (SFA), 50(33%) popliteal, and 54(36%) tibial injury. Seven patients underwent primary amputation; of the remainder, 21(15%) had ligation, 85(59%) revascularization (80% bypass grafting, 20% primary repair) and the rest observation. 24(17%) eventually required DA; 20(83%) were due to irreversible ischemia or extensive musculoskeletal damage, despite having adequate perfusion. DA rates were 26% for popliteal, 20% for tibial, and 4.4% for CFA/SFA injury. The DA group had significantly more ($p<0.05$) blunt trauma (79 v. 30%), popliteal injury (46 v. 27%), compound fracture/dislocation (75 v. 33%), bypass graft (63 v. 43%), fasciotomy (75 v. 43%), and higher MESS score (6.1±1.8 v. 4.3±1.6). Predictors of DA included younger age, higher injury severity score, popliteal or multiple tibial injury, blunt trauma, and pulseless exam on presentation.

Conclusions—Individualized decision making based on age, mechanism, pulseless presentation, extent of musculoskeletal trauma and location of injury should guide intensity of revascularization strategies after extremity arterial trauma. While patients presenting with vascular trauma in the setting of multiple negative prognostic factors should not be denied revascularization, expectations for limb salvage in both the short and long-term periods should be carefully outlined.

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INTRODUCTION

Arterial injury to the lower extremity (LEAI) in trauma patients has the potential to progress to ischemia and limb loss if not promptly recognized and treated. LEAI has been more incident, and therefore studied more extensively, in military cohorts due to the high incidence of high-energy penetrating and blast wounds. In cases where there is severe damage or prolonged ischemia, primary amputation is often performed at the discretion of the trauma team. Patients who do not require an immediate primary amputation, however, may continue on to require a delayed amputation as a result of irreversible or progressive ischemia, extensive unreconstructable soft tissue or skeletal damage, or electively for intractable pain or nonfunctional limb.

The literature on civilian arterial traumatic injuries may not reflect contemporary vascular open and endovascular management, as well advances in medical and anesthetic care. Few retrospective studies comprising few cases from US trauma centers exist secondary to the low rate of LEAI among urban civilian centers, and may reflect older management paradigms for both trauma and vascular therapy[1,2]. Several epidemiologic studies have reviewed the data available from the National Trauma Data Bank (NTDB)[3–5], but this data is not specific to arterial injury and is limited by selection due to the voluntary nature of the database. Patient selection for revascularization continues to be subjective in patients with extensive associated non-vascular extremity injury. This study examines the outcomes and predisposing factors to delayed amputation in a large cohort of patients presenting to a US tertiary level I trauma center with traumatic lower extremity arterial injury.

METHODS

After institutional review board approval of this study and exemption from informed consent, we used a prospectively collected institutional trauma registry to identify patients presenting to a large tertiary level I trauma center with lower extremity arterial injury from 2004-2014. Medical records were then reviewed and data specific to the injury collected retrospectively. Outcomes included delayed amputation and mortality during the length of hospital stay and within one year. Delayed amputation was defined as the first above or below-knee amputation performed, including guillotine amputations.

Our center’s trauma response system consists of a trauma team of resident physicians, an in-house trauma surgeon and a designated trauma emergency physician. Management decisions such as need for invasive diagnostic testing, revascularization, or primary amputation are formulated jointly by an interdisciplinary team of trauma, vascular, and orthopedic surgeons according to a standardized institutional approach in place for the duration of the study period. All such patients are entered into a prospective trauma registry upon discharge and scheduled for outpatient follow-up with the trauma service and with other vascular or orthopedic specialist visits as necessary depending on injury pattern and any intervention performed.

The decision for limb salvage versus primary amputation in our institution is made at the time of evaluation by the multidisciplinary team. Criteria for consideration of primary amputation include dense ischemia (Rutherford class 3) with greater than 6 hours of ischemic time or bony or soft tissue defects deemed unreconstructable by the orthopedic surgeon; however, despite these guiding criteria, the eventual decision is made on a case-by-case basis after multidisciplinary and, if possible, discussion with the patient and family.

Patients with hard signs of bleeding or ischemic limbs are taken immediately to the operating room for exploration. Intraoperative angiography is immediately available if needed in either a hybrid operating room equipped with fixed imaging or utilizing a portable vascular C-arm. For patients without hard signs of bleeding or with possible vascular injury due to proximity, CT angiography has replaced angiography as the preferred diagnostic modality for ruling out injury. Nonoperative management of vascular injuries consisted of antiplatelet treatment with aspirin and serial neurovascular exams. Arterial injury is defined based on either direct visualization of the injured vessel, or CT or angiographic evidence of at least an intimal defect.

Interventions were classified as surgical ligation, primary repair, surgical bypass, and endovascular coil embolization of major bleeding branches. Surgical ligation was performed proximal and distal to the area of arterial injury. Primary repair was performed as resection and reanastamosis in patients with localized arterial injury requiring less than 2cm of vessel resection and with adequate residual length to avoid undesirable tension. We used contralateral vein whenever possible for surgical bypass procedures; in situations where no vein was available, a prosthetic conduit was used. Tibial vessel injuries were ligated or observed if at least one remaining tibial artery was patent and had adequate runoff, otherwise reconstruction was attempted. Arterial injury with only intimal defects detected on imaging were also treated initially with observation. For combined vascular and orthopedic procedures, the vascular repair was preferentially performed first, with exceptions discussed on a case-by-case basis by the multidisciplinary team. The need for fasciotomy was assessed at the end of the revascularization period and based upon ischemic time and physical exam of the lower extremity. Ischemic time greater than four hours or exam suggesting tense compartments were general criteria in the decision for fasciotomy.

Standard statistical techniques including t-tests, Fisher exact test, and Wilcoxon rank-sum tests were used where appropriate for between-group comparisons. Multivariate logistic and Cox regression was used for binary and time-to-event multivariable analysis.

RESULTS

Over ten years from 2004-2014, our center received 47,640 trauma admissions. Out of these, 149 patients were identified with lower extremity arterial trauma meeting the inclusion criteria for an overall incidence of 0.3%. The mean age of the cohort was 33 ± 14 years, and 86% were male. The proportion of patients with blunt compared to penetrating trauma was 46% (n=68). High-energy blunt trauma, defined as pedestrian vs. motor vehicle or high-speed motor vehicle collision, accounted for 17% (n=25) of the total cohort and 37% of the total blunt trauma cohort. The distribution of vessel injury was 13% in the distal external iliac or common femoral artery (CFA, n=19), 17% in the superficial femoral artery (SFA, n=26), 33% in the popliteal artery (n=50), and 36% tibial injury (n=54). Of those with tibial injury, 11 had injury of more than one tibial vessel (Table I). The in-hospital mortality rate was 5.4% (n=8).

Seven patients were judged to have unsalvageable extremities by the multidisciplinary trauma team and underwent primary amputation. Of the remaining patients, 20% were observed without intervention (n=29), 4.7% received arterial coil embolization only (n=7), 15% underwent operative ligation (n=21), and the rest were revascularized (59%, n=85). The majority of surgical revascularizations were bypass grafts (81%, n=69) with a minority undergoing primary repair (19%, n=17). Intraoperative angiography was used for diagnosis or to guide therapy in 46% of patients (n=69), while 4.1% (n=6) had initial diagnosis of vascular injury by CT angiography.

A minority of patients who underwent attempted limb salvage eventually required delayed amputation (17%, n=24): eighteen patients (12.6%) underwent delayed amputation during the initial hospitalization, while six patients (4.2%) received their amputation electively following discharge. Unadjusted comparison of the delayed amputation and non-amputation groups showed a higher rate of blunt trauma, popliteal injury, fracture, revascularization, fasciotomy, and MESS score in the delayed amputation group (Table I). The majority of delayed amputations occurred despite the presence of adequate extremity perfusion after revascularization due to persistence of ischemic or necrotic tissue ("irreversible ischemia"). Three patients who underwent revascularization experienced bypass graft thrombosis in the immediate postoperative period and required subsequent delayed amputation due to a combination of prolonged ischemia and large soft tissue defects.

Delayed amputation rates by injury location were 26% for popliteal (n=11/43), 20% for tibial (n=11/54), and 4.4% for iliofemoral or SFA injury (n=2/45); within the tibial group, however, those with multiple tibial artery injuries had a delayed amputation rate of 45% (n=5/11). Blunt trauma was the predominant mechanism of injury overall and was the primary mechanism in 60% of popliteal artery injuries. Patients with blunt injury were more likely to undergo a delayed amputation (blunt 30.2%, n=19/63 vs. penetrating 6.33%, n=5/79), and high-energy blunt injury patients had the poorest limb salvage with a delayed amputation rate of nearly 40% (Table I). An increased MESS score was significantly associated with delayed amputation (OR 1.80, 95% CI [1.36 – 2.37]); using MESS > 7 as a cutoff, 42.9% of patients with a MESS > 7 (n=9) required delayed amputation compared to 12.4% with MESS < 7 (n=15).

When examining those with in-hospital compared to elective amputation, the majority of in-hospital delayed amputations were performed due to preexisting irreversible ischemia despite successful revascularization (50%, n=9/18). The rate of in-hospital delayed amputation was 4% for iliofemoral, 23% for popliteal, and 11% for tibial injuries. In contrast, the majority of amputations performed in an elective setting following discharge were secondary to insufficient soft tissue coverage or fracture nonunion (67%, n=4/6). The location of injury also differed significantly between the two types of delayed amputation (Fisher exact P<0.001): the majority of those requiring in-hospital delayed amputation presented with popliteal injury (56%, n=10/18), compared with those with elective amputation who primarily had single or multiple tibial injury (all tibial: 83%, n=5/6;

multiple tibial: 50%, n=3/6). The median time to elective amputation was 376d (IQR 180-525).

Multivariate analysis adjusting for gender and presence of fracture showed that younger age, higher injury severity score, blunt trauma, popliteal or multiple tibial injury location, and pulse deficit on presentation were significant predictors of binary delayed amputation (Table II). Other factors such as concomitant venous injury were not significant predictors. A Cox regression analysis of all delayed amputations (in-hospital and elective) identified popliteal location, multiple tibial injury, and blunt mechanism as independent predictors of any delayed amputation when adjusting for age, injury severity, pulse deficit on admission, and gender (Table II).

DISCUSSION

Lower extremity arterial injury is uncommon among civilian trauma patients[6], but notable for its potentially severe consequences including progression to limb loss. Treatment is often complex due to the involvement of multi-organ system trauma, as well as concomitant local musculoskeletal injuries. In our institution, management of lower extremity injuries is accomplished using a multidisciplinary approach between trauma, orthopedic, and vascular surgeons.

Our study reviews a ten-year experience of civilian LEAI in an urban high-volume academic trauma center with a 0.3% incidence of LEAI overall. Analysis of patients receiving any delayed amputation showed an overall rate comparable to previous studies and a low rate of delayed amputation among penetrating injuries. Blunt trauma carried a higher rate of delayed amputation, at 23% for in-hospital amputations and 30% when considering eventual elective amputations. Some of this may be attributable to the high proportion of high-energy blunt trauma within the blunt injury group, representing a cohort with greater overall injury severity.

These results are comparable to previously published outcomes. Amputation rates have dramatically improved since Debakey and Simeone[7] published a large series of popliteal vascular injuries from World War II with a high rate of amputation of 73% after primary arterial ligation. Outcomes of LEAI in the global civilian population are more difficult to quantify due to the low rate of injuries in the general population: despite the large number of patients in some studies[1,8], results have been difficult to apply to the knowledge of LEAI in the United States as the injury characteristics of many study populations differ substantially in mechanism and injury location with amputation rates ranging from 2 to 33%.

In our study, the characteristics of those who required delayed amputation during the same hospitalization differed from those who required a late elective amputation after discharge. Those requiring a late amputation had higher rates of tibial injury, and half had injury to multiple tibial arteries. The majority of amputations in these patients were secondary to insufficiency of soft tissue coverage or fracture nonunion. In contrast, nearly half of those undergoing delayed amputation during the initial hospitalization presented with popliteal artery trauma and required amputation due to irreversible ischemia despite successful revascularization. In these patients, ischemia persisted despite a patent revascularization, potentially due in part to the inability of the lower leg to survive a sudden and complete ischemic insult as well as disrupted outflow microvasculature. The importance of the popliteal artery as a primary arterial conduit to the lower leg without much redundancy renders this area extremely susceptible to even short periods of ischemia, regardless of the presence of a concomitant venous injury.

The contribution of multiple tibial artery injury to delayed and elective amputation demonstrated in our study, although strong, may be more a reflection of a pattern of extensive injury rather than the immediate result of the vascular injury itself. Although we were unable to quantify the amount of soft tissue injury in this retrospective study, patients with multiple tibial artery injuries had higher abbreviated extremity injury scores and fracture rates. In these cases, the extensive arterial injury is likely a marker of the severe mangled extremity, which should be taken into account when revascularization is considered. Due to the relatively small sample size, we were unable to determine further any characteristics or prognostic factors of patients with this injury pattern or determine whether ischemia from tibial disruption played a role in eventual amputation despite successful revascularization.

Multivariate analysis identified younger age, higher ISS, blunt trauma, popliteal or multiple tibial artery injury, and pulse deficit on presentation as significant predictors of binary delayed amputation when adjusting for gender and presence of any fracture. Surprisingly, concomitant nerve and major venous injuries were not associated with increased risk of delayed amputation as have been found in other studies[3]. This may be due to the small incidence of concomitant venous and nerve injuries in our cohort, and the potential in a retrospective study to miss these injuries due to poor or limited documentation. Sensory deficit may serve as a potential marker of nerve damage as well; however, persistent sensory deficit was not a significant factor in the analysis either and may also suffer from reliable identification or limited documentation during retrospective data collection.

The identification of younger age as a risk factor is likely a correlation due to the young patient population rather than a causation effect. However, the significant contribution of higher injury severity score, blunt trauma, location of injury, and pulselessness on presentation to delayed amputation are inherently intuitive. Primary consideration should be given to these factors when encountering a patient with extremity vascular injury when deciding on the indication for revascularization or counseling patients about postoperative limb outcomes

Late elective amputation post-discharge was extensively studied in a prospective cohort of severe orthopedic trauma by the Lower Extremity (LEAP) Study Groups[9,10]. Although the LEAP study was not designed specifically to examine the effects of arterial injury, it included many patients with significant neurovascular injury and is the largest prospective study of its kind to date. Important factors identified on multivariate analysis were similar to some of those in our study (blunt mechanism, initial pulselessness) but no consensus was reached on a single predictive model that could be used to reliably predict amputation after severe orthopedic injuries including Gustilo IIIc (with vascular involvement). The study also found that almost all limb-related events and functional recovery post-discharge happened within one year[11].

Various scoring systems have been proposed for assessing the severity of the mangled extremity, the most commonly used in vascular trauma being the MESS score. This score was introduced by Johansen and colleagues[12] in 1990, and has classically been utilized with a cutoff score of 7 to predict future viability of any limb salvage procedures. No current studies have successfully validated the ability of a score > 7 to predict delayed amputation with complete certainty, and the weighting of some elements has been previously questioned[13]. In our study, increasing MESS score did increase the risk of a delayed amputation, but more than half of patients presenting with a MESS greater than 7 had successful limb salvage despite the high score. MESS may be useful for quantifying the overall severity of extremity injury and as an adjunct for decision making. However, we suggest that a reliable cutoff for limb salvage viability likely does not exist and decisions on limb salvage should take into account the patient's overall condition.

Limitations of this study lie mainly with its retrospective nature. Although some data was acquired from a prospectively maintained registry, details of vascular exam, reconstruction, and outcomes were obtained retrospectively via a review of the medical record. Also, the degree of soft tissue damage sustained from the injury could not be determined retrospectively and was not included in the analysis. Long-term follow-up was also limited as many patients without other concomitant injury either did not return at all or were lost to follow-up within one year, which is not uncommon in young trauma patients. Nevertheless, the relatively large size of this contemporary series and the granularity of the prospective data allow us to derive useful information to guide the management of traumatic arterial injuries.

CONCLUSIONS

The type and severity of lower extremity arterial injuries vary depending on a variety of factors including geographic and demographic distributions, but overall remain uncommon. Age, injury severity score, blunt trauma, popliteal or multiple tibial injury, and pulse deficit on presentation are negative prognostic factors that should be considered when determining therapy for patients with LEAI, whether when deciding on the appropriateness of revascularization or informing patients on postoperative outcomes. Multiple tibial artery injury specifically is associated with high rates of limb loss, especially electively in the post-discharge period. As such, while patients with multiple prognostic factors including multiple tibial artery injury should not be denied revascularization, expectations for limb salvage in both the short and long-term periods should be carefully outlined. Further study is needed to determine the effect of ischemia after multiple tibial artery injury on wound healing and fracture nonunion.

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Article Highlights

- Lower extremity penetrating and blunt arterial injuries account for only 0.3% of Level I trauma admissions
- Arterial lower extremity injuries may occur throughout the arterial distribution but are frequently associated with bone fractures, soft tissue injuries, and nerve injuries
- The decision for primary amputation versus limb salvage demands a multidisciplinary approach
- Risk factors for delayed amputation include higher injury severity score, popliteal artery injury, multiple tibial artery injuries, blunt trauma, and pulseless exam on presentation

Table 1

Selected Patient and Injury Characteristics

	Total Cohort	No Amputation	Delayed Amputation	p
N	149	118	24	
Age	33.42 ± 14	33.75 ± 14.07	33.29 ± 13.90	0.88
Sex	21 (14.1%)	17 (14.4%)	4 (16.7%)	0.76
Lowest SBP	106.86 ± 39.61	106.89 ± 40.57	111.33 ± 33.83	0.62
GCS	13.08 ± 4.35	13.39 ± 4.02	12.5 ± 4.98	0.34
Intubated	26 (17.4%)	16 (13.6%)	6 (25.0%)	0.21
Mechanism				<0.001
Low Energy Blunt	43 (28.9%)	31 (26.3%)	11 (45.8%)	
High Energy Blunt	25 (16.8%)	13 (11.0%)	8 (33.3%)	
Penetrating	81 (54.4%)	74 (62.7%)	5 (20.8%)	
Arterial Location				0.009
Iliofemoral	19 (12.8%)	18 (15.3%)	1 (4.2%)	
Superficial Femoral	26 (17.4%)	25 (21.2%)	1 (4.2%)	
Popliteal	50 (33.6%)	32 (27.1%)	11 (45.8%)	
Single Tibial	43 (28.9%)	37 (31.4%)	6 (25.0%)	
Multiple Tibial	11 (7.4%)	6 (5.1%)	5 (20.8%)	
Arterial Injury Type				0.20
Occlusion	45 (30.2%)	32 (27.1%)	12 (50.0%)	
Transection	68 (45.6%)	54 (45.8%)	8 (33.3%)	
Laceration	23 (15.4%)	19 (16.1%)	4 (16.7%)	
Intimal Injury	9 (6.0%)	9 (7.6%)	0 (0.0%)	
Iatrogenic	4 (2.7%)	4 (3.4%)	0 (0.0%)	
Fracture				<0.001
Simple Fracture	24 (16.1%)	20 (16.9%)	4 (16.7%)	
Compound Fracture	64 (43.0%)	39 (33.1%)	18 (75.0%)	
Nerve Injury	42 (28.2%)	31 (26.3%)	5 (20.8%)	0.80
Venous Injury	16 (10.7%)	9 (7.6%)	1 (4.2%)	1.00
Pulse Deficit	89 (59.7%)	63 (53.4%)	19 (79.2%)	0.023
Motor Deficit	43 (28.9%)	25 (21.2%)	11 (45.8%)	0.019
Sensory Exam	40 (26.8%)	24 (20.3%)	9 (37.5%)	0.11
ISS	12.19 ± 8.44	11.67 ± 8.14	13.83 ± 10.26	0.26
AIS	2.96 ± 0.69	2.92 ± 0.71	3.08 ± 0.65	0.31
MESS	4.72 ± 1.86	4.30 ± 1.62	6.13 ± 1.78	<0.001
Time to ED Arrival (h)	1.90 ± 3.06	1.73 ± 3.07	2.29 ±2.60	0.41
Fasciotomy	70 (47.0)	51 (43.2)	18 (75.0)	0.01
Intravascular Shunt	3 (2.0)	1 (1.7)	1 (4.2)	0.4

Caption: All values are mean±SD or N(%). SBP: systolic blood pressure. ISS: injury severity score. AIS: abbreviated injury scale. MESS: mangled extremity severity score.

Table 2

Multivariate regression analysis for delayed amputation

Logistic Regression (Binary Delayed Amputation)			
Factor	**OR**	**95% CI**	**P**
Age	0.95	0.91 - 1.00	0.05
Sex	1.25	0.28-5.66	0.78
ISS	1.07	1.00 - 1.13	0.04
Blunt Mechanism	5.08	1.25 - 20.6	0.02
Popliteal Injury	10.1	1.04 - 97.3	0.04
Multiple Tibial Injury	31.2	2.07 - 469.7	0.01
Pulse Deficit	5.47	1.49 - 20.05	0.01
Any Fracture	1.94	0.78-4.85	0.16
Cox Regression (Time-to-Event Delayed Amputation)			
Factor	**HR**	**95% CI**	**P**
Age	0.97	0.93-1.00	0.08
ISS	1.04	0.99-1.09	0.09
Blunt Mechanism	3.57	1.17-10.95	0.03
Popliteal Injury	3.41	1.10-10.57	0.03
Multiple Tibial Injury	4.30	1.11-16.47	0.04
Pulse Deficit	1.97	0.63-6.21	0.25

ISS: injury severity score.