ORIGINAL ARTICLE

ARTERIAL INJURIES IN LOWER EXTREMITY TRAUMA – OUTCOMES OF A SINGLE CENTER STUDY

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Abstract

Objectives: *Femoropopliteal artery injury is a common and potentially life-threatening form of arterial injury in the lower extremities. Despite advancements in its management, there is still a considerable risk of amputation and death associated with these injuries.*

Methods: *We conducted a retrospective analysis on the patients who received treatment for lower limb trauma and concomitant arterial injury at a Level 1 Trauma Center and aimed to compare patient characteristics, injury severity scores, time to surgery, vascular repair methods, presence of fractures, and sequence of vascular and orthopedic repairs between groups: limb salvage vs amputation and survival vs death. We also aimed to identify factors contributing to amputation and death.*

Results: *Between January 2020 and June 2023, 21 patients, 71.4% male and 28.6% female patients were treated. 95.2% of the injuries were caused by blunt trauma, and the most commonly injured artery was the popliteal artery, in 61,9% of the cases. MESS scores were significantly higher in patients who died (p=0.012) and the presence of an exposed fracture was more common in patients who underwent amputation (p=0.004). 23,8% of patients were submitted to above knee amputation and a death rate of 19% was observed.*

Discussion/Conclusion: *When dealing with multiple injured limbs, the treatment approach and priorities are still under discussion, typically customized based on individual clinical situations. Our study underscores the significance of promptly performing vascular repair, reducing time delays, and taking into account bone and soft tissue injuries in the treatment strategy.*

Keywords: *Vascular injury, Femoral artery, Popliteal artery, Vascular trauma.*

INTRODUCTION

Femoropopliteal artery injury is the prevailing form of arterial injury observed in the lower extremities, constituting around one-third of all cases. This injury type carries a mortality rate of approximately 10%[1]. Advancements in the management of these lesions have evolved over time, encompassing early diagnostic techniques for detecting arterial injury and the application of advanced vascular repair methods involving hybrid surgical procedures. Despite successful arterial reconstruction efforts, reports indicate an amputation rate of up to 20%, even when appropriate reconstruction is conducted[2]. This heightened amputation risk of blunt vascular injuries is primarily attributed to the intense energy associated with such injuries, leading to extensive damage to bone, nerve, and soft tissue. Notably, this outcome is often not directly caused by the vascular injury itself[3]. Generally, fractures occur frequently in cases of blunt traumas, with some reports indicating rates as high as 80% to 100%[4]. On the other hand, penetrating trauma is associated with fracture rates ranging from 15% to 40%[4]. In scenarios with concomitant fractures, both vascular reconstruction and orthopedic fixation are deemed essential. Treatment methods and priorities remain diverse and contentious. Previous studies have identified factors that impact the success of limb preservation, being the duration of ischemia one of the most significant[4,5]. The consensus among the scientific community is that the optimal time for repairing the artery is less than 6 hours[6]. Therefore, it is crucial to prioritize minimizing delays in repairing vascular injuries. Unfortunately, a considerable number of revascularizations are performed after this timeframe[7].

To augment our comprehension of this subject, we undertook a study delving into the mechanisms, treatments, and outcomes associated with arterial injuries of the lower limb, aiming to identify the factors contributing to the occurrence of amputation and death.

METHODS

We conducted a retrospective analysis of patients who received treatment at our emergency department (Level 1 Trauma Center) for lower limb extremity trauma with concomitant arterial injury from January 2020 to June 2023. Patients who underwent primary amputation were excluded from the analysis. Data were retrospectively gathered, encompassing variables such as age, gender, injury mechanism, Injury Severity Score (ISS)[8], Mangled Extremity Severity Score (MESS)[9], approach to vascular repair, presence and quantity of fractures, and sequence of vascular and orthopedic repairs (defined as orthopedic fixation first). The total ischemic time was defined as the duration from the accident plus the revascularization procedure time (or until a shunt was employed). The repair methods varied among the cases and were decided by each physician at the time. If compartment syndrome was suspected after revascularization, we would perform a 2-incision, 4-compartment calf fasciotomy. The timing to fasciotomy was also decided by each physician.

The defined primary endpoints were amputation and mortality at 30 days. The secondary endpoints aimed to identify identify pre and intraoperative variables significantly different in patients that were amputated or died. Statistical analysis was conducted by utilizing SPSS software v.27 and considering a p value < 0.05 of statistical significance. Independent t-test, Fisher exact test and Mann-Whitney test were used to compare demographic, treatment characteristics and postoperative outcomes between groups (Limb salvage vs Amputation and Survival vs Death).

RESULTS

Between January 2020 and June 2023, a total of twenty-one patients with lower limb arterial injuries were treated in our department. Fifteen male (71.4%) and six female (28.6%) patients were included in this study. The median age of the patients was 62.5 years, with a range of 53.75 to 69 years. The youngest patient treated was 12 years old. The majority of cases (95.2%) were caused by blunt trauma, while only one case was categorized as penetrating trauma. The mean ISS was 26,7± 17,55 and the mean MESS was 26,7± 17,55. The ISS score was not significantly higher in the group of amputation neither in the patients who died. On the other hand, the MESS score was significantly higher in the death group ($p=0.012$) and had a tendency towards a higher rate of amputation ($p=0.053$) (Table 2). Over half of the patients (61.9%) had a total ischemic time greater than 7 hours. However, this factor did not prove to be significant in terms of amputation or death outcomes. Upon admission, death, lower levels of hemoglobin, higher levels of $K+$ in the blood analyses, and lower systolic blood pressure were found to be associated with death. White blood cell count, C Reactive Protein, and Creatine Kinase did not have an impact on either of the outcomes. (Table 2). The most commonly injured artery was the popliteal artery, followed by the involvement of the superficial femoral artery in 28.6% of the patients (Table 1).

During the perioperative period, half of the patients required fasciotomies. Two patients had temporary shunts employed to minimize ischemic time. Venous injuries were observed in 38% of the cases, but only one patient underwent venous reconstruction: primary venorrhaphy of the femoral vein. The repair method varied, with ten patients undergoing bypass with venous conduct, four patients receiving interposition vein grafts, three patients undergoing primary closure (end to end anastomosis after removal of the arterial injured segment), two patients undergoing thrombectomies (through a transversal arteriotomy), and two patients being treated with covered stent implantation (Table 1). The method of repair did not have an impact on amputation or death outcomes ($p>0.05$). Either control angiography or doppler ultrasound was performed at the end, pending on the decision of the vascular specialist. If the patient had the vascular reconstruction first, the image control was repeated after the orthopedic fixation.

Neurological injury was diagnosed in 28.6% of the cases, but it did not have an impact on the primary outcomes: amputation and death. While the presence of an orthopaedic injury, observed in 85.7% of the cases, did not reach statistical significance, the presence of an exposed fracture was related to the amputation outcome ($p=0.004$). In spite of receiving successful arterial reconstruction, five patients (23,8%) ultimately had to undergo above-knee amputation. Four patients (19%) died due to multiorgan failure.

DISCUSSION

The femoropopliteal artery is the most commonly injured artery in lower extremity trauma. Despite

Table 1 **Comparison of the patients' characteristics in terms of arterial injury location and method of repair.**

	Total (n=21)	Amputation (n=5)	Death (n= 4)	*p-value (Amputation)*
Location - Artery - n (%)				0,152
Iliac	1 (4,8)	-		
Superficial Femoral	6 (28,6)	1 (20,0)	3 (75,0)	
Popliteal	13 (61,9)	3 (60,0)	1 (25,0)	
Crural axis	1 (4,8)	1 (20,0)	-	
Method of repair - n (%)				0,806
Primary Closure	3 (14,3)	1 (20,0)	1 (25,0)	
Thrombectomy	2 (9,5)	-	-	
Interposition vein graft	4 (19,0)	1 (20,0)	-	
Bypass with venous conduct	10 (47,7)	3 (60,0)	2 (50,0)	
Covered stent implantation	2 (9,5)	-	1 (35,0)	
Fasciotomy	10 (47,6)	3 (60,0)	3 (75,0)	0,635

advancements in management and vascular repair techniques, the risk of amputation remains high, particularly in cases of blunt trauma that involve extensive damage to bone, nerve, and soft tissue. Fractures are also frequently associated with these types of injuries, further complicating the treatment process. In our study, we aimed to identify the factors contributing to the occurrence of amputation and death in patients with lower limb arterial injuries. Fractures were observed in 85.7% of our cases, with exposed fractures being significantly associated with amputation, probably in relation to concomitant extensive soft tissue injury. This highlights the importance of both vascular reconstruction and orthopedic fixation in cases where fractures occur simultaneously. The order in which these procedures should be performed remains uncertain. In our study, patients submitted to orthopedic fixation first did not reveal to be in a higher risk to amputation. Previous studies have shown that the optimal time for repairing the artery is less than 6 hours[6]. However, in our study, more than half of the patients had a total ischemic time greater than 7 hours, indicating a delay in revascularization. Our department's treatment delays can be attributed to receiving patients from level II trauma centers located 2 to 3 hours aways. Although, this delay may contribute to higher amputation rates, in our patient cohort, this factor was not statistically associated to amputation. This lack of significance may be due to type II statistical error. To reduce the time to vascular repair, several strategies can be employed. Delays in revascularization often occur because patients are transferred from facilities located several hours away. Creating direct transport protocols to higher-level trauma centers when a vascular injury is suspected could help minimize these delays. Enhancing the capabilities of smaller trauma centers with specialized training for early identification of vascular injuries. Additionally, the use of portable diagnostic tools, such as handheld Doppler devices, in pre-hospital settings could facilitate the early detection of arterial injuries and direct transfer to level I trauma centers.

The use of temporary vascular shunts can be a critical factor in managing arterial injuries, especially in scenarios where prolonged ischemia is a concern. The discussion of shunt use remains relevant, as it is a widely recognized strategy to stabilize patients when there are concomitant injuries requiring attention, such as severe fractures or soft tissue damage. The use of shunts can be particularly beneficial in patients with extensive associated trauma that need prolonged orthopedic fixation or complex surgical interventions before definitive vascular repair can be performed. Shunts may also be considered in situations where transfer times from lower-level trauma centers are extended, providing a temporary solution to reduce the total ischemic burden.

In terms of the surgical approach to vascular repair, our study showed that the repair method did not have a significant impact on amputation or death outcomes. Different methods, such as bypass with venous conduit, interposition vein grafts, primary closure, thrombectomy, and covered stent implantation, were used based on the discretion of the treating physician in order to individualize the treatment. This lack of a standardized approach is due to a high variability in injury patterns and surgeon discretion, demanding an individualized treatment in these complex cases.

In our study, we also assessed the impact of patient characteristics and laboratory values on outcomes. Higher

Table 2 **Comparison of the patients' characteristics, operative method and blood analysis between the limb salvage, amputation and death groups.**

	Total (n=21)	Limb Salvage (n=16)	Amputation		Death	
			(n=5)	*p-value*	(n=4)	*p-value*
Age, years - median (IQR)	62,5 (53,75-69)	65 (56-69)	56 (35,5-62)	0,208	73 (69,5-75)	**0,004**
Gender - n (%)				0,262		0.861
Female	6 (28,6)	6 (37,5)	0 (0,0)		1 (25,0)	
Male	15 (71,4)	10 (62,5)	5 (100,0)		3 (75,0)	
Comorbidities - n (%)						
Hypertension	10 (47,6)	9 (56,3)	1 (20,0)	0,311	2 (50,0)	0,916
Diabetes	4 (19,0)	4 (25,0)	0 (0,0)	0,532	2 (50,0)	0,080
Cardiac disease	1 (4,8)	1 (6,3)	0 (0,0)	0,567	0 (0,5)	0,619
Smoking History	3 (14,3)	3 (18,8)	0 (0,0)	0,549	1 (25,0)	0,489
Mechanism of injury - n (%)				0,567		1,000
Blunt	20 (95,2)	15 (93,8)	5 (100,0)		4 (100,0)	
Penetrating	1 (4,8)	1 (5,3)	0 (0,0)		0 (0,0)	
Polytrauma – n (%)	9 (42,9)	5 (31,3)	4 (80,0)	0,119	4 (100,0)	**0,021**
Head Trauma – n (%)	4 (19,0)	14 (87,5)	2 (40,0)	0,228	3 (75,0)	0,12
Venous injury– n (%)	8 (38,1)	7 (43,8)	1 (20)	0,606	2 (50)	0,618
Neurological injury– n (%)	6 (28,6)	3 (18,8)	3 (60)	0,115	0 (0,0)	0,281
Orthopaedic injury– n (%)	18 (85,7)	13 (81,3)	5 (100,0)	**0,549**	4 (100,0)	1,000
Presence of exposed fracture – n (%)	5 (23,8)	1 (6,3)	4 (80,0)	**0,004**	2 (50,0)	0,228
Orthopaedic fixation first – n (%)	11 (52,4)	9 (56,3)	2 (40,0)	0,635	4 (100,0)	0,090
ISS (Mean±Standard deviation)	26,7± 17,55	22,4± 15,69	37,8± 18,89	0,082	35,8± 16,68	0,223
MESS (Mean±Standard deviation)	7,4±2,52	6,8± 2,61	8,8± 1,48	**0,053**	10,0± 1,60	**0,012**
Total ischemic time>7h – n(%)	13 (61,9)	8 (50)	5 (100,0)	0,111	4 (100,0)	0,131
Systolic Blood Pressure at the admission mmHg (Median -IQR)	125 (99-135)	134 (102-135)	109 (91,5-127)	0,275	84,5 (69,5-94)	**0,001**
Blood analysis at the admission						
Haemoglobin g/dL (Mean±Standard deviation)	10,66±1,51	10,79±1,43	10,24±1,70	0,478	8,9± 1,15	**0,005**
White blood cell count x109/L (Median -IQR)	15,5 (10,3-21,0)	15,0 (12,0-21,0)	17,0 (10,0-32,0)	0,842	18,0 (10,5-32,5)	0,635
C Reactive Protein mg/dL (Median -IQR)	1,5 (0,2-5,2)	3 (0,97-10)	1 (0,1-3,5)	0,266	3,5 (1,0-13,0)	0,385
Creatine Kinase U/L (Median -IQR)	453 (219-1909)	328 (141-1560)	1637 (754-12005)	0,062	11 500 (10 070-23 500)	0,120
K+ mmol/L (Median -IQR)	4,2 (4,0-4,9)	4,2 (4,0-5,0)	4,1 (3,4-4,9)	0,445	5,3 (4,8-6,5)	**0,006**

Mangled Extremity Severity Score was associated with a higher rate of death and a tendency towards a higher rate of amputation. This is consistent with previous studies that have identified MESS as a predictive factor for limb salvage and amputation[12]. Lower hemoglobin levels, higher K+ levels, and lower systolic blood pressure upon admission were found to be associated with death. These findings suggest that the initial hemodynamic status and laboratory values can provide important prognostic information which should be integrated in the patient's clinical decision.

We recognize several limitations in this study, such as its retrospective design, concentration on a single medical center, and a restricted number of patients with high risk of type II statistical error, heterogeneous population and intervention types and potential selection bias. Therefore, it is important to exercise caution when making comparisons between different groups. Prospective studies with larger sample sizes are needed to confirm our findings and further investigate the factors contributing to amputation and death in lower limb arterial injuries.

While advancements in modern techniques have made it possible to reconstruct severely injured limbs that would have otherwise been amputated, the limb functional status should also be thought through when attempts to save the limbs necessitates multiple operations, often resulting in partial or complete loss of functions, which imposes a greater financial and psychological burden on patients. Furthermore, the development of bioengineering in prosthetics can also offer amputees a good function, with some studies reporting better functional prognosis of amputees after wearing a prosthesis compared to patients with limb salvage[13,14]. In addition, attempting to preserve the limb may potentially endanger the patient's life as it could lead to revascularization syndrome, ultimately resulting in multiorgan dysfunction.

CONCLUSION

In conclusion, lower limb arterial injuries, particularly femoropopliteal artery injuries, continue to pose significant challenges in terms of limb salvage and amputation rates. In the context of a multiply injured limb, treatment decisions and priorities remain complex and often require an individualized approach in clinical practice. While our study did not find a statistically significant impact of prolonged ischemic times on outcomes, the data suggests that other factors, such as the severity of bone and soft tissue injury, may play a more crucial role in determining limb salvage and overall prognosis. This underscores the need to carefully assess the extent of non-vascular injuries when planning treatment. Further research with larger sample sizes is essential to clarify the optimal timing for vascular repair and to identify the most effective surgical strategies and predictive factors for amputation and mortality in lower limb arterial injuries.

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