

Revascularization Strategies for Post-Traumatic Delayed Limb Ischemia: Outcomes and Challenges

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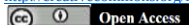
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ABSTRACT

Delayed limb ischemia following trauma, which becomes apparent or is treated at least 24 hours post-injury, has a high risk of reperfusion injury, infection, and amputation. The study examined outcomes of different revascularization techniques and determined what factors affect limb salvage.

This was a cross-sectional study of 103 patients who had been treated for post-traumatic limb ischemia in hospitals in Baghdad, Iraq, in the period between June 2025 and June 2026. The primary outcome was limb salvage, and the secondary outcomes were luminal patency (primary and secondary), complications, and mortality.

In addition, among the people examined, 75.7% had involvement of the lower limbs and 79.6% had fractures that also occurred. The average time of injury until revascularization was 3.2 days. The most popular method of surgery was the reversed interposition of the great saphenous vein (39.8%). The primary (30 days) and secondary (30 days) patency were 84.5% and 93.2%, respectively, with limb salvage in 30 days constituting 91.3%. The most commonly encountered complications were reperfusion injury (16.5%) and surgical site infection (18.4%); the mortality rate at 30 days was 2.9%. At the median follow-up, limb salvage after 16 months was found to be 88.3%, while the Kaplan-Meier limb salvage was 95.2%, 85.0%, and 71.3% in the case of revascularization conducted within 72 hours, between 3 and 7 days, and after 7 days, respectively.

Revascularization is able to salvage the majority of limbs in the case of post-traumatic ischemia, but the outcomes are worsening with time passing and soft-tissue injury or infections becoming graver.

Introduction

Vascular injuries at the level of the extremities represent a considerable amount of both military and civil vascular trauma [1]. These injuries are often associated with fractures, dislocations, nerve damage, open wounds, and other forms of damage to soft tissues. Once arterial injury is diagnosed and addressed, the next step is repair, which allows for restoration of blood flow to the limb [2, 3]. However, many of these patients seek medical help late or are not diagnosed through the presence of distal resistance that allows blood flow because other injuries are more serious or if intimal injury leads to thrombosis occurring hours or days after the initial injury [4].

Delayed limb ischemia poses unique clinical and technical challenges. Lengthy ischemia leads to damage to both muscle and nerve tissue, while the later restoration of blood flow may cause reperfusion injury, compartment syndrome, myoglobinuria and acute renal failure [5].

Delayed cases are complicated by propagation of the thrombus forming further obstructions to distal vessels, necrotic tissues or contamination of the wound requiring either autoplasty, synthetic-bypass, thrombectomy, patching or endovascular surgeries [6]. Severity scores such as the Mangled Extremity Severity Score (MESS) and the Rutherford classification are utilized for decision-making but lack proven prognostic value in delayed presentations [7].

Currently, the guidelines for peripheral vascular trauma include initiating flow restoration, providing temporary shunts in injured extremities, and doing fasciotomy as needed. However, recommendations are mostly extracted from studies related to acute trauma [8]. The purpose of this research was to identify injury types and techniques utilized for vascular restoration in patients with post-traumatic delayed limb ischemia, to evaluate the short- and mid-term results (patency, limb preservation, complications, and mortality) of such treatment, and to define clinical problems and issues leading to limb amputation.

Patients & Method

For this study, a cross-sectional design was utilized in the vascular surgery and trauma department of Baghdad, Iraq hospitals from June 2025 to June 2026.

Patients were capable of qualifying for this study if they had gone through revascularization of traumatic arterial injury with limb ischemia after more than 24 hours of the injury. Patients who underwent first amputation at arrival, those who got treated within 24 hours of injury, and all the patients with either non-traumatic injury or iatrogenic injury were excluded from the study. By the end of the day, 103 patients met the criteria.

Finally, the data was extracted from hospital records. The data included age, sex, present illnesses, cause and side of the injury, open or closed injury, presence of fractures, nerve injury, and compartment syndrome at the time of present. The time interval from injury to revascularization was recorded in days and was classified under 24 to 72 hours, 3 to 7 days, and over 7 days.

Ischemia severity was measured using the Rutherford categories (IIa, IIb and III) and MESS (with 7 points or more classified as being at high risk). The location and nature of the arterial injury was established using duplex ultrasound, computed tomography angiography, or intra-operative angiography.

The choice of the revascularization technique was made by the surgeon taking into account the length of the defect, pathology of the vessel, wound contamination, and availability of conduit. The alternatives were reversed GSV interposition graft, primary end-to-end repair, patch angioplasty, thrombectomy, synthetic bypassing, and endovascular treatment (stent grafting, angioplasty, or drug therapy). A temporary vascular shunt was used when skeletal stabilization was required, and fasciotomy was done in a therapeutic or prophylactic manner depending on the ischemia duration.

After the procedure, antithrombotic medication was provided to the patients. They were observed for the occurrence of reperfusion injuries, function of kidneys, and problems related to the wounds. Follow-ups were made on the patients after 1, 3, 6, and 12 months and ever since that on an annual basis. The basic parameter in the outcome of the procedure was the limb, which remained intact, i.e., it was still attached after the operation. The secondary parameters included primary and secondary patency (with and without surgery), incidence of complications achieved after 30 days, and death rate.

Continuous variables are expressed as corresponding standard deviations plus the mean, or as the median with the interquartile range, while categorical variables are expressed as numbers and percentages. Outcomes of revascularization techniques were compared using a chi-square test. The association of factors with limb loss was determined using crude odds ratios and their 95% confidence interval estimates. A two-tailed alpha of 0.05 or less was deemed a statistically significant result. Analyses were conducted using SPSS version 26.0.

Results

Table 1: Baseline demographic features of 103 patients.

Characteristic	Value (N = 103)
Demographics	
Age, years, mean $\pm$ SD (range)	34.6 $\pm$ 11.8 (16–71)
Male sex, n (%)	87 (84.5)
Current smoker, n (%)	52 (50.5)
Diabetes mellitus, n (%)	11 (10.7)
Hypertension, n (%)	17 (16.5)
Mechanism of injury	
Road traffic collision	46 (44.7)
Fall from height	17 (16.5)
Penetrating (firearm/stab)	15 (14.6)
Crush injury	13 (12.6)
Other blunt trauma (sports, industrial)	12 (11.7)
Injury pattern	
Lower limb / upper limb	78 (75.7) / 25 (24.3)
Open injury	58 (56.3)
Associated fracture	82 (79.6)
Associated joint dislocation	21 (20.4)
Associated nerve injury	29 (28.2)
Compartment syndrome at presentation	24 (23.3)
Ischemia severity and delay	
Interval from injury to revascularization, days, median (IQR)	3.2 (1.9–5.8)
24–72 hours	49 (47.6)
3–7 days	36 (35.0)
> 7 days	18 (17.5)
Rutherford IIa / IIb / III	38 (36.9) / 47 (45.6) / 18 (17.5)
MESS, mean $\pm$ SD	5.1 $\pm$ 1.9
MESS $\geq$ 7	22 (21.4)

Table 2: Determination of the diagnostic outcomes related to arterial injury.

Category	n	%
A. Site of arterial injury		
Common femoral artery	6	5.8
Superficial femoral artery	29	28.2
Popliteal artery	31	30.1
Tibial/peroneal arteries	12	11.7
Axillary artery	4	3.9
Brachial artery	14	13.6
Radial/ulnar arteries	7	6.8
B. Underlying vascular pathology		
Thrombosis after intimal injury/dissection	44	42.7
Transection or laceration with secondary thrombosis	27	26.2
Pseudoaneurysm with distal embolization/occlusion	12	11.7
Vasospasm / external compression (fracture–dislocation)	11	10.7
Arteriovenous fistula with distal steal	9	8.7
Total	103	100.0

Table 3: Classification of the revascularization techniques in accordance with operative time.

Strategy	N (%)	Operative time, min (mean $\pm$ SD)
Reversed GSV interposition graft	41 (39.8)	182 $\pm$ 46
Primary repair (end-to-end)	14 (13.6)	124 $\pm$ 33
Patch angioplasty	8 (7.8)	139 $\pm$ 38
Thrombectomy $\pm$ repair	15 (14.6)	96 $\pm$ 29
Synthetic / extra-anatomic bypass	12 (11.7)	201 $\pm$ 52
Endovascular (stent-graft, PTA, lysis)	13 (12.6)	88 $\pm$ 31
Fasciotomy (total)	47 (45.6)	-----
Temporary vascular shunt	19 (18.4)	-----
Skeletal stabilization before revascularization	31 (30.1)	-----
Intra-operative angiography	74 (71.8)	-----

Table 4: Post-revascularization outcomes and complications.

Strategy	n	Primary patency, 30 d n (%)	Limb salvage, 30 d n (%)	Early amputation, n (%)
<i>A. Outcomes by strategy</i>				
GSV interposition graft	41	36 (87.8)	38 (92.7)	3 (7.3)
Primary repair	14	13 (92.9)	14 (100)	0 (0)
Patch angioplasty	8	7 (87.5)	8 (100)	0 (0)
Thrombectomy $\pm$ repair	15	11 (73.3)	12 (80.0)	3 (20.0)
Synthetic / extra-anatomic bypass	12	9 (75.0)	10 (83.3)	2 (16.7)
Endovascular	13	11 (84.6)	12 (92.3)	1 (7.7)
All patients	103	87 (84.5)	94 (91.3)	9 (8.7)
<i>B. Early complications and late status (all patients)</i>				
Early occlusion ($\leq$ 30 d)	16 (15.5)	9 rescued by re-intervention, 7 amputated		
Secondary patency at 30 d	96 (93.2)			
Reperfusion injury	17 (16.5)			
Surgical-site infection	19 (18.4)			
Post-operative compartment syndrome	8 (7.8)	Required fasciotomy		
Re-exploration for bleeding	6 (5.8)			
Acute kidney injury	9 (8.7)	2 required dialysis		
Sepsis	5 (4.9)			
30-day mortality	3 (2.9)	Sepsis/MOF 2, pulmonary embolism 1		
Hospital stay, days, median (IQR)	12 (8–19)			
Persistent neurological deficit at last follow-up	14 (13.6)			
Limb salvage at last follow-up	91 (88.3)	Median follow-up 16 mo (IQR 9–24)		

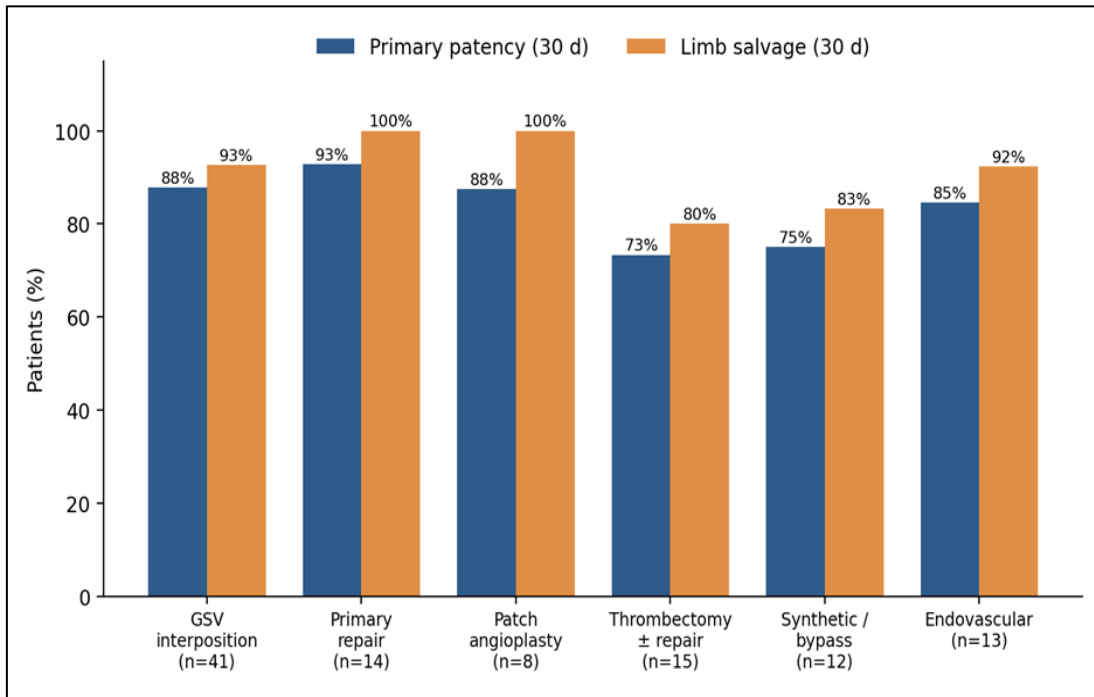


Figure 1: Patency and limb salvage within 30 days after performing revascularization.

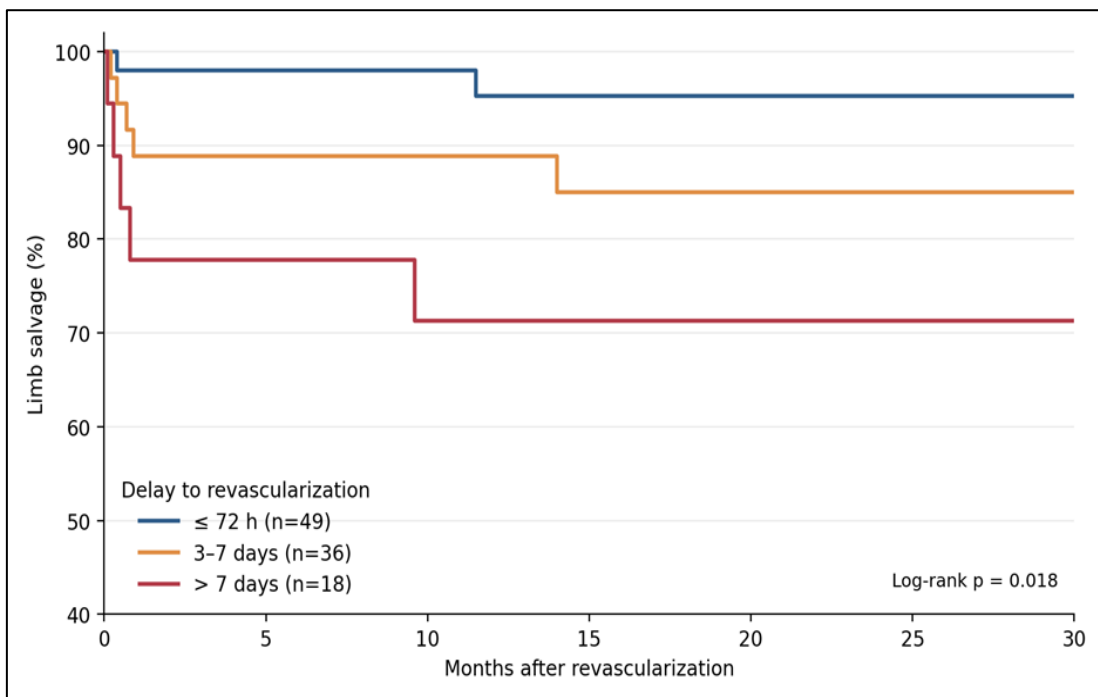


Figure 2: Kaplan-Meier figuring out limb salvage by interval between injury and revascularization.

Table 5: Univariate regression analysis of risk factors associated with limb loss during 12-month follow-up.

Factor	Crude OR (95% CI)	p value
Delay > 7 days	4.29 (1.18–15.56)	0.034
MESS $\geq$ 7	7.09 (1.98–25.37)	0.003
Rutherford category III	6.58 (1.82–23.78)	0.006
Popliteal/tibial injury	3.20 (0.90–11.42)	0.116
Post-operative wound infection	6.00 (1.68–21.47)	0.008
Fasciotomy performed	0.36 (0.09–1.40)	0.217

Discussion

In a study of 103 patients with post-traumatic delayed limb ischemia, revascularization was found to salvage limbs in 91.3% of the patients at 30 days and 88.3% at final follow-up. The significant finding was the time interval between injury and reperfusion as the most clinically relevant and modifiable factor affecting outcome: Kaplan-Meier leg salvage ranged from 95.2% when revascularization was done within 72 hours to 71.3% when conducted after 7 days. Some studies indicated that prolonged ischemia leads to muscle, nerve, and microvasculature damages; reduces the ability of the distal bed to accept blood flow; and increases the risk of reperfusion injury and infection [9 – 12].

Using autologous vein interposition, which is used in 40% of cases, provides acceptable results in terms of patency and limb salvage and is still the conduit of choice for contaminated and injured situations according to the traditional principles of vascular trauma surgery. Primary repair and patch angioplasty produced the best early results; however, these methods were applied only for some selected patients who suffered from clean cuts or some small lesions (focal wall injuries); thus, the great effect is most likely caused by selection but not by the technique in itself [13, 14]. However, on the contrary, thrombectomy alone and synthetic or extra-anatomic bypass showed worse results (73.3% and 75.0% of early patency rates, respectively).

Residual intimal damage may occur with thrombectomy, and synthetic grafts are used only in the absence of vein, or in cases of contamination of the operative field, increasing the probability of poor results [15 – 18]. In patients compiled for endovascular treatment, the operator sacrificed a small amount of time, and the application is mostly used when the patients have a disease in the proximal part of the vessels, and as the result of the procedure has a very good outcome which is effective [19].

Reperfusion injury (16.5%) and post-operative compartment syndrome (7.8%) demonstrate the particular risks of late reperfusion. A fasciotomy was conducted for 45.6% of patients and was related to fewer amputations (6.4% vs. 16.1%), although this association is likely to be confounded by indication. UK studies suggest that fasciotomy be carried out at an early stage in cases of prolonged ischemia, as recommended in trauma guidelines. Surgical-site infection (18.4%) was also common and strongly related to limb loss, with an OR of 6.00, which emphasizes the significance of early debridement, fracture stabilization, soft-tissue coverage, and antibiotic use, which requires an interdisciplinary approach combining vascular, orthopedic, and plastic surgery [20 – 22].

Amputation was found to be significantly related to a MESS score of $\geq$ 7 and Rutherford III ischemia. Despite the fact that MESS was designed to predict amputation following a serious trauma to the lower limbs and has been criticized for not being responsive in certain instances, our findings indicate that it still detects a group with elevated likelihood of undergoing amputation in the delayed stage [23].

Conclusion

The technique of revascularization can be effective in avoiding limb amputation in cases of post-traumatic delayed ischemia, as shown in this study wherein the limb salvage rate was 88.3%. However, the chances of success are reduced in cases of delayed treatment, severe trauma (high MESS, Rutherford III), and infection of the wound. Most patients were treated by means of autogenous vein interposition or primary repair, whereas thrombectomy and synthetic bypasses were less effective.

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