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Revascularization Outcomes in Post-Traumatic Delayed Limb Ischemia: A Multicenter Study

Dr. Mansour Mikhlif Mhaidi [1]***, Dr. Bashar Berjes Alqaisy*** [2] ***and Dr. Akram Rasool Kadhim*** [3]

[1]*M.B.Ch.B., F.I.B.M.S. \ (Cardithoracic and Vascular Surgery) Iraqi Ministry of Health, Anbar Health Directory, Ramadi Teaching Hospital, Anbar, Iraq*

[2]*M.B.Ch.B., F.I.B.M.S. \ (Cardithoracic and Vascular Surgery) Iraqi Ministry of Health, Anbar Health Directory, Ramadi Teaching Hospital, Anbar, Iraq*

[3]*M.B.Ch.B., F.I.C.M.S. \ (Specialists Internal Medicine) Iraqi Ministry of Health, Thi Qar Health Directorate, Al-Shatra General Hospital, Thi-Qar, Iraq.*

Abstract: Delayed limb ischemia following trauma poses significant challenges for limb salvage where in our study early revascularization is optimal, the outcomes and prognostic factors associated with revascularization beyond the conventional 6-hour ischemic window remain underexplored in multicenter cohorts, while paper refered A multicenter cohort study of 80 patients with ischemia exceeding 6 hours revealed that early revascularization is crucial but outcomes remain underexplored through The cohort consisted mainly of young males, averaging 35.2 years, with a mean ischemic duration of 10.3 hours in addition to Bypass grafting was performed in 56.3% of cases, achieving 88.8% limb salvage. Significant risks for amputation included an elevated Mangled Extremity Severity Score (MESS), shock, and combined arterial and bone injuries. Common complications were reperfusion injury (16.3%) and infection (8.75%). The mean hospital stay for amputees was significantly longer. The study suggests that delayed revascularization can yield favorable outcomes in select trauma patients, underscoring the importance of prognostic indicators like MESS and postoperative care.

Keywords:. Delayed Limb Ischemia, Revascularization, Traumatic Vascular Injury, Limb Salvage, Mangled Extremity Severity Score (Mess), Amputation Risk Factors, Bypass Grafting, Thrombectomy, Postoperative Complications, Reperfusion Injury, Hospital Length Of Stay.

INTRODUCTION

Timely arterial revascularization is the cornerstone of treatment. Without this procedure, the interest rate for limb loss (amputation) would approach where Direct blood flow to the ankle or foot via at least one tibial artery for patients with 20 tissue loss is very important, but this is not essential for patients with ischemic rest pain (Özyaprak, B. *et al.*, 2022).

Amputation rates and revascularization strategies vary widely in patients with severe chronic ischemia of chronic limbs. 21 Many patients undergo primary ankle amputation without attempting to revascularize. (Wang, Y. *et al.*, 2025) Furthermore, the choice of revascularization strategies for revascularization to save grem and the frequency of these procedures in the US vary. 22 Furthermore, it was reported that the strength of the vascular supply within the area (defined as the percentage of patients who had one or more revascularization procedures prior to the cutting) was connected to the cutting speed (Khatri, P. *et al.*, 2009; Malan, E., & Tattoni, G. 1963) However, higher supply costs (observed by increased revascularization rates) were not associated with a significant decrease in cutting speed (Agarwal, V. *et al.*, 2016) This emphasizes the importance of the quality of the revascularization process rather than the volume.

Chronic critical limbs (CLI), a condition of peripheral arterial disease (PAD), characterized by chronic tissue complications in peace, is associated with reduced quality of life and significantly higher morbidity and mortality. 1In contrast to acute ischemia (a severe limb angel that lasts less than 2 weeks), CLI (also important ischemia as significant as serious limb, chronic limb angel, or serious limb ischemia) is defined as ischemic foot pain that lasts longer than 2 weeks, and is defined as unstigmatized wounds or objectively documented diseases (Glass, G. E. *et al.*, 2009; Helfet, D. L. *et al.*, 1990; Johansen, K. *et al.*, 1990).

The year CLI incidence is estimated at 220 and 3,500 cases per million residents. 2.3 CLI - The prevalence of Imiemie is between 1% and 2%, but can range up to 11% in patients with known peripheral arterial disease. It is estimated that two limbs, thromboembolism, thromboembolism trauma, arterial style, vasculitis, scientific anatomy, disease, vasculitis, enteritis, and interventional chronic ischemia occur in over 5% to 10% of asymptomatic peripheral arterial disease (PAD) or intermittent Cystic changes in the peritoneum (Liang, N. L. *et al.*, 2016; Loja, M. N. *et al.*, 2017; Sharrock, A. E. *et al.*, 2019).

***Corresponding Author:** Dr. Mansour Mikhlif Mhaidi*

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MATERIAL AND METHOD

The aim of this retrospective multicenter study was to assess outcomes following delayed revascularization in patients with limb ischemia secondary to trauma where A total of 80 patients with study period from 1-6-2024 to 2-5-2025 where late limb ischemia (ischemic time >6 hours) as a consequence of a traumatic vascular injury were recruited from multiple trauma-emanating centers within a stipulated timeframe with Patient demographics, injury characteristics, treatment modalities, and clinical outcomes were gathered and analysed and The mean age was 35.2 ± 12.1 years so There were 85.0% of the men. Blunt trauma was reported in 62.5% of patients and penetrating trauma in 37.5% while The Mangled Extremity Severity Score (MESS), a validated prognostic tool, was assigned to each patient and demonstrated an average of 8.6 ± 2.5 and in our study according to Vascular injuries were categorized based on intraoperative assessment and findings on imaging where Injury patterns identified were transection of the artery in 50.0% of cases, thrombosis of the artery in 31.3%, moreover combined arterial and venous injuries in 18.7% of cases also According to the type of injury and in agreement with the vascular surgeon, the corresponding revascularization procedures were performed: bypass grafting (56.3%), thrombectomy (37.5%), and primary repair (6.25%). The primary outcome of interest was limb salvage (defined as the avoidance of major amputation), while 95% CI and odds ratios (OR) were used to identify risk factors for secondary amputation. A MESS score above 9 (OR 4.5), the presence of shock (OR 3.8), and combined arterial and bone injury (OR 3.2) were all significant predictors. Patients undergoing secondary amputation had a significantly longer average hospital stay (63.8 days) than those undergoing limb salvage (33.1 days, p=0.02).

Descriptive statistics, such as means and standard deviations for continuous variables and frequencies for categorical variables, were used in the data analysis, and when comparing categorical data using chi-square tests, likelihood ratios and odds ratios with 95% CIs were presented and assessed risk factors for unfavorable results, deeming p-values below 0.05 to be significant. However, Patient consent was either obtained or waived in accordance with retrospective study criteria, and the study was approved by the institutional review board and adhered to ethical standards. Also, Data were handled anonymously and with confidentiality. As shown below are the inclusion and exclusion criteria.

Table 1: Descriptive statistics of inclusion and exclusion criteria

Criteria	**Description**
Inclusion Criteria	Adults aged 18 years or older Traumatic limb ischemia with ischemic time >6 hours Confirmed arterial injury requiring revascularization Underwent surgical revascularization (bypass grafting, thrombectomy, primary repair) Complete clinical and operative records available Admitted to multicenter trauma/vascular units during study period
Exclusion Criteria	Acute ischemia due to non-traumatic causes (e.g., embolism, atherosclerosis) Ischemia of upper extremities or isolated venous injuries Ischemic time ≤6 hours Primary major amputation without revascularization attempt Incomplete data or lost to follow-up before outcome assessment Irreversible limb necrosis at presentation Iatrogenic vascular injuries or ischemia Severe comorbidities are prohibitive of surgery or affecting outcomes independently

Table 2. Patient Demographics and Injury Characteristics (n=80)

Parameter	**Mean ± SD**	**Frequency (n, %)**
Age (years)	35.2 ± 12.1	-
Male sex	-	68 (85.0%)
Ischemic time (hours)	10.3 ± 3.1	-
Mechanism of injury	-	
Blunt trauma	-	50 (62.5%)
Penetrating trauma	-	30 (37.5%)

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MESS score	8.6 ± 2.5	-

Table 3. Types of Vascular Injuries and Procedures (n=80)

Injury Type	Frequency (n, %)	Procedure frequency (n, %)
Arterial transection	40 (50.0%)	Bypass grafting: 45 (56.3%)
Arterial thrombosis	25 (31.3%)	Thrombectomy: 30 (37.5%)
Combined arterial/venous	15 (18.7%)	Primary repair: 5 (6.25%)

Table 4. Limb Salvage and Amputation Outcomes (n=80)

Outcome	Frequency (n, %)	Mean MESS ± SD	p-value	Likelihood ratio (χ^2)
Limb salvage	71 (88.8%)	7.9 ± 2.2	<0.01	6.24
Secondary amputation	9 (11.2%)	10.8 ± 3.1	<0.01	6.24

Table 5. Complications Post-Revascularization (n=80)

Complication	Frequency (n, %)	Mean creatine kinase (IU/L) ± SD	p-value
Reperfusion injury	13 (16.3%)	1450 ± 350	0.21
Acute renal impairment	5 (6.25%)	-	0.33
Infection/sepsis	7 (8.75%)	-	0.15
Mortality	1 (1.25%)	-	-

Table 6. Factors Associated with Secondary Amputation (n=80)

Risk Factor	Odds Ratio (OR) (95% CI)	p-value	Likelihood ratio (χ^2)
MESS score > 9	4.5 (2.0–10.2)	<0.001	10.6
Presence of shock	3.8 (1.5–9.6)	0.002	8.3
Combined arterial & bone	3.2 (1.1–7.4)	0.03	4.7

Table 7. Length of Hospital Stay (days) by Outcome (n=80)

Outcome	Mean ± SD	Range (days)	p-value
Limb salvage	33.1 ± 10.4	15–54	0.02
Secondary amputation	63.8 ± 12.1	45–85	0.02

Table 8. Functional Outcomes at 1 Year Follow-up (n=80)

Functional Status	Frequency (n, %)
Ambulate unaided	54 (67.5%)
Ambulate with aid	15 (18.8%)
Wheelchair bound	6 (7.5%)
Death or lost to follow-up	5 (6.2%)

DISCUSSION

The outcomes derived using this multicenter analysis of revascularization of late-presenting limb ischemia following trauma yield significant information relating to outcomes of patients, experienced complications, and predictors of limb salvage and amputation (Mavrogenis, A. F. *et al.*, 2016; Garg, R. *et al.*, 2021). The outcomes yield significant evidence to inform clinical decision-making and highlight potential points of improvement within the management of late-presenting vascular trauma.

The demographics matched known epidemiologic findings of traumatic vascular injuries, which document a predominance of young males (85%) and a mean age of early to mid-30s. The latter is typical of the anticipated risk profile of healthy, robust individuals with a propensity to high-energy trauma. Most had blunt trauma (62.5%), a frequent mechanism of extremity vascular injuries that frequently entails multifocal tissue damage surrounding the vessels (Inaba, K. *et al.*, 2011). The average ischemic interval of roughly 10 hours raises a flag about presentation or referral delays that not infrequently attend everyday practice settings, and specifically by centers offering coverage to vast geographic areas or with limited resources (Table 2).

The majority of vascular injuries were arterial transection or thrombosis, with surgery adjusted correspondingly. Bypass grafting proved to be the most frequent procedure due to the common necessity of segmental arterial substitution within transection injuries, whereas thrombectomy took care of thrombotic occlusions (Table 3). The results correspond to the current literature on

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vascular trauma that stresses individualized revascularization according to lesion and patient-specificities.

Notably, the limb salvage rate of approximately 89%, even in the context of prolonged ischemic durations, validates that delayed revascularization, while complicated, remains a feasible option for specific patients. This observation aligns with prior research that has documented salvage rates between 80-90% when ischemic periods exceed the traditional 6-hour threshold. The heightened MESS scores observed in patients necessitating secondary amputation underscore the prognostic relevance of the score; specifically, a score exceeding nine significantly elevated the likelihood of amputation (Table 4). This reinforces the function of MESS in the assessment of injury severity, duration of ischemia, and physiological shock. The existence of shock alongside concurrent arterial and bone injuries further delineated risk categories, emphasizing the complex nature of limb loss.

Postoperative adverse effects were substantial but within reasonable bounds for this high-risk patient population. Reperfusion injury was found to be 16.3%, consistent with ischemia-reperfusion pathology marked by muscle cell necrosis and systemic inflammatory response. Acute renal insufficiency was comparatively rare (6.25%) but clinically significant due to its potential to be life-threatening. Infection and sepsis were below 10%, consistent with difficulty dealing with contaminated wounds and post-trauma immune suppression (Table 5). Mortality was low at 1.25%, an indicator of effective perioperative care and preoperative selection of patients.

Length of hospital stay was considerably longer among amputees (64 days) compared with salvaged limbs (33 days), and this emphasizes the resource burden of salvage failure and secondary procedures (Table 6). Prolonged hospital stay influences healthcare costs and the quality of life of patients. Functional outcome data showed that two-thirds of salvaged patients achieved independent ambulation, with significant limb utility and effective rehabilitation potential (Table 7). Ambulation with or wheelchair dependence represents residual functional impairment not uncommon following extensive trauma and revascularization.

These results have significant implications within trauma systems, particularly within those with late referral or limited access to specialized care for vessels. Surgeons should have a high index of suspicion of a potentially salvageable limb with late ischemia, with meticulous balance between risk and benefit (Spitler, C. A. *et al.,* 2022; McHenry, T. P. *et al.,* 2002; Singh, D., & Pinjala, R. K. 2005).

Limitations of retrospective design and the possibility of treatment variability by center exist, but multicenter recruitment and comprehensive statistical analysis augment generalizability (Singh, D., & Pinjala, R. K. 2005; Fowler, J. *et al.,* 2009). Future prospective trials might better define optimal thresholds of timing, improve prognostic models, and define adjunctive treatments to diminish reperfusion injury. (Hornez, E. *et al.,* 2015; Williams, T. K., & Clouse, W. D. 2016)

The long-term revascularization outcomes in patients with post-traumatic delayed limb ischemia reveal significant correlations with limb salvage rates, according to Studies indicate that while delayed revascularization can lead to complications, it can still achieve favorable limb salvage outcomes under certain conditions and also A study involving 20 patients with major extremity vascular injuries showed a 95% limb salvage rate despite a mean revascularization time of 30.8 hours (Agarwal *et al.,* 2022), while In military settings, the probability of limb salvage drastically decreases with prolonged ischemia; it drops to 6.7% when ischemia exceeds 6 hours (Perkins *et al.,* 2022) (Perkins *et al.,* 2022), moreever A comparative study found limb salvage rates of 91.67% for early presentations versus 72.73% for delayed presentations, indicating that while outcomes are generally favorable, delays can impact success (Chaudhari *et al.,* 2020).

Complications such as muscle sloughing and foot drop were noted in delayed revascularization cases, highlighting the risks associated with prolonged ischemia (Agarwal *et al.,* 2022).

CONCLUSION

In general, this research corroborates the paradigm that late revascularization can attain acceptable limb salvage and functional results in extremities that historically would have been considered not salvageable. Nevertheless, accurate patient selection with objective scoring tools such as MESS serves to identify the benefit vs. those with significant amputation risk. Additionally, close monitoring and management of reperfusion

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adverse effects and infection continue to be necessary.

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