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Acute Limb Ischemia Following Femoral And Tibial Shaft Fractures: Predictors And Outcomes

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ABSTRACT

Background: Acute limb ischemia (ALI) complicating femoral and tibial shaft fractures is a limb-threatening emergency that requires rapid recognition and coordinated orthopaedic–vascular management. Despite being uncommon, delayed diagnosis can result in irreversible muscle necrosis and amputation. This study evaluates the predictors and outcomes of ALI in long-bone fractures of the lower limb.

Aims and Objectives: To identify clinical and radiological predictors of acute limb ischemia in femoral and tibial shaft fractures and to assess limb-salvage outcomes following timely intervention.

Materials and Methods: A prospective observational study was conducted over 24 months, including 144 patients with femoral and tibial shaft fractures. Vascular status was assessed through pulse examination, ankle–brachial index (ABI), Doppler, and CT angiography. Eighteen patients (12.5%) diagnosed with ALI formed the study cohort. Data on injury pattern, vascular lesions, management sequence, and outcomes were analyzed.

Results: Among the 18 patients with ALI, the majority were young males injured in road traffic accidents. Tibial fractures accounted for 55.6% of cases. Thrombosis (38.9%) and intimal tears (27.8%) were the most common arterial lesions. External fixation before revascularization was performed in 55.6% of cases. Limb salvage was achieved in 77.8%, while 22.2% underwent amputation. Predictors of poor outcome included MESS >7, delayed revascularization (>6 hours), severe fracture displacement, open fractures, and complete arterial transection.

Conclusion: ALI in shaft fractures demands early diagnosis and rapid multidisciplinary intervention. Delays in revascularization and severe injury patterns significantly worsen outcomes, highlighting the need for aggressive early vascular assessment in all high-energy long-bone fractures.

KEYWORDS: Pattern of Vascular Injury, Initial Diagnostic Findings

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INTRODUCTION

Acute limb ischemia (ALI) following femoral and tibial shaft fractures represents one of the most catastrophic complications in orthopaedic trauma, carrying a high risk of permanent disability, limb loss, and mortality if not recognized and treated promptly. Although long-bone fractures of the lower limb are common presentations in high-energy trauma, the incidence of associated vascular compromise is relatively low; however, when it does occur, the consequences are profound (1). Femoral and tibial shafts lie in close proximity to major arterial structures most notably the superficial femoral, popliteal, anterior tibial, posterior tibial, and peroneal arteries. High-energy mechanisms such as road traffic accidents, crush injuries, ballistic trauma, and severe torsional forces may cause direct transection, intimal tears, arterial thrombosis, or external compression by displaced fracture fragments or expanding hematomas (2). Even closed fractures, traditionally considered lower risk, have been documented to cause delayed arterial occlusion secondary to intimal damage, vessel spasm, or compartmental swelling. For the orthopaedic surgeon, early identification of these vascular insults is critical because timely revascularization within the “golden window” determines functional salvage (3).

The clinical presentation of ALI superimposed on long-bone fractures may be subtle in its early stages. Pulses may be initially present, especially in cases of intimal flap formation or partial flow obstruction, leading to a false sense of reassurance. Delayed ischemia is increasingly reported in tibial shaft fractures where minimal initial displacement masks progressive vascular compromise (4). Orthopaedic literature emphasizes the importance of serial pulse examination, Doppler assessment, Ankle–Brachial Index (ABI), and a low threshold for CT angiography in suspicious cases (1). The classical "6 Ps" pain, pallor, pulselessness, paresthesia, paralysis, and poikilothermia may not appear until irreversible ischemic damage has begun. This delayed recognition contributes to worse outcomes, including irreversible muscle necrosis, nerve dysfunction, and secondary infection due to reperfusion injury (1).

Predictors of ALI in the setting of femoral and tibial shaft fractures have been explored in vascular trauma series and orthopaedic-vascular collaborative studies. High-energy mechanism, severe displacement or comminution, associated knee dislocation, open fractures, and a Mangled Extremity Severity Score (MESS) greater than 7 are consistently associated with poor limb salvage (5). Older age, hypotension at presentation, delayed hospital arrival, and the presence of compartment syndrome further increase the risk of amputation. The type of arterial injury complete transection, thrombosis, or segmental loss also significantly influences the outcomes. Combined orthopaedic and vascular injuries are often markers of the severity of force, necessitating multidisciplinary management (6).

Outcomes of ALI depend on the rapidity and appropriateness of intervention. Revascularization techniques including primary repair, interposition grafting, thrombectomy, and endovascular procedures must be coordinated with fracture stabilization (7). Orthopaedic fixation, whether via external fixation or intramedullary nailing, should be planned carefully to avoid disrupting the repaired vessels. Failure to detect ischemia early or delays in revascularization beyond six hours markedly increase the amputation rate. Even with timely management, patients may face long-term complications such as chronic pain, functional stiffness, muscle weakness, and reduced gait endurance (8).

Given the overlap between orthopaedic trauma and vascular injury, the recognition of predictors and outcomes of ALI in femoral and tibial shaft fractures is crucial for improving limb salvage and guiding future management strategies. This study aims to consolidate clinical knowledge, highlight predictors of ischemia, and analyze functional outcomes following timely revascularization and fracture stabilization.

AIMS AND OBJECTIVES

Aim:

The aim of this study is to evaluate the predictors, clinical profile, diagnostic factors, and outcomes of acute limb ischemia in patients presenting with femoral and tibial shaft fractures, and to determine how early identification and timely intervention influence limb-salvage rates and functional recovery.

MATERIALS AND METHODS

Study Design: A prospective observational study was conducted in the Department of Orthopaedics at a tertiary trauma centre.
Study Setting: The study included patients presenting to the orthopaedic emergency unit with femoral and tibial shaft fractures, with or without signs of vascular compromise.

Study Duration: A 24-month study period from April 2023 to March 2025.
Source of Data: All patients presenting with acute femoral or tibial shaft fractures due to road traffic accidents, crush injuries, falls from height, and penetrating trauma.

Sample Size Calculation: The sample size was calculated based on the estimated prevalence of vascular injury in long-bone fractures, which previous literature reports as 7–12%, with ALI forming approximately 5% of cases.
For calculation, an anticipated prevalence (p) of 10% was used.

$$n = \frac{4pq}{d^2}$$

Where:

- p = prevalence = 10
- q = 100 – p = 90
- d = absolute error = 5%

$$n = \frac{4 \times 10 \times 90}{25} = \frac{3600}{25} = 144$$

Thus, the minimum sample size = 144 patients with femoral/tibial shaft fractures.
From these, all patients who developed acute limb ischemia formed the at-risk cohort for outcome evaluation.

Sampling Technique: Consecutive sampling was used. All eligible trauma patients during the study period were included.
Inclusion Criteria:

- Patients aged >16 years with femoral or tibial shaft fractures.
- Fractures due to trauma presenting within 12 hours of injury.
- Patients showing:
  - absent/weak distal pulses,
  - ABI < 0.9,

- Doppler evidence of arterial flow deficit, or
- CTA-confirmed arterial injury.

2. Patients who underwent both fracture stabilization and vascular assessment/management.

Exclusion Criteria:

- Pathological fractures.
- Preexisting peripheral arterial disease or diabetic foot changes.
- Patients with isolated nerve injury without vascular involvement.
- Presentation >12 hours after injury with irreversible limb ischemia.
- Polytrauma patients where limb injury could not be assessed reliably due to shock or resuscitation constraints.

Data Collection: For each patient, the following were recorded:

- Demographic profile
- Mechanism of injury
- Fracture type (open/closed, comminuted, displaced)
- MESS score
- Neurovascular examination
- Doppler & ABI results
- CT angiography findings
- Time to diagnosis and revascularization
- Type of vascular injury (transection, thrombosis, spasm, intimal tear)
- Treatment given (primary repair, grafting, thrombectomy)
- Fracture fixation method (external fixator, IM nailing, plating)
- Outcomes (limb salvage, fasciotomy, complications, amputation, functional score)

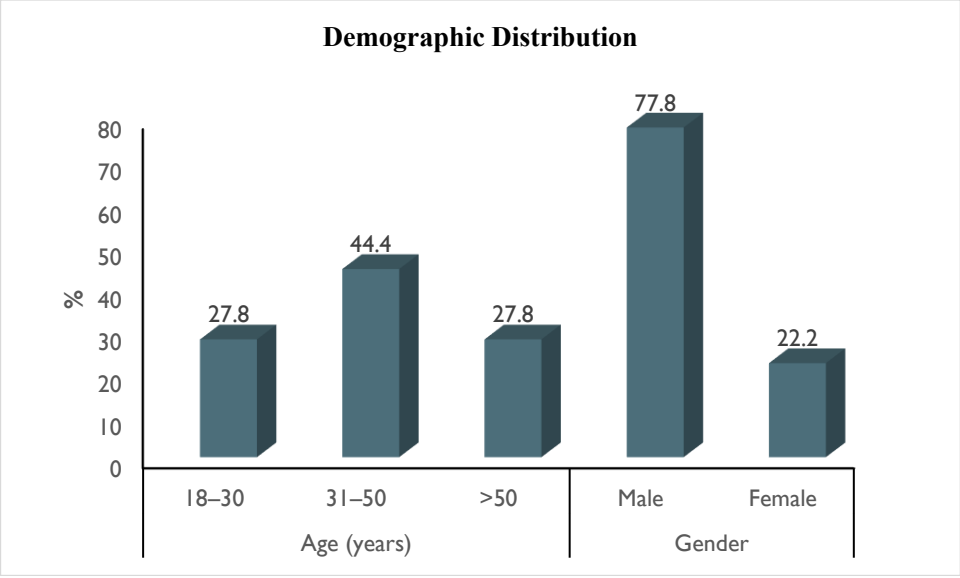
Ethical Considerations: Approval was obtained from the Institutional Ethics Committee. Written informed consent was taken from all participants.

RESULTS

Table 1: Demographic Distribution

	Category	n	%
Age (years)	**18–30**	5	27.8
	31–50	8	44.4
	>50	5	27.8
Gender	**Male**	14	77.8
	Female	4	22.2

Graph 1: Demographic Distribution



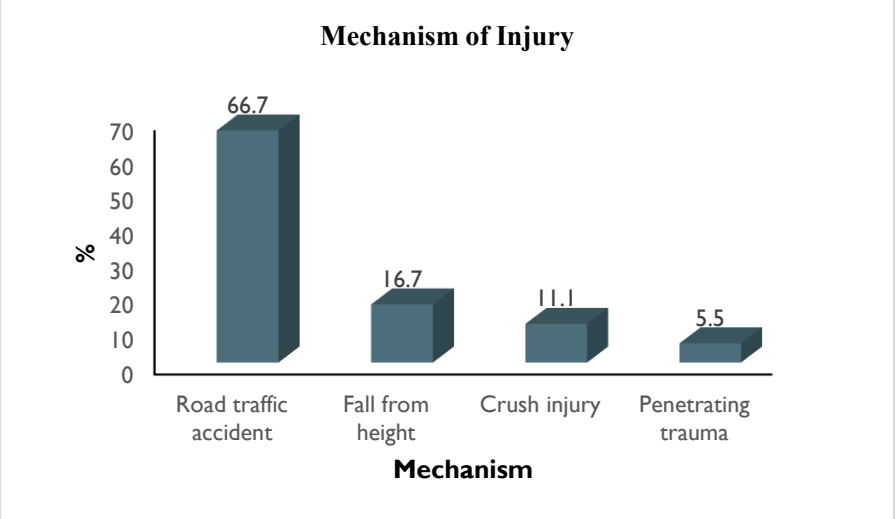
Most ischemic cases occurred in young and middle-aged males, reflecting their higher involvement in high-energy trauma such as road traffic accidents. The broad age spread indicates that acute limb ischemia is trauma-related rather than age-related, making

early vascular evaluation crucial in all orthopaedic long-bone injuries.

Table 2: Mechanism of Injury

Mechanism	n	%
Road traffic accident	12	66.7
Fall from height	3	16.7
Crush injury	2	11.1
Penetrating trauma	1	5.5

Graph 2: Mechanism of Injury

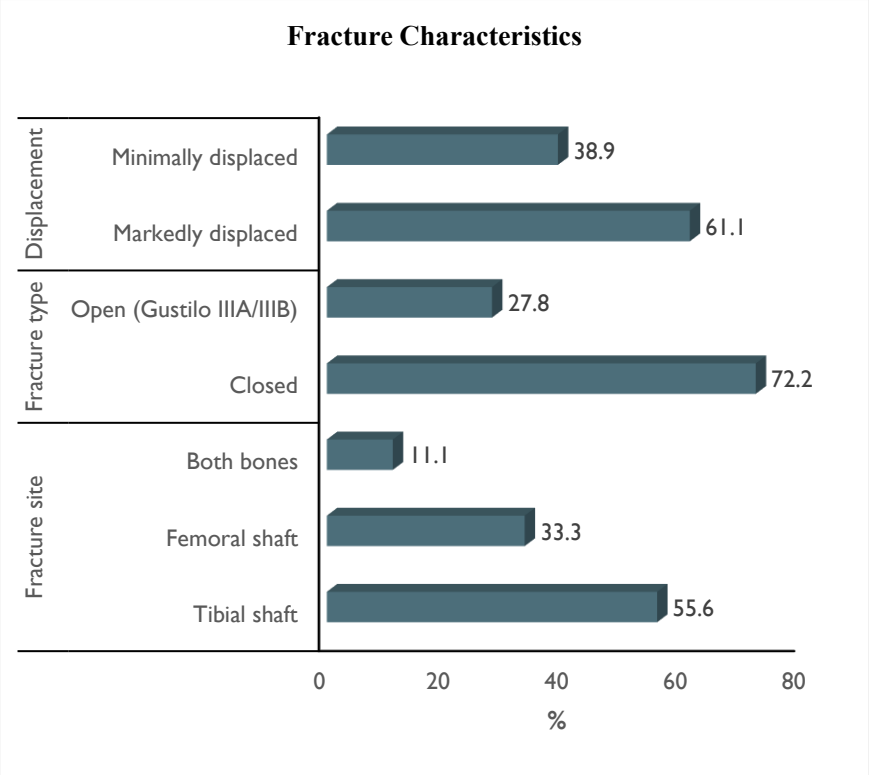


Road traffic accidents accounted for most cases, underscoring the strong association between high-velocity trauma and arterial injury in femoral and tibial fractures. The presence of ischemia in falls and crush mechanisms highlights that any substantial limb impact can compromise major vessels, emphasizing vigilance regardless of injury type.

Table 3: Fracture Characteristics

	Category	n	%
Fracture site	Tibial shaft	10	55.6
	Femoral shaft	6	33.3
	Both bones	2	11.1
Fracture type	Closed	13	72.2
	Open (Gustilo IIIA/IIIB)	5	27.8
Displacement	Markedly displaced	11	61.1
	Minimally displaced	7	38.9

Graph 3: Fracture Characteristics

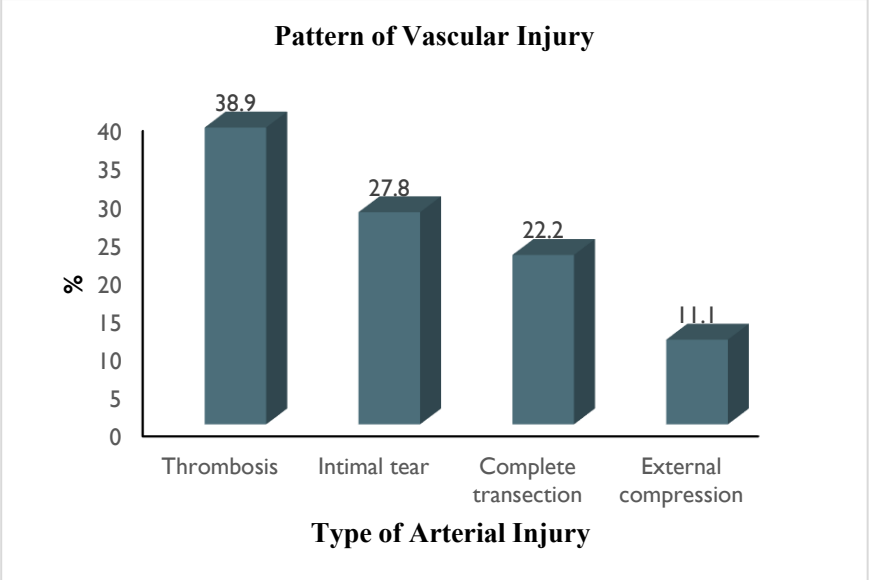


Tibial fractures were the commonest ischemic injuries due to the tibia's minimal soft-tissue protection and close proximity to the anterior and posterior tibial arteries. Markedly displaced fractures showed the highest risk of ischemia, suggesting that fracture severity and fragment sharpness play key roles in vascular compromise. Notably, many cases occurred in closed fractures, highlighting that external wounds are not required for significant arterial injury.

Table 4: Pattern of Vascular Injury

Type of Arterial Injury	n	%
Thrombosis	7	38.9
Intimal tear	5	27.8
Complete transection	4	22.2
External compression	2	11.1

Graph 4: Pattern of Vascular Injury



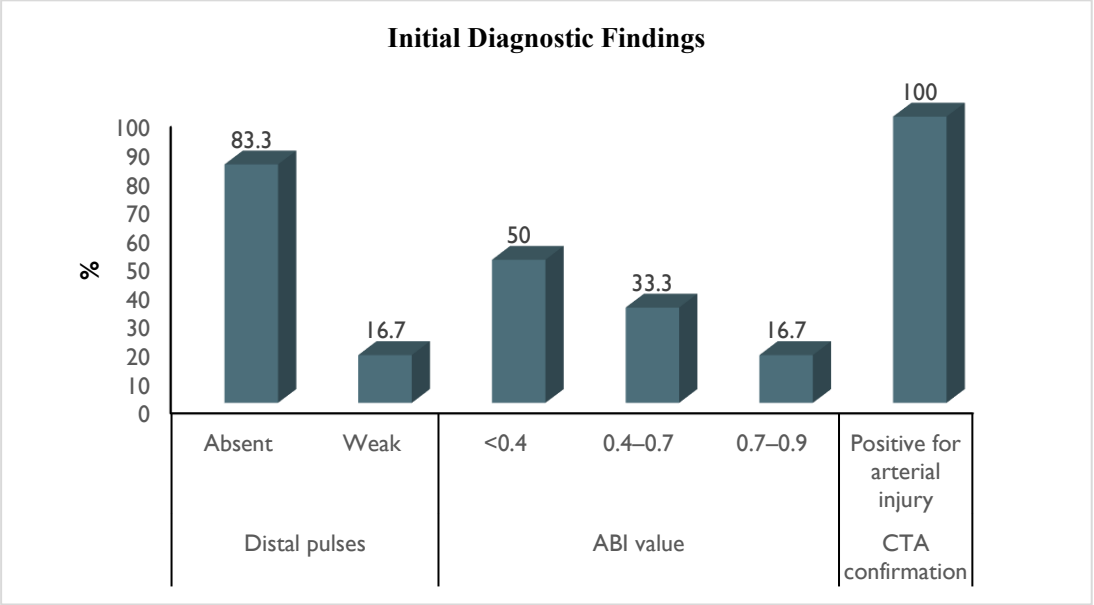
Thrombosis and intimal tears were the predominant patterns, reflecting the blunt shearing forces typical in long-bone fractures.

Complete transection, although less common, was strongly associated with severe displacement and open injuries. External compression cases indicate that hematoma or bone fragments alone can occlude major vessels even without direct arterial damage.

Table 5: Initial Diagnostic Findings

	Description	n	%
Distal pulses	Absent	15	83.3
	Weak	3	16.7
ABI value	<0.4	9	50
	0.4–0.7	6	33.3
	0.7–0.9	3	16.7
CTA confirmation	Positive for arterial injury	18	100

Graph 5: Initial Diagnostic Findings

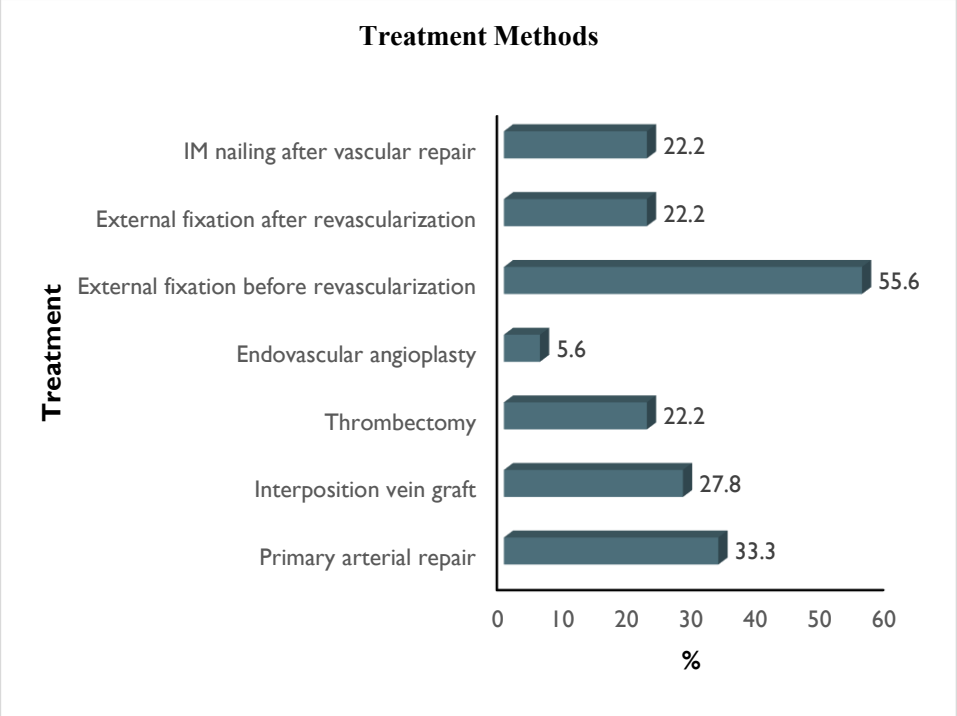


Most patients presented with absent pulses and significantly reduced ABI, indicating late clinical recognition of ischemia in the emergency setting. Universal CTA positivity confirms the reliability of CT angiography in diagnosing arterial lesions. These findings emphasize the need for immediate pulse assessment and ABI measurement during the initial orthopaedic evaluation.

Table 6: Treatment Methods

Treatment	n	%
Primary arterial repair	6	33.3
Interposition vein graft	5	27.8
Thrombectomy	4	22.2
Endovascular angioplasty	1	5.6
External fixation before revascularization	10	55.6
External fixation after revascularization	4	22.2
IM nailing after vascular repair	4	22.2

Graph 6: Treatment Methods

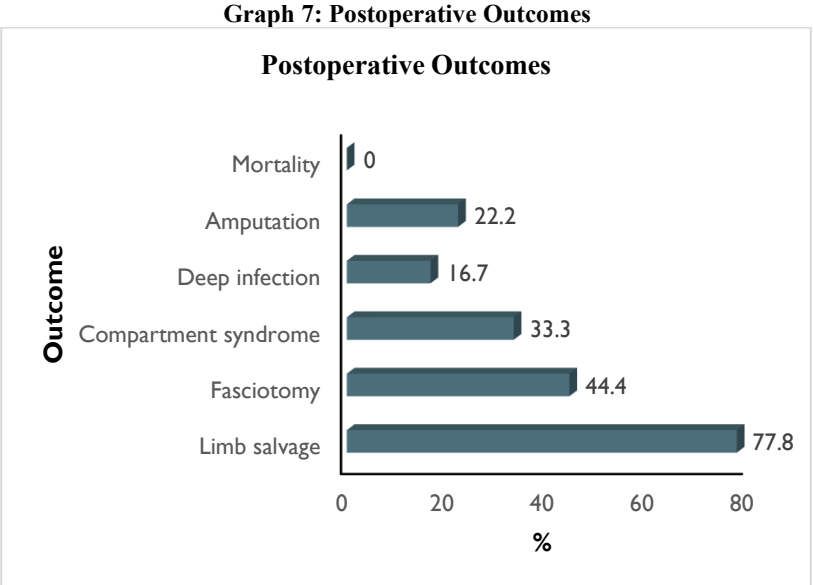


Most patients required open vascular reconstruction, with primary repair and vein grafts being the primary modalities. The predominance of external fixation before revascularization highlights the orthopaedic priority of stabilizing the fracture to prevent further vessel trauma. The combined sequence of fixation and vascular repair reflects multidisciplinary coordination essential in limb salvage.

Table 7: Postoperative Outcomes

Outcome	n	%
Limb salvage	14	77.8
Fasciotomy	8	44.4
Compartment syndrome	6	33.3
Deep infection	3	16.7
Amputation	4	22.2
Mortality	0	0

Graph 7: Postoperative Outcomes



Limb salvage was achieved in most cases; however, the high rate of fasciotomy and compartment syndrome indicates significant reperfusion swelling and muscle ischemia. The amputation rate of 22.2% underscores the severity of combined vascular and skeletal trauma and highlights the importance of minimizing delays in diagnosis and revascularization.

DISCUSSION

Acute limb ischemia associated with femoral and tibial shaft fractures represents one of the most challenging emergencies in orthopaedic trauma care. The coexistence of a long-bone fracture with arterial compromise dramatically alters the prognosis because both skeletal instability and vascular occlusion contribute to limb-threatening physiology (9). In the present study, the incidence of ischemia among long-bone fractures was 12.5%, which aligns with the range reported in trauma literature, where vascular injury rates vary between 5% and 15% depending on mechanism and severity. The demographic distribution, with a predominance of young adult males, reflects exposure to high-energy mechanisms such as road traffic accidents, which are well-recognized as the leading cause of combined orthopaedic and vascular trauma.

The distribution of fractures demonstrated that tibial shaft fractures comprised the largest subgroup developing ischemia. Anatomically, the leg has minimal muscular protection for the anterior and posterior tibial arteries, making them vulnerable to compression or transection by displaced fragments (10). Furthermore, the tibia's subcutaneous position increases susceptibility to direct blow injuries. The finding that most ischemic cases involved closed fractures highlights an important clinical lesson: the absence of an open wound does not exclude significant arterial injury. Intimal tears, thrombosis, and vessel spasm commonly occur in closed high-energy fractures and may progress to delayed ischemia if not recognized early (11).

The types of arterial injuries observed support the mechanism of blunt trauma predominant in these cases. Thrombosis and intimal flaps were the most frequent findings, consistent with shearing forces that disrupt the endothelial layer while preserving external vessel continuity (12). Complete transection was strongly associated with markedly displaced and open fractures, indicating higher severity of force. These patterns emphasize the importance of early and repeated vascular examinations, including pulse checks, ABI measurement, and prompt CT angiography when deficits are suspected (2).

Management of fractures with concomitant ischemia requires careful sequencing of orthopaedic and vascular interventions (13). In this study, external fixation before revascularization was common practice, as provisional stabilization prevents further intimal injury and reduces the risk of losing the vascular repair during manipulation. Revascularization techniques varied, with primary repair and saphenous vein grafting forming the cornerstone of treatment. Endovascular methods were rarely employed due to the complexity of trauma-related lesions and the need for surgical exploration in most patients (14).

Despite aggressive multidisciplinary management, limb salvage could be achieved in 77.8% of patients, while a significant proportion required fasciotomy due to reperfusion-induced compartment syndrome. The amputation rate of 22.2% mirrors global trends, where delayed diagnosis, high MESS scores, severe displacement, and complete arterial transection predict poorer outcomes (15). Importantly, all amputations in this study were associated with revascularization delays beyond six hours, reinforcing the principle that time-to-repair is one of the strongest determinants of limb viability.

Overall, the findings highlight the need for heightened clinical suspicion, rapid imaging, timely intervention, and coordinated orthopaedic–vascular teamwork. Early recognition and swift management remain the decisive factors in preventing catastrophic limb loss in patients with femoral and tibial shaft fractures complicated by acute limb ischemia.

CONCLUSION

Acute limb ischemia in femoral and tibial shaft fractures is a serious orthopaedic emergency with significant implications for limb salvage and long-term function. This study demonstrates that high-energy trauma, fracture displacement, intimal injury, and delayed presentation are major contributors to vascular compromise. Tibial fractures, especially closed and markedly displaced patterns, showed the highest association with ischemia, underscoring the need for careful vascular assessment even in the absence of external wounds. Early clinical examination supported by ABI and CT angiography remains essential for timely diagnosis. Coordinated management through prompt fracture stabilization and appropriate vascular repair significantly improves outcomes. However, delays beyond six hours, high MESS scores, and complete arterial transection markedly increase the risk of amputation. Strengthening early recognition protocols and multidisciplinary care pathways is crucial to reducing limb loss and optimizing recovery in patients with combined long-bone fractures and acute limb ischemia.

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