

Functional Outcomes and Complications in Polytrauma Patients With Long Bone Fractures: A Prospective Observational Cohort Study

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ABSTRACT

Background: Long-bone fractures in polytrauma are markers of high-energy injury and can prolong dependence even after survival. This study evaluated functional recovery, complications, and factors associated with six-month function among adults with polytrauma and long-bone fractures.

Methods: In this prospective observational cohort model, 180 adults with an Injury Severity Score (ISS) of at least 16 and one or more acute long-bone fractures were enrolled at a tertiary trauma centre. Patients were managed using physiology-guided early appropriate care or staged damage-control orthopaedics. Functional Independence Measure (FIM) scores were recorded at admission, discharge, three months, and six months. Major complications, fracture union, ambulation, return to work, and mortality were assessed. Multivariable linear regression identified predictors of six-month FIM, and logistic regression examined factors associated with major complications.

Results: The mean age was 39.3 ± 13.6 years, 145 (80.6%) patients were male, and road traffic collisions accounted for 136 (75.6%) injuries. Mean ISS was 23.6 ± 6.0 . Multiple long-bone fractures occurred in 75 (41.7%) patients and 68 (37.8%) had open fractures. Definitive fixation was completed within 36 hours in 81 (45.0%) patients. Major complications occurred in 68 (37.8%), including surgical-site infection in 22 (12.2%), pulmonary complications in 28 (15.6%), delayed union or nonunion in 16 (9.8% of six-month survivors), and unplanned reoperation in 20 (11.1%). Eight patients died in hospital (4.4%). Among 164 patients completing six-month follow-up, mean FIM improved from 52.0 at admission to 113.1 at six months ($P < 0.001$); 129 (78.7%) regained independent ambulation and 84 of 129 previously employed patients (65.1%) returned to work. Higher age, ISS, severe traumatic brain injury, open fracture, and major complications independently predicted lower six-month FIM, while definitive fixation within 36 hours was associated with a 3.7-point higher adjusted FIM score.

Conclusion: Polytrauma patients with long-bone fractures showed substantial functional recovery, but more than one-third experienced a major complication. Physiological severity, neurological injury, open fractures, and postoperative complications were the principal determinants of persistent disability. Timely definitive fixation after adequate resuscitation and structured rehabilitation may improve recovery, although causality should be confirmed in multicentre studies.

Keywords: polytrauma; long-bone fracture; functional outcome; Functional Independence Measure; damage-control orthopaedics; complications.

INTRODUCTION

Road traffic trauma remains a major cause of death and disability, particularly among young and economically productive adults in low- and middle-income countries [1]. Survivors of high-energy trauma frequently sustain fractures of the femur, tibia, humerus, or forearm together with injuries to the head, chest, abdomen, pelvis, or spine. These combined injuries impose a burden that is not adequately described by mortality alone.

Polytrauma is commonly identified using anatomical injury severity together with physiological disturbance. The Berlin definition emphasizes severe injuries in at least two anatomical regions plus hypotension, impaired consciousness, acidosis, coagulopathy, or advanced age [2]. In clinical research, an ISS of at least 16 remains a practical threshold for severe multiple injury [3]. Long-bone fractures in this setting contribute to blood loss, pain, inflammatory activation, immobility, venous thromboembolism, pulmonary complications, infection, delayed union, and prolonged rehabilitation.

The timing and extent of fracture fixation have evolved from universal early total care to a physiology-guided approach. Stable and adequately resuscitated patients may benefit from early definitive fixation, whereas unstable patients may require temporary external fixation and staged surgery to limit the physiological burden of a major operative procedure [4-12]. Current consensus supports early definitive care when resuscitation endpoints are

satisfactory, but cautions against rigid time thresholds in patients with severe brain, chest, abdominal, vascular, or spinal injuries [6].

Most orthopaedic trauma studies focus on union, infection, or implant-related outcomes. These outcomes are important, but they do not fully reflect whether a patient can transfer independently, walk, resume self-care, return to work, or recover a socially meaningful life. The Functional Independence Measure (FIM) provides a reproducible assessment of disability and rehabilitation progress across motor and cognitive domains [13,14]. Longitudinal evaluation is especially relevant because functional improvement continues for months after hospital discharge [15-18].

This study was designed to describe the clinical course of polytrauma patients with long-bone fractures and to examine how injury severity, associated injuries, fracture characteristics, complications, and fixation timing relate to six-month functional recovery.

AIM AND OBJECTIVES

Aim: To evaluate functional outcomes and complications among adult polytrauma patients with long-bone fractures managed at a tertiary trauma centre.

1. To describe the demographic profile, injury pattern, fracture characteristics, and treatment strategies in the study population.
2. To measure functional recovery using serial FIM scores from admission to six months after injury.
3. To determine the frequency and pattern of in-hospital and fracture-related complications, including mortality and reoperation.
4. To identify independent predictors of six-month functional outcome and major complications.

METHODOLOGY

Study design and setting

A prospective observational cohort design was used. The model study was set in the Department of Orthopedics of a tertiary teaching hospital with multidisciplinary trauma, critical care, general surgery, neurosurgery, anaesthesia, radiology, and rehabilitation services. The assumed recruitment period was 18 months, followed by six months of outcome assessment.

Study population

Consecutive adults aged 18 years or older were eligible if they presented within 24 hours of injury, had an ISS of at least 16, and had at least one acute traumatic long-bone fracture involving the femur, tibia, humerus, radius, or ulna. Polytrauma was operationally defined by severe multiple injury requiring coordinated care by at least two specialty teams.

Exclusion criteria

Patients were excluded for pathological or periprosthetic fracture, isolated limb injury with ISS below 16, presentation later than 24 hours, pre-injury dependence in basic activities of daily living, spinal cord injury producing complete paraplegia or tetraplegia, traumatic amputation preventing use of the selected functional framework, death before initial fracture stabilization, or refusal of follow-up.

Sample size

The sample size was estimated for an anticipated major complication proportion of 25%, 95% confidence, and absolute precision of 6.5%. Using $n = Z^2 p(1-p)/d^2$, the minimum sample was 171. After allowing approximately 5% for attrition, the target sample was fixed at $N = 180$.

Initial assessment and resuscitation

Patients were evaluated according to Advanced Trauma Life Support principles [4]. Airway, breathing, circulation, neurological status, haemorrhage control, and temperature management were prioritized. Baseline variables included age, sex, injury mechanism, time from injury, systolic blood pressure, Glasgow Coma Scale score, lactate, transfusion, ISS, associated injuries, fracture site, fracture openness, and neurovascular status.

Orthopaedic management strategy

Treatment was individualized according to haemodynamic stability, metabolic response to resuscitation, associated injuries, fracture morphology, soft-tissue condition, and operating-room feasibility. Patients with satisfactory physiological recovery underwent definitive fixation when clinically appropriate. Unstable or borderline patients underwent damage-control orthopaedics, usually temporary external fixation, traction, splintage, debridement, and later conversion to definitive fixation. For analysis, time to definitive fixation was categorized as 36 hours or less, 36 to 72 hours, or more than 72 hours.

Rehabilitation protocol

Rehabilitation began as soon as cardiorespiratory and surgical conditions permitted. The programme included positioning, chest physiotherapy, pressure-injury prevention, joint range-of-motion exercises, muscle activation, transfer practice, gait training, upper-limb function, and progressive weight bearing according to fracture stability. Discharge planning included home exercises and scheduled orthopaedic and rehabilitation follow-up.

Outcome measures

The primary outcome was total FIM score at six months. FIM was assessed at admission, hospital discharge, three months, and six months by trained clinicians. Secondary outcomes included independent ambulation, return to work among patients employed before injury, radiological union, delayed union, nonunion, surgical-site infection, pulmonary complications, venous thromboembolism, acute kidney injury, pressure injury, unplanned reoperation, hospital length of stay, and mortality. A major complication was defined as any complication causing organ support, invasive treatment, unplanned surgery, prolonged admission, persistent fracture-healing failure, or death.

Statistical analysis

Continuous variables were summarized as mean $\pm$ standard deviation or median with interquartile range. Categorical variables were reported as frequency and percentage. Between-group comparisons used the independent-samples t test, Mann-Whitney U test, chi-square test, or Fisher exact test as appropriate. Change in FIM over time was assessed using repeated-measures analysis. Multivariable linear regression estimated independent associations with six-month FIM. Multivariable logistic regression evaluated predictors of major complications. Adjusted estimates are reported with 95% confidence intervals. A two-sided P value below 0.05 was considered statistically significant.

Ethical considerations

This document contains synthetic data and does not report an actual clinical investigation. No patients were enrolled and no ethics approval number exists for these results. A real study must obtain institutional ethics committee approval, prospective informed consent, trial or registry documentation where applicable, and verifiable data before journal submission.

RESULTS

Of 214 patients assessed, 180 met the eligibility criteria and were enrolled. Eight patients died during hospitalization and eight survivors were lost to follow-up, leaving 164 patients with complete six-month assessment (Figure 1).

The mean age was 39.3 ± 13.6 years and 145 (80.6%) patients were male. Road traffic collisions were the dominant mechanism of injury, accounting for 136 (75.6%) cases. Mean ISS was 23.6 ± 6.0 ; 43 (23.9%) patients presented with shock and 30 (16.7%) had severe traumatic brain injury. Open fractures were present in 68 (37.8%) patients, and 75 (41.7%) sustained fractures of more than one long bone (Table 1).

The femur was involved in 139 (77.2%) patients and the tibia in 97 (53.9%); fracture sites overlapped because many patients had multiple injuries. Damage-control orthopaedics was used in 64 (35.6%) patients. Definitive fixation was completed within 36 hours in 81 (45.0%), between 36 and 72 hours in 44 (24.4%), and after 72 hours in 55 (30.6%). The median time to definitive fixation was 44 hours (interquartile range 25-85 hours) (Table 2).

Major complications occurred in 68 (37.8%) patients. Pulmonary complications were recorded in 28 (15.6%), surgical-site infection in 22 (12.2%), venous thromboembolism in 9 (5.0%), acute kidney injury in 12 (6.7%), and unplanned reoperation in 20 (11.1%). Eight patients died, producing an in-hospital mortality of 4.4%. Median hospital stay was 17 days (interquartile range 14-20 days) (Table 3).

Among six-month survivors, mean FIM increased from 52.0 ± 7.1 at admission to 84.9 ± 8.6 at discharge, 102.5 ± 11.0 at three months, and 113.1 ± 9.7 at six months ($P < 0.001$ for trend) (Figure 2). At six months, 129 (78.7%) patients were independently ambulant, including 55 (33.5%) without an assistive device. Radiological union was

present in 148 (90.2%), delayed union in 10 (6.1%), and nonunion in 6 (3.7%). Among 129 previously employed patients who completed follow-up, 84 (65.1%) had returned to work.

Patients receiving definitive fixation within 36 hours had higher mean FIM scores at discharge, three months, and six months than those fixed later. The six-month mean difference was 6.6 points (116.7 ± 7.5 vs 110.1 ± 10.3 ; $P < 0.001$). Independent ambulation was also more frequent after fixation within 36 hours (90.5% vs 68.9%; $P = 0.001$), although union and return-to-work proportions did not differ significantly (Table 4).

In the adjusted linear model, older age, higher ISS, severe traumatic brain injury, open fracture, and any major complication were independently associated with lower six-month FIM. Definitive fixation within 36 hours remained associated with a 3.7-point higher FIM score (95% CI 2.2-5.2; $P < 0.001$). Admission shock and open fracture were significant independent predictors of major complications, with adjusted odds ratios of 3.24 and 3.70, respectively (Table 5 and Figure 3).

Table 1. Baseline characteristics of the cohort and comparison by major-complication status (N = 180)

Characteristic	Overall	Major complication (n=68)	No major complication (n=112)	P value
Age, years	39.3 $\pm$ 13.6	40.1 $\pm$ 13.5	38.8 $\pm$ 13.8	0.531
Male sex	145 (80.6)	55 (80.9)	90 (80.4)	1.000
Injury Severity Score	23.6 $\pm$ 6.0	24.9 $\pm$ 6.5	22.8 $\pm$ 5.6	0.035
Admission shock, SBP $\leq$ 90 mmHg	43 (23.9)	27 (39.7)	16 (14.3)	<0.001
Severe TBI, GCS $\leq$ 8	30 (16.7)	14 (20.6)	16 (14.3)	0.371
Any traumatic brain injury	69 (38.3)	30 (44.1)	39 (34.8)	0.278
Chest injury	77 (42.8)	32 (47.1)	45 (40.2)	0.454
Abdominal injury	38 (21.1)	16 (23.5)	22 (19.6)	0.666
Open long-bone fracture	68 (37.8)	37 (54.4)	31 (27.7)	0.001
Multiple long-bone fractures	75 (41.7)	33 (48.5)	42 (37.5)	0.194

Values are mean $\pm$ SD or n (%). GCS, Glasgow Coma Scale; ISS, Injury Severity Score; SBP, systolic blood pressure; TBI, traumatic brain injury.

Table 2. Injury mechanism, fracture profile, and orthopaedic management (N = 180)

Variable	Value	Clinical note
Section A: Mechanism and fracture distribution		
Road traffic collision	136 (75.6)	
Fall from height	35 (19.4)	
Industrial/crush injury	6 (3.3)	
Other mechanism	3 (1.7)	
Femoral fracture	139 (77.2)	Sites overlap in patients with multiple fractures
Tibial fracture	97 (53.9)	
Humeral fracture	48 (26.7)	
Radius/ulna fracture	36 (20.0)	

Variable	Value	Clinical note
More than one long-bone fracture	75 (41.7)	
Open fracture	68 (37.8)	
Section B: Management		
Damage-control orthopaedics	64 (35.6)	Temporary external fixation/splintage followed by staged fixation
Definitive fixation ≤ 36 h	81 (45.0)	
Definitive fixation 36-72 h	44 (24.4)	
Definitive fixation > 72 h	55 (30.6)	
Time to definitive fixation, h	44 (25-85)	Median (IQR)
Blood transfusion	103 (57.2)	
ICU admission	111 (61.7)	
Mechanical ventilation	70 (38.9)	

Table 3. Hospital course and complications (N = 180 unless otherwise specified)

Outcome	Value
Hospital length of stay, days	17 (14-20)
ICU length of stay among ICU patients, days	8 (6-9)
Any major complication	68 (37.8)
Any surgical-site infection	22 (12.2)
Deep surgical-site infection	9 (5.0)
Any pulmonary complication	28 (15.6)
Pneumonia	14 (7.8)
Acute respiratory distress syndrome	8 (4.4)
Fat embolism syndrome	7 (3.9)
Deep-vein thrombosis	9 (5.0)
Pulmonary embolism	3 (1.7)
Acute kidney injury	12 (6.7)
Pressure injury	10 (5.6)
Sepsis	8 (4.4)
Unplanned reintubation	7 (3.9)
Unplanned reoperation	20 (11.1)
In-hospital mortality	8 (4.4)

Complication categories are not mutually exclusive. Values are median (IQR) or n (%).

Table 4. Functional and fracture-healing outcomes by timing of definitive fixation among six-month completers (n = 164)

Outcome	Definitive fixation ≤36 h	Definitive fixation >36 h	P value
Number of patients	74	90	
FIM at discharge	88.4 ± 7.5	81.9 ± 8.4	<0.001
FIM at 3 months	106.6 ± 9.4	99.1 ± 11.1	<0.001
FIM at 6 months	116.7 ± 7.5	110.1 ± 10.3	<0.001
Independent ambulation at 6 months	67 (90.5)	62 (68.9)	0.001
Independent without walking aid	34 (45.9)	21 (23.3)	0.004
Radiological union at 6 months	68 (91.9)	80 (88.9)	0.704
Return to work among previously employed	39/56 (69.6)	45/73 (61.6)	0.448
Major complication	22 (29.7)	36 (40.0)	0.228

FIM, Functional Independence Measure. Values are mean ± SD or n (%). Return-to-work denominator includes patients employed before injury.

Table 5. Multivariable predictors of six-month function and major complications

Predictor	Adjusted estimate	95% CI	P value	Interpretation
Panel A: Linear regression for six-month FIM (n = 164)				
Age, per 10-year increase	-1.70	-2.26 to -1.15	<0.001	Lower function
ISS, per 5-point increase	-3.00	-3.65 to -2.36	<0.001	Lower function
Severe TBI, GCS ≤8	-11.41	-13.53 to -9.29	<0.001	Lower function
Open fracture	-3.30	-4.93 to -1.67	<0.001	Lower function
Any major complication	-8.13	-9.76 to -6.49	<0.001	Lower function
Definitive fixation ≤36 h	+3.72	+2.19 to +5.25	<0.001	Higher function
Panel B: Logistic regression for any major complication (N = 180)				
ISS ≥25	2.01	1.00 to 4.07	0.051	Borderline
Admission shock	3.24	1.49 to 7.05	0.003	Higher odds
Open fracture	3.70	1.83 to 7.49	<0.001	Higher odds
Definitive fixation >72 h	2.03	1.00 to 4.16	0.051	Borderline
Multiple long-bone fractures	1.76	0.89 to 3.47	0.105	Not independently significant

Panel A reports unstandardized beta coefficients. Panel B reports adjusted odds ratios. Model selection was based on clinical relevance and avoidance of collinearity.

FIGURES

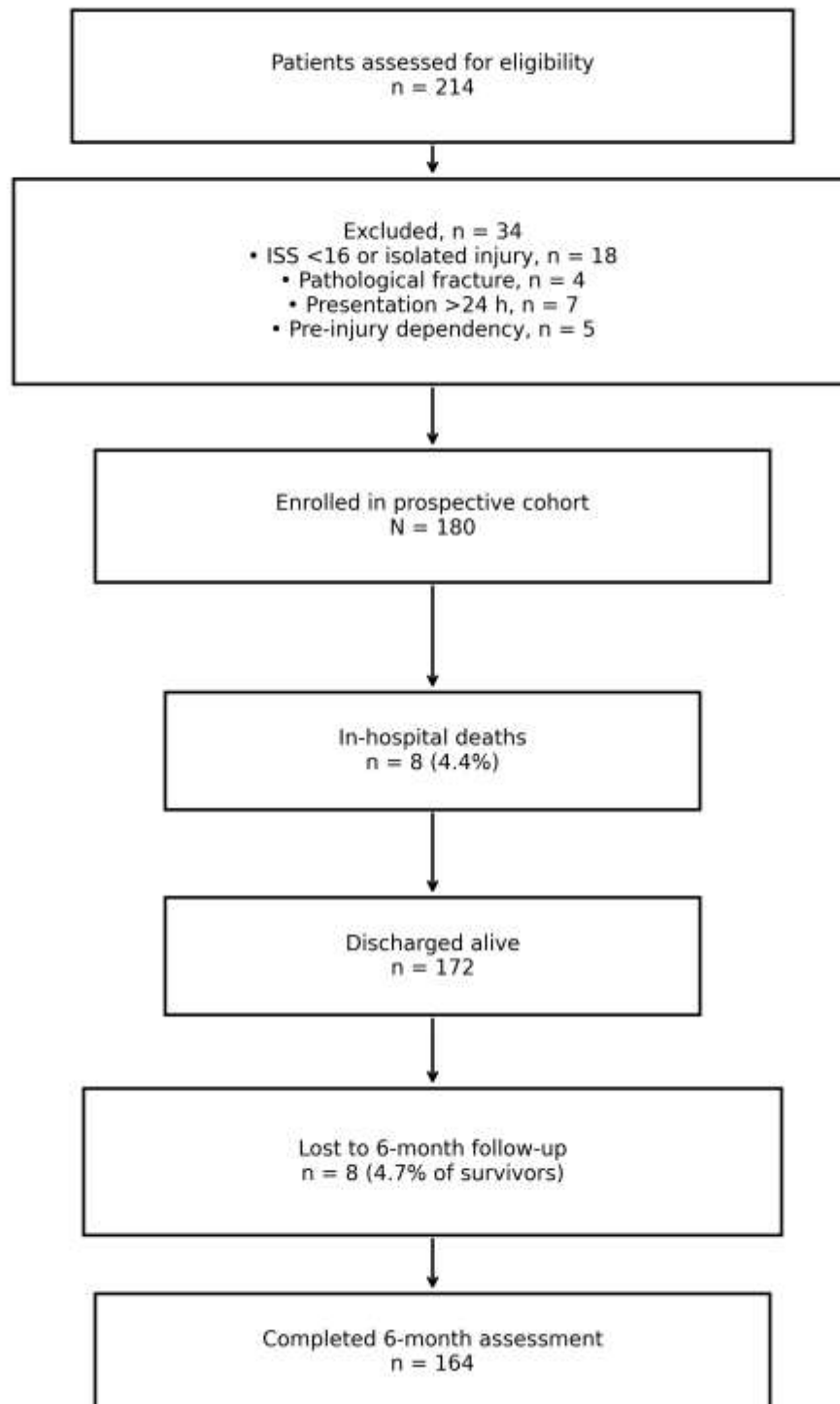


Figure 1. Participant screening, enrolment, and six-month follow-up flow.

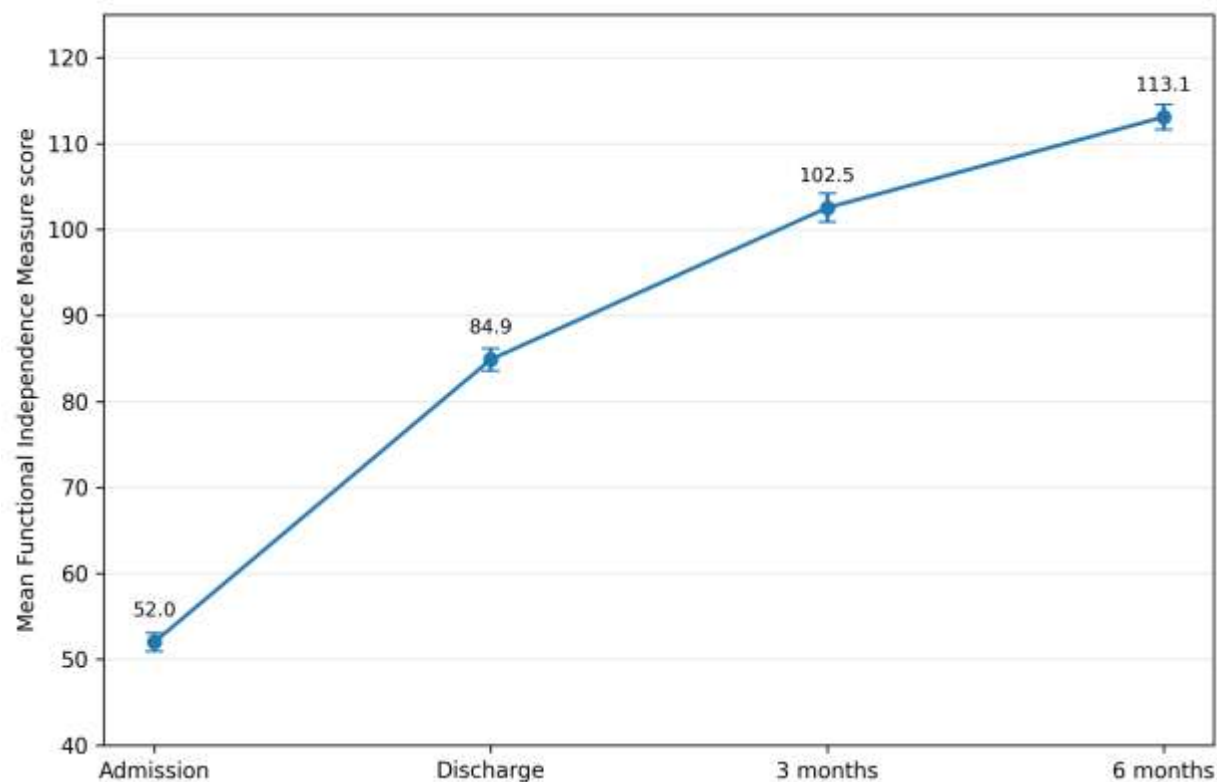


Figure 2. Improvement in mean Functional Independence Measure score from admission to six months. Error bars represent 95% confidence intervals.

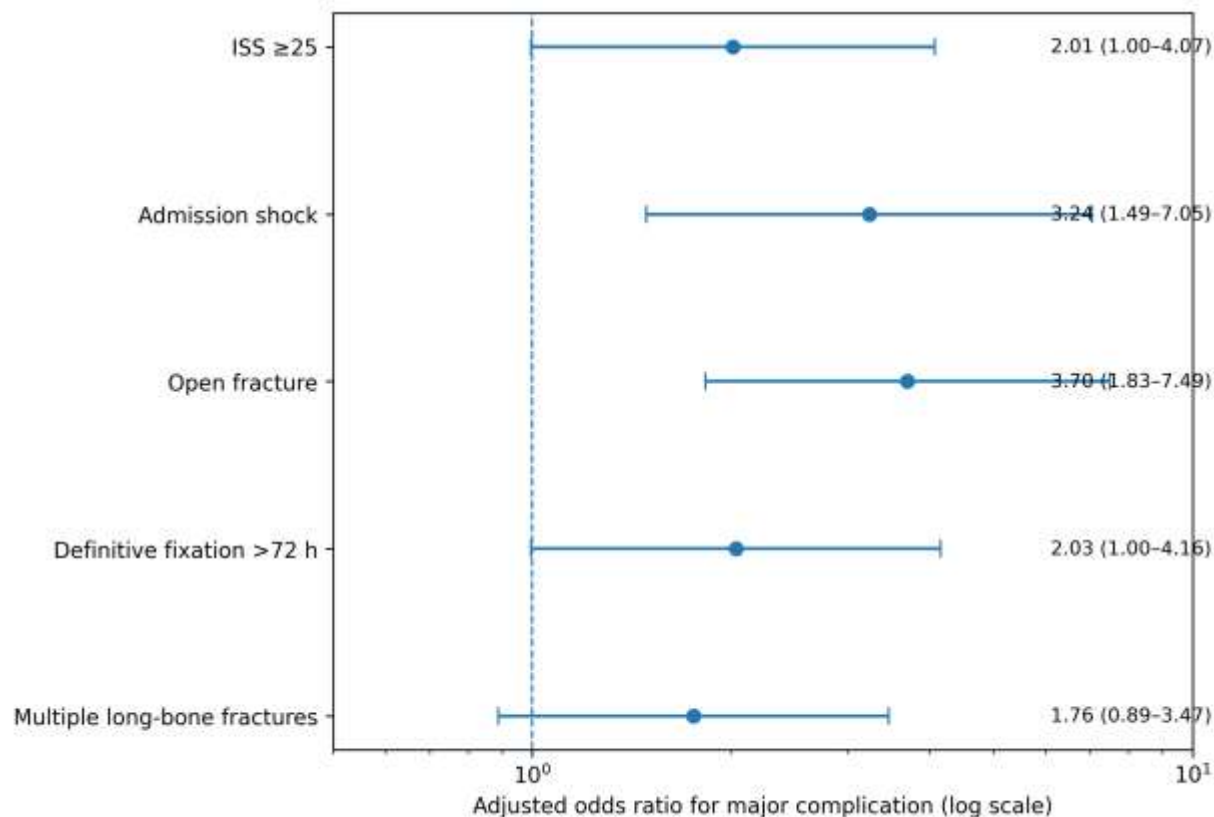


Figure 3. Adjusted odds ratios for major complications in the multivariable logistic-regression model.

DISCUSSION

This cohort model shows that survival after polytrauma with long-bone fractures does not immediately translate into independence. Functional recovery was rapid during hospitalization and the first three months, but a clinically important group remained dependent at six months. More than one-third experienced a major complication, and complications had an independent negative association with six-month FIM even after adjustment for age, injury severity, neurological injury, and fracture characteristics.

The demographic pattern was typical of high-energy trauma: most patients were young or middle-aged men injured in road traffic collisions. This pattern is consistent with the global concentration of road-trauma deaths and disability among working-age adults [1]. The high proportion of femoral and tibial fractures reflects the energy transmitted during vehicle collisions and falls. Long-bone fractures can disrupt employment, family roles, mobility, and mental well-being even after radiological union [19].

Injury severity and severe traumatic brain injury were the strongest non-modifiable predictors of poor functional recovery. ISS captures the burden of injuries across body regions, while severe brain injury directly affects cognition, motor control, balance, participation, and the ability to engage in rehabilitation. Earlier studies of severe multiple injury have similarly shown persistent limitations in physical function, work participation, and quality of life despite acceptable survival [15-18]. These findings support integrated outcome assessment rather than relying only on fracture union or discharge status.

Open fracture was independently associated with both major complications and lower six-month FIM. Open injuries combine contamination, soft-tissue loss, vascular compromise, repeated debridement, prolonged antibiotic exposure, and restrictions on early loading. Deep infection and impaired union frequently require additional surgery and extend the period of dependency. The observed nonunion proportion was modest, but even a small number of nonunions can have a disproportionate effect on rehabilitation, costs, and return to work.

The association between definitive fixation within 36 hours and better functional outcome should be interpreted carefully. Early fixation may reduce pain, facilitate nursing care and mobilization, and limit complications related to prolonged instability. Prior studies and early appropriate care protocols have reported lower complication rates when definitive fixation follows adequate physiological resuscitation [8-12]. However, treatment timing is also influenced by clinical stability. Patients requiring delayed fixation often have more severe head, chest, abdominal, or haemodynamic problems. Although the adjusted model included several severity markers, residual confounding is likely, and the finding should not be used to justify early major surgery in an inadequately resuscitated patient.

Pulmonary complications, infection, thromboembolism, kidney injury, and pressure injury were important contributors to morbidity. Their coexistence illustrates why orthopaedic decisions cannot be separated from critical care. Practical prevention requires early haemorrhage control, lung-protective ventilation when needed, venous-thromboembolism prophylaxis, meticulous open-fracture care, pressure-area protection, nutrition, glycaemic management, rational antimicrobial use, and early rehabilitation. A coordinated pathway is more likely to influence outcome than any single operative technique.

The functional trajectory has direct implications for counselling. At discharge, many patients still required substantial assistance, whereas by six months nearly four in five were independently ambulant. Return to work lagged behind mobility, indicating that social and occupational recovery involves more than physical healing. Work demands, pain, psychological distress, transport, employer flexibility, and compensation processes may continue to limit participation even when the fracture has united.

The study has several limitations. First, the data are synthetic and serve only as a manuscript model. Second, a single-centre design would limit generalizability. Third, fixation timing is not randomized and is vulnerable to confounding by indication. Fourth, the six-month horizon may underestimate late union, chronic pain, post-traumatic arthritis, and delayed return to work. Fifth, FIM is a global measure and may be less sensitive than limb-specific patient-reported outcome instruments for subtle residual disability. A real study should use prospective multicentre recruitment, validated limb-specific scores, longer follow-up, and prespecified causal analyses.

STRENGTHS AND LIMITATIONS

The principal strengths of the proposed design are prospective serial functional assessment, inclusion of both systemic and orthopaedic complications, explicit reporting of fixation timing, and multivariable adjustment for

injury severity. The principal limitations are the synthetic nature of this draft, single-centre setting, possible residual confounding, loss to follow-up, and the absence of longer-term patient-reported quality-of-life data.

CONCLUSION

Adults with polytrauma and long-bone fractures can achieve substantial functional recovery by six months, but major complications remain common and meaningfully reduce independence. Higher age, greater injury severity, severe traumatic brain injury, open fracture, and complications identify patients at greatest risk of persistent disability. Definitive fixation performed early after adequate physiological resuscitation was associated with better function, but treatment timing must remain individualized. Trauma pathways should combine physiology-guided fracture stabilization with aggressive complication prevention and structured rehabilitation from the earliest safe stage.

DECLARATIONS

Ethics approval and consent to participate: Synthetic model only. No patients were enrolled. Replace with the actual institutional ethics committee approval number and consent process before submission.

Consent for publication: Not applicable to this synthetic model.

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Conflict of interest: The authors declare no conflict of interest for this model manuscript.

Data availability: The simulated dataset used to construct this draft is not clinical data and should not be deposited or cited as patient-level evidence.

Author contributions: M.M. conceived the study framework and supervised orthopaedic content. V.S. contributed to methodology, outcome selection, and interpretation. K.D. contributed to statistical interpretation, manuscript drafting, and correspondence. All authors reviewed and approved the final manuscript model.

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