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Assessment of Post-Traumatic Complications of Long Bone Fractures in Iraq: A Multicenter Prospective Study

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Abstract

Background: Long bone fractures are a major driver of orthopaedic trauma morbidity in Iraq, where high-energy mechanisms, constrained resources, and operative delays plausibly increase risks of infection and impaired union. Yet prospective multicenter estimates of complication burden and its determinants remain limited. We aimed to quantify the incidence and pattern of post-traumatic complications and to identify independent predictors following operative fixation of long bone fractures at three Iraqi tertiary referral hospitals.

Methods: We conducted a prospective cohort study at 3 private hospitals in Baghdad city from January 2021 to December 2023. Adults (≥18 years) with femur, tibia, humerus, radius, or ulna fractures undergoing operative fixation within 72 hours of presentation were enrolled. Outcomes at 12 months were pre-specified: surgical site infection, delayed union/nonunion, malunion, compartment syndrome, implant failure, and amputation. Independent predictors of major complications were evaluated using multivariable binary logistic regression.

Results: Of 912 screened patients, 847 were enrolled (mean age 34.7 ± 14.2 years; 76.3% male); 803 completed 12-month follow-up. Road traffic accidents accounted for 58.4% of injuries, and 43.2% of fractures were open. Overall, 38.6% developed at least one major complication (327/847). Surgical site infection was most common (18.9%), followed by delayed union/nonunion (12.9%), malunion (8.4%), and implant failure (6.7%); the amputation rate was 3.2%. Multidrug-resistant organisms were recovered in 54.4% of positive wound cultures. Independent predictors of major complications were Gustilo–Anderson type III open fracture (aOR 4.82; 95% CI 3.21–7.24), operative delay >24 hours (aOR 3.17; 95% CI 2.08–4.83), diabetes mellitus (aOR 2.94; 95% CI 1.76–4.91), blast/gunshot mechanism (aOR 2.63; 95% CI 1.59–4.35), and BMI >30 kg/m² (aOR 1.87; 95% CI 1.23–2.84).

Conclusion: Major complications after operative fixation of long bone fractures are frequent in Iraqi tertiary trauma care, with infection and impaired union predominating and MDR pathogens common. Risk concentrates in type III open injury, delayed surgery, diabetes, high-energy penetrating/blast mechanisms, and obesity—factors that are partially modifiable at system and patient levels. Priorities include antibiotic prophylaxis at first contact, streamlined pathways to definitive surgery, and antimicrobial stewardship.

Keywords:

long bone fracture; postoperative complication; open fracture; surgical site infection; nonunion; antimicrobial resistance; Iraq.

Introduction

Fractures of the long bones of the femur, tibia/fibula, humerus, radius, and ulna continue to be one of the most common forms of orthopedic trauma globally. Studies have shown that these types of fractures are also responsible for a significant proportion of hospitalizations and long-term disability compared to other types of skeletal injuries.[1] Their consequences extend beyond just providing acute surgical care: long-term rehabilitation, work disability and ongoing downstream resource utilization related to the treatment of complications.[2] The evidence illuminates that resource-limited countries have inadequate pre-hospital care; limitations in the availability of surgical resources, imaging technology, and follow-up surveillance will predictably lead to an increase in complication rates.[3]

Complications from the fixation of long bone fractures can range from temporary wound complications to limb threatening problems such as deep infection, nonunion that cannot be repaired, and major amputation. The clinically relevant endpoints include delayed/nonunion, surgical site infection, osteomyelitis, malunion, compartment syndrome, implant failure, and thromboembolic events.[4,5] Risk is determined by the interaction of the patient (age, nutritional status, immune competency, smoking habits, metabolic disease), and the type of injury (pattern of injury, soft tissue injury, injury to the periosteum, and blood supply loss).[5,6].

Open fractures have the highest risk profile for complications. The Gustilo–Anderson classification system is the current standard for grading the severity of open fractures, and also utilized for predicting the risk for developing an infection.[7,8] Patients with Type III open fractures have been shown to have greater than a 10% chance of developing an infection and more than 30% chance for developing a nonunion, even in an advanced trauma center.[9], In addition, Papakostidis et al. in a systematic review found a reported range of 44% deep infection rates in Type IIIB open tibial shaft fractures and an increase in complication risk with rising grades.[9] Regions of conflict have a negative effect on this population through the mechanism of injury (i.e. blast or high-velocity projectiles) creating more Type IIIB/IIIC injuries, and increasing the complex nature of definitive reconstructive surgery.[10,11]

The burden on Iraq as a result of orthopedic injuries is substantial. The ongoing violence in Iraq has left scars on the country. The last few decades of war and violence have caused a variety of injuries in both civilian and military populations throughout Iraq. There are also increasing numbers of people suffering from infections and other medical conditions related to these injuries. In addition, civilian healthcare and delivery systems in Iraq have been devastated by fighting (as well as emigration, attrition, and damage to healthcare infrastructure). This situation is exacerbated by long supply chains and unreliable methods of inter-hospital transfer, significantly extending the amount of time until definitive treatment is available. All of this has resulted in increased rates of complications resulting from injury (e.g., infected grafts), delayed reunions of bones, or infections in non-union. Access to hospitals, blood banks, and critical care beds appears to be irregular across different regions of the country, particularly with significant differences between Baghdad and peripheral governorates such as Al-Anbar, Nineveh, and Diyala. In addition to these problems related to medical care, the types of organisms that cause infections in Iraq differ markedly from those that are typically seen in developed countries. Infections of wounds in Iraq typically include multidrug-resistant (MDR) Acinetobacter baumannii and ESBL-producing Enterobacteriaceae which are likely driven by poor infection control capabilities, a lack of access to microbiologically directed therapy, and the wide-ranging use of broad-spectrum antibiotics prior to diagnosis.[5,15] This resistance limits the options available for treating patients, leads to prolonged treatments, and creates a higher frequency of chronically infected implants and amputations.[16,17] There is limited use of the Cierny classification, which is useful for treating chronic osteomyelitis, among Iraqi hospitals.[16]

The other major problem associated with osteomyelitis is nonunion. The successful uniting of 2 bone segments is dependent on mechanical stability; an adequate blood supply from the periosteum; the presence of osteogenic cells, growth factors and an osteoconductive scaffold.[6,18] Road injuries sustained during military conflict are often associated with contamination, periosteal stripping, and severe malnutrition which prevents the achievement of any one or more of the above prerequisites, thereby putting the possibility of achieving union at risk.[4] The nonunion rates for open tibial fractures vary widely from approximately 4% for low-grade injuries treated with reamed intramedullary nailing to more than 20% for severely comminuted (grade IIIB) fractures and the rates for injuries located in the long bones of the body are consistently higher than those reported from around the world.[19] The use of management options (exchange nailing, bone grafting, biological augmentation) places added pressure on the budget of these healthcare facilities that are already unable to meet even basic healthcare requirements.[20]

Clinically, malunion or healing at an unacceptable angle, rotation, or shortening is an important concern in a low-resource area; it remains to be reported in the literature. Most malunions occur secondary to inadequate reduction at initial treatment, premature bearing weight, or continued alignment loss from bone loss due to infection.[21,22] These patients will suffer long-term functional problems including gait disturbances, abnormal joint loading, an increased likelihood of developing arthritis and chronic pain with a measurable decrease in quality of life and work capacity due to the malunion complications they experience.[23,24] The majority of these patients are young men of working-age; therefore, restoring functional mobility will significantly affect the young working-age male demographic that makes up the majority of traumatic injuries in Iraq.

Despite this information and the associated problems, there is a distinct lack of epidemiologic data in Iraq related to the occurrence of post-trauma complications. Research studies conducted in Iraq have largely been limited to retrospective reviews of single-centre patients with insufficient follow-up and small numbers of patients undergoing the same procedure, which limits physicians' ability to compare, contrast, or synthesise data.[10] There are no multicentre prospective clinical studies evaluating post-trauma complications within the framework of a guideline developed specifically for the Iraqi healthcare system, and this has made it difficult to develop evidence to support targeted investment in Iraq's trauma care delivery system.

The primary goal of this prospective multicentre study is to help fill the void described above. The primary objective is to determine the incidence, spectrum, and timing of major complications following operative management of long-bone fractures in adult patients at 3 private hospitals in Baghdad city. The secondary objectives include determining independent predictors at both the patient and injury levels; evaluating the microbiology and antimicrobial resistance profiles of deep infections; and comparing patient outcomes across anatomical locations and fixation methods. The objective is to provide clinically useful information that will support quality improvement initiatives, promote appropriate use of antibiotics, and promote targeted investments in Iraq's trauma delivery systems.

Methods

Study Design and Setting

This prospective observational cohort study was conducted at 3 private hospitals in Baghdad city. The study ran from 1 January 2021 to 31 December 2023 with a minimum follow-up of 12 months per participant. All participants provided written informed consent.

Eligibility Criteria

Inclusion criteria were age ≥18 years, traumatic fracture of a long bone (femur, tibia with or without fibula, humerus, radius, ulna), and operative fixation at a participating centre within 72 hours of initial presentation. Exclusion criteria were pathological fracture due to primary or metastatic tumour; periprosthetic fracture; pre-existing osteomyelitis or chronic bone infection; inability to provide informed consent (cognitive impairment, altered consciousness, or no legally authorised representative); or low likelihood of follow-up as judged by the enrolling clinician. Patients who did not attend any scheduled follow-up visit for six months were excluded from the primary outcome analysis to preserve outcome ascertainment.

Data Collection

Standardised electronic case report forms were completed by trained research coordinators at each centre after unified pre-study training. Baseline variables included demographics (age, sex, BMI, governorate, occupation), mechanism (road traffic accident, fall, blast/gunshot, crush, other), anatomical location, and AO/OTA fracture morphology; open fractures were graded by Gustilo–Anderson. Comorbidities included diabetes mellitus, hypertension, chronic kidney disease, ischaemic heart disease, and current tobacco use. Time from injury to presentation and from presentation to surgery were recorded to the nearest hour. Operative variables included fixation strategy (intramedullary nail, plate, external fixation, staged conversion), antibiotic prophylaxis regimen/duration, operative time, estimated blood loss, and need for vascular or soft tissue reconstruction.

Follow-up visits were scheduled at 2 weeks, 6 weeks, 3 months, 6 months, and 12 months after fixation. Each visit included clinical review and standard anteroposterior and lateral radiographs of the injured segment underweight bearing where appropriate. A study nurse confirmed attendance by telephone 48 hours before each appointment. Unscheduled emergency and outpatient attendances were also captured and incorporated into the dataset.

Outcome Definitions

The primary endpoint was any pre-specified major complication within 12 months. Surgical site infection (SSI) was classified using United States Centers for Disease Control and Prevention (CDC) surveillance definitions (superficial incisional, deep incisional, and organ/space, the latter equivalent to osteomyelitis). Deep infection was confirmed by intraoperative tissue culture at return to theatre or by wound swab culture in the presence of clear clinical infection. Nonunion was defined as absence of radiographic bridging at nine months post-fixation; delayed union was absence of bridging callus across ≥3 of 4 cortices at six months in fractures expected to unite within that interval. Malunion was defined as angulation >5° in any plane, rotation >10°, or limb shortening >10 mm, measured using standardised digital radiographic assessment and clinical goniometry.

Acute compartment syndrome was diagnosed clinically (pain out of proportion and on passive stretch, tense compartments, and paraesthesia). In equivocal cases, intracompartmental pressure was measured using the Stryker IntraCompartmental Pressure Monitor System; a delta pressure (diastolic blood pressure minus compartment pressure) <30 mmHg was the operative threshold. Implant failure was any breakage, loosening, or clinically significant migration requiring unplanned revision or resulting in loss of acceptable reduction. Amputation was any major limb amputation performed as a direct consequence of the index injury or its complications.

Bacteriological Assessment

For confirmed deep infection or clinical osteomyelitis, at least three intraoperative tissue specimens per site were collected with separate sterile instruments and processed for aerobic/anaerobic and fungal culture with susceptibility testing according to European Committee on Antimicrobial Susceptibility Testing (EUCAST) standards. Organisms were identified by MALDI-TOF MS where available or by conventional biochemical methods. MDR was defined as non-susceptibility to ≥1 agent in ≥3 antimicrobial categories using standard international criteria. Species distribution and resistance patterns were tabulated.

Statistical Analysis

Data were entered into an encrypted REDCap database (v12.5; Vanderbilt University, Nashville, TN, USA) with range checks and mandatory validation, then analysed in IBM SPSS Statistics v26 (IBM Corporation, Armonk, NY, USA). Continuous variables are reported as mean ± SD (normal) or median [IQR] (non-normal), assessed using the Shapiro–Wilk test. Categorical variables are reported as n (%). Group comparisons used independent-samples *t*-test or Mann–Whitney U test for continuous variables and Pearson chi-square or Fisher's exact test for categorical variables.

Independent predictors of major complications were assessed using multivariable binary logistic regression, including candidate variables with univariable screening $p < 0.10$. Model fit was assessed with Hosmer–Lemeshow testing; discrimination was assessed by AUC. Results are reported as adjusted odds ratios (aOR) with 95% confidence intervals; two-tailed $p < 0.05$ was considered statistically significant. Sample size was calculated a priori assuming a 35% complication rate, ±5% precision, and 95% confidence, yielding a minimum of 786 patients; allowing 10% loss to follow-up, the recruitment target was 870.

Results

Cohort and follow-up

Over 36 months, 912 patients were screened; 65 were excluded (23 declined, 18 met exclusion criteria, 14 were transferred to non-participating facilities, and 10 could not provide consent), leaving 847 enrolled. At 12 months, 803 (94.8%) completed follow-up and formed the primary analytical cohort. Forty-four patients were lost between 6 and 12 months; their last-contact data were retained for secondary analyses. Baseline sociodemographic and injury characteristics are summarised in Table 1.

Table 1. Baseline Sociodemographic, Clinical, and Injury Characteristics of the Study Cohort (n = 847)

Variable	**Value**
Age (years), mean ± SD	34.7 ± 14.2
Male sex, n (%)	647 (76.4%)
Body mass index (kg/m²), mean ± SD	26.3 ± 5.1
BMI ≥30 kg/m², n (%)	154 (18.2%)
Diabetes mellitus, n (%)	98 (11.6%)
Hypertension, n (%)	74 (8.7%)
Tobacco use (current), n (%)	187 (22.1%)
Chronic kidney disease, n (%)	31 (3.7%)
Injury mechanism, n (%)	
Road traffic accident	495 (58.4%)
Fall from height	180 (21.3%)
Blast or gunshot injury	124 (14.6%)
Other mechanism	48 (5.7%)
Open fracture, n (%)	366 (43.2%)
Gustilo–Anderson Type I	69 (18.9%)*
Gustilo–Anderson Type II	118 (32.2%)*
Gustilo–Anderson Type IIIA	102 (27.9%)*
Gustilo–Anderson Type IIIB	52 (14.2%)*
Gustilo–Anderson Type IIIC	25 (6.8%)*
Time from injury to presentation, hours, median [IQR]	3.2 [1.8–6.7]
Time from presentation to surgery, hours, median [IQR]	18.4 [10.2–31.6]
Surgical delay >24 hours, n (%)	289 (34.1%)

* Percentage of open fractures only. SD, standard deviation; IQR, interquartile range; BMI, body mass index.

Injury and fracture profile

The tibia/fibula was most frequently injured (38.7%), followed by the femur (28.4%), forearm bones (16.7%), and humerus (16.2%). Open fractures were most prevalent in tibial injuries

(52.1%). Gustilo–Anderson type III injuries accounted for 21.1% of all fractures and 48.9% of open fractures. Fracture distribution by anatomical location is detailed in Table 2.

Table 2. Distribution and Classification of Long Bone Fractures by Anatomical Location (n = 847)

Bone Fractured	Total n (%)	Open n (%)	GA Type III n (%)	Bilateral/Multiple n (%)
Femur	241 (28.4%)	88 (36.5%)	42 (17.4%)	37 (15.4%)
Tibia/Fibula	328 (38.7%)	171 (52.1%)	98 (29.9%)	29 (8.8%)
Humerus	137 (16.2%)	52 (37.9%)	21 (15.3%)	4 (2.9%)
Radius/Ulna	141 (16.7%)	55 (39.0%)	18 (12.8%)	8 (5.7%)
Total	**847 (100%)**	**366 (43.2%)**	**179 (21.1%)**	**78 (9.2%)**

GA, Gustilo–Anderson; Multiple, ipsilateral or contralateral concurrent long bone fracture.

Complication burden at 12 months

At 12 months, 38.6% (327/847) experienced at least one major complication. SSI was most frequent (18.9%), followed by delayed union/nonunion (12.9%), malunion (8.4%), implant failure (6.7%), compartment syndrome (4.1%), major amputation (3.2%), and thromboembolic events (2.6%). Complications were consistently more common after open versus closed fractures (any major complication: 59.6% vs 22.7%). Stratified complication rates are shown in Table 3.

Table 3. Incidence of Post-Traumatic Complications at 12-Month Follow-Up (n = 803)

Complication	Overall n (%)	Open Fractures n/N (%)	Closed Fractures n/N (%)
Any major complication	327 (38.6%)	218/366 (59.6%)	109/481 (22.7%)
Surgical site infection	160 (18.9%)	131/366 (35.8%)	29/481 (6.0%)
Superficial SSI	61 (7.2%)	45/366 (12.3%)	16/481 (3.3%)
Deep/organ-space SSI	99 (11.7%)	86/366 (23.5%)	13/481 (2.7%)
Delayed union/Nonunion	109 (12.9%)	84/366 (22.9%)	25/481 (5.2%)
Malunion	71 (8.4%)	46/366 (12.6%)	25/481 (5.2%)
Implant failure	57 (6.7%)	41/366 (11.2%)	16/481 (3.3%)
Compartment syndrome	35 (4.1%)	28/366 (7.7%)	7/481 (1.5%)
Amputation (major)	27 (3.2%)	25/366 (6.8%)	2/481 (0.4%)

Thromboembolic event	22 (2.6%)	14/366 (3.8%)	8/481 (1.7%)

SSI, surgical site infection.

Microbiology of deep infection

Among 160 culture-confirmed deep infections, *Staphylococcus aureus* was most common (31.3%), followed by *Pseudomonas aeruginosa* (22.5%) and *Acinetobacter baumannii* (18.1%). MDR organisms were identified in 54.4% (87/160) of cultures; pan-drug-resistant *Acinetobacter baumannii* represented the most treatment-refractory subgroup. Full microbiological findings are provided in Table 4.

Table 4. Bacteriological Profile of Culture-Confirmed Deep Wound Infections (n = 160)

Organism	Isolates n (%)	MDR n (%)	Resistance Note
Staphylococcus aureus	50 (31.3%)	28 (56.0%)	MRSA: 28/50 (56%)
Pseudomonas aeruginosa	36 (22.5%)	22 (61.1%)	Carbapenem-R: 14/36 (38.9%)
Acinetobacter baumannii	29 (18.1%)	24 (82.8%)	Pan-drug-R: 8/29 (27.6%)
Klebsiella pneumoniae	18 (11.3%)	12 (66.7%)	ESBL-producing: 12/18 (66.7%)
Escherichia coli	12 (7.5%)	7 (58.3%)	ESBL-producing: 7/12 (58.3%)
Other gram-negative bacilli	9 (5.6%)	4 (44.4%)	Mixed species
Anaerobes	6 (3.7%)	1 (16.7%)	*Bacteroides* spp.: 4/6
Total / Overall MDR	**160 (100%)**	**87 (54.4%)**	—

MDR, multidrug-resistant; MRSA, methicillin-resistant *Staphylococcus aureus*; ESBL, extended-spectrum beta-lactamase; Carbapenem-R, carbapenem-resistant; Pan-drug-R, pan-drug-resistant.

Independent predictors of major complications

In multivariable analysis, independent predictors of major complications were Gustilo–Anderson type III open fracture (aOR 4.82; 95% CI 3.21–7.24), surgical delay >24 hours (aOR 3.17; 95% CI 2.08–4.83), diabetes mellitus (aOR 2.94; 95% CI 1.76–4.91), blast/gunshot mechanism (aOR 2.63; 95% CI 1.59–4.35), BMI >30 kg/m² (aOR 1.87; 95% CI 1.23–2.84), tibial fracture location (aOR 1.71; 95% CI 1.18–2.48), and age ≥60 years (aOR 1.68; 95% CI 1.02–2.77) (Table 5). Male sex showed a positive association but was not statistically significant (aOR 1.43; 95% CI 0.94–2.17; $p = 0.092$). Model discrimination was good (AUC 0.81; 95% CI 0.78–0.84) with adequate calibration (Hosmer–Lemeshow $\chi^2 = 9.34$; $p = 0.317$).

Table 5. Multivariable Logistic Regression: Independent Predictors of Major Post-Traumatic Complications (n = 803)

Predictor Variable	Adjusted OR	95% CI	p-value
Gustilo–Anderson type III open fracture	4.82	3.21–7.24	<0.001
Surgical delay >24 hours	3.17	2.08–4.83	<0.001
Diabetes mellitus	2.94	1.76–4.91	<0.001

Blast or gunshot mechanism	2.63	1.59–4.35	<0.001
BMI >30 kg/m²	1.87	1.23–2.84	0.003
Tibial fracture location	1.71	1.18–2.48	0.005
Age ≥60 years	1.68	1.02–2.77	0.042
Male sex	1.43	0.94–2.17	0.092

OR, odds ratio; BMI, body mass index. AUC = 0.81 (95% CI 0.78–0.84). Male sex was retained as a variable of a priori clinical interest.

Discussion

Principal findings

This prospective multicenter cohort demonstrates a high burden of major complications after operative long bone fracture management in Iraq (38.6% at 12 months). This exceeds typical rates reported in high-income trauma systems (approximately 10–20% for comparable operative cohorts)[9,25] and aligns more closely with estimates from other resource-limited and conflict-affected settings in the region. [10,11] The consistency of complication rates across three geographically distinct tertiary centres suggests system-level determinants rather than isolated centre effects. Collectively, these results argue for targeted, context-specific quality improvement rather than direct transplantation of protocols developed in materially different health systems.

Infection burden and antibiotic timing

SSI was the most frequent complication (18.9% overall; 35.8% in open fractures). These rates sit at the upper end reported for open tibial and femoral fractures in low- and middle-income settings and exceed the 5–15% typically reported for Gustilo–Anderson type III injuries in high-income centres.[9,26] A key explanatory signal in this cohort is antibiotic timing: fewer than 60% of open fractures received a preoperative dose before debridement, largely because initial presentation occurred at peripheral facilities without reliable antibiotic supply. Seminal and subsequent data demonstrate that antibiotics administered within hours of injury markedly reduce infection risk in open fractures.[12,13] In practical terms, the most immediate, system-modifiable intervention supported by these data is prophylaxis at first contact (including district hospitals) through standardised protocols and ready-to-use kits.[13]

Antimicrobial resistance and infection management

The microbiology has direct implications for empiric therapy in Iraq. MDR pathogens accounted for 54.4% of deep infections; *Acinetobacter baumannii* showed the heaviest resistance burden, including pan-drug resistance in 27.6% of isolates, consistent with reports from Iraqi and regional conflict-zone hospitals. [5,15] MRSA comprised 56% of *Staphylococcus aureus* isolates, and ESBL-producing Enterobacteriaceae were common. Under these conditions, standard empiric regimens (first-generation cephalosporin ± aminoglycoside) are likely inadequate for a substantial proportion of deep infections. Frameworks for implant-associated infection and osteomyelitis management emphasise early culture confirmation and structured surgical decision-making. [15,16] Operational priorities therefore include reliable microbiology capacity with susceptibility testing, consistent use of staging/management frameworks, and formal antimicrobial stewardship (including carbapenem restriction to confirmed indications, prescribing audit, and infection-control training).

Union outcomes and fixation strategy

Delayed union/nonunion affected 12.9% overall and 22.9% of open fractures, consistent with published estimates for open tibial and femoral injuries. [19,27] Prior work identifies tibia and femur fractures as carrying the greatest absolute burden of nonunion globally,[28] mirroring the high tibial complication burden in this cohort. The diamond concept provides a useful biological synthesis—cells, growth factors, scaffold, and stability—and each component is plausibly compromised here by periosteal stripping in blast injuries, nutritional depletion, contamination, and reliance on less stable constructs when intramedullary nails are unavailable.[18] Evidence supports reamed intramedullary nailing as a strategy that reduces nonunion and reoperation risk in tibial shaft fractures, with open grade and comminution as key predictors.[29] System-level measures that stabilise implant procurement and reduce avoidable surgical delay are therefore likely to yield high-impact reductions in impaired union, with downstream cost benefits.[20]

Malunion and reconstruction quality

Malunion occurred in 8.4% overall and was more frequent after staged external fixation with delayed conversion. This likely reflects both alignment limitations inherent to external fixation in comminuted injuries and the technical challenges of exchange nailing in the setting of infection. Biomechanical principles emphasise construct design, initial reduction quality, and maintenance of alignment through consolidation.[21] Observational data also associate tibial malunion with inadequate intraoperative reduction and non-interlocked constructs.[22] Long-term functional consequences are substantial: LEAP analyses show that disability after severe lower-limb trauma is strongly influenced by the quality of reconstruction and surgeon-controlled variables, even after adjusting for injury severity.[30,31] These findings support investment in intraoperative imaging, training in anatomical reduction, and structured quality assurance for alignment.

High-energy penetrating/blast injury and wound management

Blast and gunshot mechanism independently predicted major complications (aOR 2.63), consistent with the pathobiology of high-velocity injury. Cavitation and devitalised tissue commonly extend beyond the visible wound, supporting staged debridement to viable margins rather than early primary closure.[11,31] In this context, primary closure at first debridement—reported in some centres due to throughput constraints—likely contributes to the high deep infection burden.[9] Negative pressure wound therapy between staged debridements and definitive coverage offers a practical strategy for managing contaminated wounds and facilitating planned reconstruction; comparative evidence suggests improved wound management outcomes versus conventional dressings.[32]

Operative delay and system constraints

Operative delay of greater than 24 hours was a strong independent predictor of significant complication (adjusted odds ratio of 3.17), which is consistent with literature demonstrating correlation between timely debridement/fixation and increased infection/union outcomes.[12,13] Although the median time to undergo surgery was 18.4 hours, there was marked variance around this value (interquartile range of 10.2 to 31.6) and one-third of patients delayed into greater than 24 hour operative intervals. The reasons for delay are structural, with there being issues such a competing emergency workload, anaesthetic limitations during after hours, limitations with implant stock, and a lack of dedicated theatre capacity for open fractures. There needs to be a focus on the improvement of the overall transfer and prioritisation of patients in-hospital; specifically, through the implementation of dedicated trauma surgeries, 24 hour through trauma coverage for access to implants, and protocols that enable for fast tracking patients who are admitted with an open fracture diagnosis. The rationale for implementing these recommendations is further supported by the large downstream costs which are associated with complications from nonunion and infection, which are avoidable.[20]

Conclusion

In Iraq, there are a significant number of complications after long-bone fractures (38.6% of patients experience this type of complication at 12 months), with the most common complications being infections and impaired bone union, and where open and/or blast related fractures are disproportionately affected by both problems. The majority of cultured deep infections in this population were caused by MDR pathogens (greater than 50%), which limits the effectiveness of standard empirical methods of treating these patients. There are several independent predictors (type III open fractures, >24 hours of operative delay, diabetes, blast or gunshot mechanism of injury, and obesity) which provide specific targets for intervention. The main priorities for trauma management are: perform prophylactic antibiotics at first medical contact; create expedited pathways to debridement and definitive fixation for open and/or blast related injuries; develop more robust methods of microbiology and infection control; provide additional resources for wound management (NPWT) when required for staged reconstruction. A national trauma data base, including prospective complication tracking, must be established for the purpose of assessing outcomes and driving a continual quality improvement agenda for Iraqi orthopaedic trauma care.

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