

Ketamine-Based Anesthesia for Orthopaedic and Trauma Surgery in a Regional Trauma Centre: A Pragmatic Service Delivery Model

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Abstract

Background: Limited access to main operating theatres and shortages of anaesthesia personnel remain major barriers to timely orthopaedic and trauma care in low- and middle-income countries (LMICs). In such settings, ketamine is an attractive anaesthetic option because it provides dissociative anaesthesia and analgesia while generally preserving spontaneous ventilation and airway reflexes. This study reports a five-year institutional experience of ketamine-based anaesthesia for orthopaedic and trauma surgery in a regional trauma centre and evaluates its clinical safety, feasibility, and service-delivery relevance. **Objectives:** The objectives are: 1) To evaluate the clinical safety, feasibility, and service delivery impact of ketamine-based anaesthesia for orthopaedic and trauma surgery in a regional trauma centre over a five-year period. 2) To describe patient clinical profiles and assess anaesthesia-related adverse events and perioperative complications. 3) To evaluate the procedural success rate and postoperative recovery characteristics following ketamine-assisted orthopaedic and trauma surgeries. **Methods:** This retrospective observational study included haemodynamically stable or adequately resuscitated patients who underwent selected orthopaedic and musculoskeletal trauma procedures under ketamine-based anaesthesia between January 2021 and December 2025. Eligibility criteria, monitoring standards, anaesthetic workflow, adjunct medication use, and complication-management pathways were standardized institutionally. Primary outcomes were procedural success, perioperative adverse events, recovery characteristics, and selected service-delivery indicators. Descriptive statistics were used, and exact 95% confidence intervals (CIs) were calculated for major event rates. **Results:** Of 1728 orthopaedic and trauma procedures performed during the study period, 1207 (69.8%) were completed under ketamine-based anaesthesia. Patients ranged from 3 to 75 years; 861

(71.3%) were male and 886 (73.4%) were emergency trauma cases. External fixation with or without wound debridement was the commonest procedure (47.1%). Procedural success, defined as completion of the planned procedure without conversion to general anaesthesia, unplanned airway intervention, or abandonment, was 100% (1207/1207; 95% CI 99.7 - 100). No anaesthesia-related mortality occurred (0/1207; 95% CI 0.0 - 0.31). The commonest perioperative adverse event was transient hypertension in 69 patients (5.7%; 95% CI 4.5 - 7.2), followed by nausea/vomiting in 19 (1.6%; 95% CI 1.0 - 2.4), transient desaturation in 7 (0.6%; 95% CI 0.23 - 1.19), delayed recovery in 7 (0.6%; 95% CI 0.23 - 1.19), and hypersalivation in 3 (0.25%; 95% CI 0.05 - 0.72). There were no emergence reactions and no unplanned airway interventions. Most patients recovered sufficiently and transferred to the wards within 20 to 45 minutes, and selected day-case patients were discharged the same day. **Conclusion:** Ketamine-based anaesthesia was a safe, feasible, and efficient approach for selected orthopaedic and trauma procedures in this regional trauma centre. Within a structured service-delivery model that includes careful case selection, minimum monitoring standards, and emergency readiness, ketamine can expand access to timely trauma surgery in resource-constrained settings.

Keywords

Ketamine Anesthesia, Orthopaedic Surgery, Musculoskeletal Trauma Surgery, Regional Trauma Centre, Procedural Sedation, Theatre Utilization in Low-Resource Settings

1. Introduction

Timely surgical intervention remains a cornerstone of effective orthopaedic and musculoskeletal trauma care. Delays in fracture stabilization, wound debridement, and emergency trauma procedures are associated with worsening symptoms as well as increased infection rates, prolonged hospitalization, higher complication burden, and poor functional outcomes [1] [2]. In low- and middle-income countries (LMICs), these challenges are compounded by limited access to operating theatre space, shortages of trained anesthesia personnel, inadequate monitoring infrastructure, and high trauma caseloads [3]. These systemic constraints necessitate innovative and pragmatic approaches to trauma anesthesia that are safe, cost-effective, and operationally efficient.

Ketamine, a phencyclidine derivative introduced into clinical practice in the 1960s, has emerged as a uniquely suitable anesthetic agent for trauma and emergency surgical settings [4]. Unlike conventional sedative-hypnotic agents, ketamine produces a dissociative anesthetic state characterized by profound analgesia, amnesia, and sedation while preserving protective airway reflexes and spontaneous respiration [4]. Its primary mechanism of action involves non-competitive antagonism of the N-methyl-D-aspartate (NMDA) receptor, resulting in inhibition of excitatory neurotransmission in the central nervous system [4]. In addi-

tion, ketamine interacts with opioid receptors, monoaminergic pathways, and voltage-gated calcium channels, contributing to its analgesic and sympathomimetic properties [5].

Pharmacokinetically, ketamine demonstrates rapid onset of action, typically within 30 - 60 seconds following intravenous administration and 3 - 5 minutes following intramuscular injection [5]. The duration of dissociative anesthesia ranges from 10 to 20 minutes after a single intravenous bolus, with prolonged analgesic effects mediated by active metabolites such as norketamine [6]. Hepatic metabolism through cytochrome P450 enzymes allows predictable clearance, enabling repeat bolus dosing or infusion during short to moderate duration procedures.

Ketamine dosing is flexible and adaptable to procedural requirements. Intravenous doses of 0.5 - 1.0 mg/kg provide effective procedural sedation, while 1 - 2 mg/kg achieves dissociative anesthesia. Intramuscular dosing typically ranges from 3 - 5 mg/kg when intravenous access is unavailable [7]. Sub-dissociative doses (0.1 - 0.3 mg/kg) have been shown to provide effective analgesia with minimal psychotropic effects and are increasingly used as part of multimodal pain strategies [8].

One of ketamine's major advantages in trauma and orthopaedic care is cardiovascular stability. Unlike agents such as propofol or benzodiazepines that may cause hypotension and respiratory depression, ketamine stimulates sympathetic tone, resulting in mild increases in heart rate and blood pressure [9]. This property is particularly beneficial in patients with borderline hemodynamic reserve. Additionally, preservation of spontaneous respiration reduces the need for airway instrumentation, an important consideration in centres with limited anesthesia equipment and critical care capacity.

Ketamine is frequently combined with adjunct medications to improve patient comfort and minimize adverse effects. Benzodiazepines such as midazolam are commonly administered to reduce emergence phenomena, while anticholinergic agents such as atropine or glycopyrrolate may be used to control hypersalivation [10]. Opioids, paracetamol, and non-steroidal anti-inflammatory drugs may be combined for multimodal analgesia. Low-dose propofol combinations ("ketofol") have also been explored to optimize sedation depth and recovery profiles [11].

Despite its favourable safety profile, ketamine may be associated with known side effects including nausea, vomiting, hypersalivation, transient hypertension, tachycardia, and emergence reactions characterized by hallucinations or agitation [12]. Rare complications such as laryngospasm and oxygen desaturation have been reported, particularly in pediatric populations, but remain uncommon with appropriate patient selection, dosage and monitoring [13].

Ketamine has been widely utilized in emergency departments, battlefield medicine, humanitarian missions, and trauma care in resource-limited environments [14]. Its inclusion on the World Health Organization Essential Medicines List highlights its clinical importance and global applicability [15]. However, most

published studies focus on short-term procedural sedation or small cohort experiences. There remains limited long-term institutional evidence evaluating ketamine as an integrated anesthesia strategy within trauma service delivery models.

This study therefore reports a four-year institutional experience using ketamine-based anesthesia for orthopaedic and trauma surgery in a regional trauma centre, focusing on clinical safety, procedural success, and operational impact on theatre utilization and service delivery.

2. Methods

This was a retrospective observational study conducted at a high-volume regional trauma centre with a dedicated trauma operating unit functionally separate from the hospital's main operating theatre complex. The trauma unit was used for selected orthopaedic and trauma procedures considered suitable for ketamine-based anaesthesia under a standardized institutional protocol. All eligible procedures performed between 1 January 2021 and 31 December 2025 were reviewed with the study population comprised all patients who underwent selected orthopaedic and musculoskeletal trauma procedures under ketamine-based anaesthesia during the study period.

Patients were eligible and included if they met all of the following criteria: 1) Haemodynamic stability, defined as systolic blood pressure ≥ 90 mmHg in adults (or age-appropriate blood pressure in children), heart rate appropriate for age, no ongoing requirement for active fluid bolus or vasopressor support, and absence of clinical shock at the time of transfer to the trauma unit, 2) Adequately resuscitated trauma state, including patients initially unstable at presentation but stabilized sufficiently for urgent or damage-control orthopaedic procedures, 3) Preserved spontaneous respiration, defined as spontaneous breathing without need for endotracheal intubation, bag-mask ventilation, or advanced ventilatory support before the procedure, 4) Procedure expected to be short-to-moderate in duration, operationally defined as a procedure expected to last ≤ 90 minutes under the trauma-unit workflow, 5) No evidence of raised intracranial pressure, such as deteriorating consciousness attributable to severe head injury, focal neurological decline, or radiological/clinical features suggesting intracranial hypertension, 6) No known hypersensitivity or contraindication to ketamine, and 7) Selected stable elective orthopaedic cases, where the same safety and monitoring criteria were satisfied.

Patients were excluded if they had any of the following: 1) Need for advanced airway management, including anticipated difficult airway requiring intubation, ongoing airway compromise, or inability to maintain oxygenation without airway support, 2) Severe head injury with impaired consciousness, defined pragmatically as Glasgow Coma Scale < 13 attributable to head injury, 3) Polytrauma requiring intensive monitoring, defined as multisystem injury requiring ICU-level care, invasive monitoring, ongoing transfusion, ventilatory support, or coordinated management by multiple acute specialties in a high-dependency environ-

ment, 4) Need for prolonged muscle relaxation or major prolonged surgery, including procedures expected to exceed 90 minutes or requiring formal general anaesthesia with muscle relaxants, 5) Significant comorbidity, defined as severe cardiorespiratory instability, decompensated systemic disease, uncontrolled seizure disorder, severe psychiatric disturbance affecting safe sedation, or other physician-judged conditions requiring consultant-led main-theatre anaesthesia and 6) Procedures requiring full general anaesthesia or neuraxial techniques as primary anaesthetic strategy.

All patients and relatives received pre-procedural counselling regarding the surgical procedure and planned ketamine-based anaesthesia. Anaesthesia was administered by trained team members in procedural sedation and perioperative monitoring, supported by theatre nursing staff and the operating surgeon. They were responsible for drug administration, physiological monitoring, and management of sedation-related complications throughout the procedure and recovery period.

A standardized ketamine-based protocol was used. Pre-procedural preparation entails: fasting history was checked when feasible, although emergency trauma need took precedence; baseline vital signs were documented; intravenous access was secured; multiparameter monitoring was connected; oxygen source, suction, bag-valve-mask device, airway adjuncts, and emergency drugs were confirmed to be immediately available.

Adjuncts were used according to patient age, body weight, procedural invasiveness, and clinical need. Commonly used adjuncts included: atropine for selected patients at risk of troublesome salivation; diazepam for anxiolysis and reduction of emergence reactions; pentazocine, paracetamol, diclofenac, or ketorolac for multimodal analgesia; prophylactic antibiotics where indicated surgically and tranexamic acid where indicated for haemostasis.

Because this was a retrospective service study, the exact adjunct combination varied by case type; however, the protocol generally followed a sequence of baseline assessment, adjunct analgesia/anxiolysis when indicated, then titrated ketamine.

Ketamine was administered intravenously by bolus dosing, not by continuous infusion with the initial IV ketamine dose: 1 - 2 mg/kg, supplemental IV ketamine dose of 0.5 mg/kg, redosing approach which was a repeat bolus administered when anaesthetic depth was judged inadequate or when the procedure outlasted the initial dissociative period, redosing interval was based on clinical response and procedure duration. The maximum cumulative dose was generally kept within 3 mg/kg.

Intraoperative monitoring and emergency readiness were in place. Minimum monitoring standards in the trauma unit included: continuous pulse oximetry, non-invasive blood pressure measurement at regular intervals, heart-rate monitoring, continuous direct clinical observation of respiratory effort, airway patency, and chest excursion. Emergency-readiness standards included immediate availa-

bility of: oxygen supply by facemask or nasal prongs, suction apparatus, bag-valve-mask ventilation equipment, oropharyngeal airway adjuncts, laryngoscopy and intubation equipment, emergency resuscitation drugs and intravenous fluids.

Staff roles were predefined which include the team who focused on sedation and monitoring, the surgeon performed the procedure, and theatre/recovery nurses supported monitoring, oxygen delivery, documentation, and recovery-room observation.

The trauma unit used pragmatic predefined responses: 1) Desaturation: airway repositioning, supplemental oxygen escalation, suction if needed, temporary interruption of surgical stimulation, bag-mask support if unresolved. 2) Transient hypertension/tachycardia: observation and reduction of external stimulation; persistent clinically significant elevation prompted senior review and supportive management. 3) Hypersalivation: suctioning, lateral positioning if needed, and anticholinergic use where indicated. 4) Nausea/vomiting: lateral positioning, suctioning, antiemetic administration, and continued monitoring. 5) Emergence reactions/agitation: environmental calming, verbal reassurance, benzodiazepine administration if required.

Procedures included: closed fracture reduction/manipulation, external fixation with or without wound debridement, wound debridement with or without soft tissue repair, implant removal, soft tissue release, limb deformity correction, hemiarthroplasty, incision and drainage, arthrodesis, amputation, sequestrectomy and other minor orthopaedic procedures

Primary outcomes include: 1) Procedural success: completion of the intended procedure without conversion to general anaesthesia, abandonment of the procedure for anaesthetic reasons, or unplanned airway intervention. 2) Perioperative complications: any documented anaesthesia-related or sedation-related adverse event occurring intraoperatively or during immediate recovery, including transient hypertension, nausea/vomiting, hypersalivation, oxygen desaturation, emergence reaction, delayed recovery, unplanned airway intervention, or death. 3) Recovery characteristics: time to recovery of consciousness adequate for transfer out of the recovery area and need for same-day discharge versus ward admission and 4) Service-delivery indicators: proportion of all orthopaedic/trauma cases managed in the trauma unit under ketamine rather than in the main theatre.

Secondary operational definitions include 1) Delayed recovery: failure to achieve recovery suitable for ward transfer within 45 minutes after the end of the procedure. 2) Transient desaturation: fall in oxygen saturation below 92% that responded to simple airway manoeuvres and/or supplemental oxygen without endotracheal intubation. 3) Significant transient hypertension: perioperative systolic blood pressure rise of >20% above baseline or a clinician-documented hypertensive episode requiring observation or minor intervention.

Data extracted included: age and sex, emergency versus elective status, procedure type, perioperative complication profile, recovery course, disposition after recovery, annual volume of orthopaedic/trauma procedures and proportion man-

aged under ketamine in the trauma unit. Data were analysed descriptively using frequencies, proportions, means, and standard deviations where appropriate. Exact binomial 95% confidence intervals were calculated for key event rates, including procedural success, mortality, transient hypertension, nausea, vomiting, transient desaturation, delayed recovery, and hypersalivation. Available records were analysed case-wise; missing data were not imputed. Because the dataset was primarily service-evaluation oriented and no formal comparator group was available, the analysis was mainly descriptive.

Institutional ethical approval was obtained. Patient confidentiality was maintained in accordance with accepted research ethics standards.

3. Results

A total of 1728 patients in the study period, 1207 (69.8%) underwent ketamine-assisted orthopaedic and trauma procedures during the five-year study period. The age range was 3 to 75 years. The males were 861 (71%) while females were 346 (29%) (Table 1) patients given M: F of 2.4:1. The indications for the procedures (Table 2) included closed fracture reduction with or without manipulation, external fixation with or without wound debridement, wound debridement with or without soft tissue repair, implant removal, soft tissue release, limb deformity correction, hemiarthroplasty, incision and drainage, arthrodesis, amputation, sequestrectomy and other minor orthopaedic procedure.

All patients demonstrated rapid recovery with early return of consciousness except 7 (0.58%) who had delayed recovery. Most were transferred to wards within a short postoperative observation period of 20 to 45 minutes, while selected stable cases (day-cases) were discharged on the same day. The observe side effects or complication were minimal (Table 3).

The ketamine-based trauma anesthesia model significantly reduced dependence on main theatre slots, shortened waiting times for trauma surgery, and improved overall trauma surgical throughput with a very good safety profiles, procedural success rates, recovery characteristics and theatre utilization.

Table 1. Demographic characteristics of study population (N = 1207).

| Variable | Number (%) |
|------------------------------------|-------------|
| Male | 861 (71%) |
| Female | 346 (29%) |
| Paediatric (<18 years) | 474 (39.3%) |
| Adults (18 - 60 years) | 557 (46.1%) |
| Elderly (>60 years) | 176 (14.6%) |
| Emergency trauma cases | 886 (73.4%) |
| Elective trauma-related procedures | 321 (26.6%) |

Comments:

- Male are significantly more (71%).

- Most surgery were on adults.
- Majority (73.4%) of the cases were emergency trauma.

Table 2. Distribution of surgical procedures.

| Procedure Type | Number (%) |
|--|-------------|
| Closed fracture reduction/manipulation | 109 (9.0%) |
| External fixation plus or minus wound Debridement | 568 (47.1%) |
| Wound debridement with or without soft tissue repair | 127 (10.5%) |
| Implant removal | 103 (8.5%) |
| Soft tissue release | 22 (1.8%) |
| Limb deformity correction | 31 (2.6%) |
| Hemi-arthroplasty | 35 (2.9%) |
| Incision and drainage, | 41 (3.4%) |
| Arthrodesis | 4 (0.3%) |
| Amputation | 87 (7.2%) |
| Sequestrectomy | 29 (2.4%) |
| Other minor orthopaedic operations. | 51 (4.3%) |

Comments:

- External fixation plus or minus wound Debridement accounted for the majority (47.1%) of the procedure.
- Arthrodesis was the lowest (0.3%) performed procedure.

Table 3. Observed perioperative complications.

| Complication | Frequency (%) |
|-------------------------------|---------------|
| Transient hypertension | 69 (5.7%) |
| Nausea/vomiting | 19 (1.6%) |
| Emergence reaction | 0 (0%) |
| Hypersalivation | 3 (0.3) |
| Transient desaturation | 7 (0.6%) |
| Delayed Recovery | 7 (0.6%) |
| Unplanned airway intervention | 0 (0%) |
| Mortality | 0 (0%) |

Comment:

- All adverse events were self-limiting and resolved without long-term sequelae.
- Transient hypertension was the commonest (5.7%) complications.

Figure 1 below shows a service delivery model practiced in the management of the patients in the study.

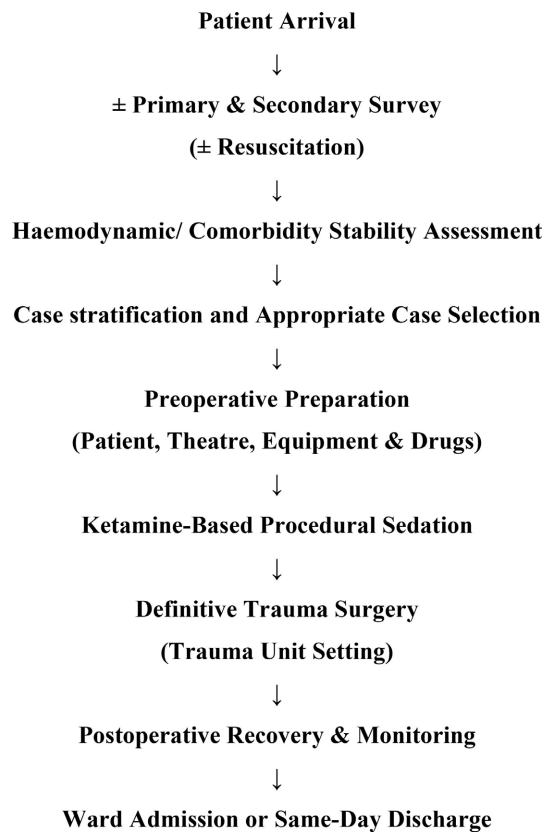


Figure 1. Ketamine-Based trauma surgery workflow (conceptual model).

Comment:

- This decentralized workflow allowed selected orthopaedic and trauma procedures to be performed independently of main theatre scheduling, thereby improving institutional efficiency.

4. Discussion

This study demonstrates that ketamine-based anesthesia is a safe, effective, and operationally efficient strategy for delivering high-volume orthopaedic and trauma surgery in a regional trauma centre within a resource-constrained environment. Over the five-year study period, ketamine was successfully utilized in 1207 patients, accounting for nearly 70% of trauma and orthopaedic surgical procedures performed in the centre. The absence of anesthesia-related mortality, a high procedural completion rates, and a low incidence of perioperative complications provide strong institutional evidence supporting the clinical safety and feasibility of this model.

The procedural success observed in this cohort is particularly significant. All surgeries were completed without conversion to general anesthesia or the need for unplanned airway intervention. This aligns with ketamine's unique pharmacological profile, which allows the achievement of dissociative anesthesia while preserving spontaneous respiration and protective airway reflexes [4] [5]. In contrast to

sedative-hypnotic agents such as propofol or benzodiazepines, which are associated with dose-dependent respiratory depression and hypotension, ketamine offers a margin of safety that is especially valuable in trauma and orthopaedic patients, and in centres with limited airway equipment and critical care support [6] [7]. Similar procedural success rates have been reported in emergency departments and battlefield medicine, reinforcing ketamine's reliability in austere surgical environments [14].

The perioperative complication profile observed in this study was favourable. Minor adverse events were infrequent and self-limiting, with transient hypertension being the most common (5.7%). This finding is consistent with ketamine's sympathomimetic effects, mediated through inhibition of catecholamine reuptake and direct stimulation of the central sympathetic nervous system [4] [9]. Importantly, this physiological response may be advantageous in trauma patients with borderline haemodynamic reserve, helping to maintain cerebral and coronary perfusion during surgical stress. Notably, no emergence reactions were recorded in this cohort, likely reflecting the routine use of benzodiazepine adjuncts and adherence to standardized dosing protocols. The absence of unplanned airway interventions and zero anesthesia-related mortality further underscore the safety of this approach when applied within a structured institutional framework [10] [12].

Postoperative recovery characteristics represent another major strength of the ketamine-based anesthesia model demonstrated in this study. Most patients regained full consciousness rapidly and were transferred from the recovery area within 20 - 45 minutes, with same-day discharge achieved in selected stable cases. These findings are consistent with ketamine's short distribution half-life and minimal residual sedative effects [6]. In resource-limited trauma centres, where prolonged postoperative monitoring and high-dependency beds are scarce, rapid recovery translates directly into improved patient flow, reduced bed occupancy, and enhanced institutional efficiency. Comparable benefits have been reported in studies of procedural sedation and emergency surgery, where ketamine use has been associated with shorter recovery times and reduced need for intensive postoperative care [7] [11].

Beyond individual patient outcomes, the operational impact of this service-delivery model is particularly noteworthy. By decentralizing selected orthopaedic and trauma procedures to a dedicated trauma unit independent of the main theatre complex, the institution significantly reduced competition for main theatre slots. This resulted in shorter waiting times for emergency trauma surgery, reduced elective-emergency scheduling conflicts, and increased daily surgical throughput. In LMICs, where operating theatre congestion is a well-recognized barrier to timely trauma care, such system-level innovations are critical to improving access and outcomes [3] [16].

The demographic and procedural distribution observed in this study further emphasizes the relevance of ketamine-based anesthesia to trauma care in LMICs.

The predominance of young adult males and emergency trauma cases reflects the epidemiology of musculoskeletal injuries in these settings [1]. External fixation and wound debridement procedures that accounted for more than half of all interventions are well suited to ketamine anesthesia and are central to damage-control orthopaedics. Early fracture stabilization and infection control are known to reduce complications and improve functional outcomes, particularly when delays to definitive care are minimized [2].

It is important to emphasize that the success of this model extends beyond ketamine as a pharmacological agent. Structured patient selection, standardized anesthesia protocols, continuous monitoring, use of adjunct medications, and clearly defined postoperative pathways were integral to achieving favourable outcomes. This supports existing recommendations that ketamine-based anesthesia should be delivered within formal governance frameworks rather than as an ad hoc substitute for general anesthesia [7] [13]. When appropriately implemented, ketamine expands the capacity of trauma systems without compromising patient safety.

From a global health perspective, the findings of this study have important implications. Ketamine is inexpensive, widely available, included on the World Health Organization Model List of Essential Medicines, and familiar to clinicians working in emergency and trauma care [15]. Its integration into trauma service-delivery frameworks offers a scalable solution to anesthesia workforce shortages and infrastructural limitations, particularly in district and regional hospitals. By improving access to timely surgery, ketamine-based anesthesia has the potential to reduce preventable morbidity associated with delayed fracture stabilization, prolonged immobilization, and hospital-acquired complications.

Nevertheless, the findings should be interpreted in light of the study's limitations. The retrospective design and absence of a comparator group using conventional general anesthesia limit direct comparisons. The procedures varied largely and the duration of the procedures was not included. Long-term functional outcomes and patient-reported satisfaction were not assessed.

Despite these limitations, the large sample size, consistency of results, and real-world operational impact provide compelling evidence supporting ketamine-based anesthesia as a pragmatic and effective component of orthopaedic trauma care.

5. Conclusion

Ketamine-based anaesthesia provided a safe, feasible, and pragmatic means of delivering selected orthopaedic and trauma procedures in a regional trauma centre over a five-year period. Within a structured framework of case selection, monitoring, emergency preparedness, and trained personnel, the model achieved high procedural success, rapid recovery, and low complication rates. It also expanded trauma-unit procedural capacity and reduced reliance on the main theatre pathway. These findings support ketamine-based anaesthesia as a useful service-delivery option for trauma systems in resource-constrained settings.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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