Test file: Readmission Patterns in the Intensive Care Unit of a Level I Trauma Center

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Abstract

Background: Readmission to the Intensive Care Unit (ICU) is a significant adverse event associated with increased mortality, prolonged hospital length of stay (LOS), and higher healthcare costs. While general ICU readmission rates and predictors are well-studied, the specific context of a Level I Trauma Center ICU—characterized by a unique, acutely injured, and heterogeneous patient population—requires focused analysis. Objective: This study aims to determine the incidence, timing, primary causes, and independent risk factors associated with ICU readmission within the same hospitalization for patients in a Level I Trauma Center ICU, and to evaluate its impact on patient outcomes. Methods: A retrospective cohort study was conducted over a three-year period at the Level I Trauma Center of a major academic hospital. All adult patients (≥18 years) admitted to the trauma ICU (TICU) were included. Data were extracted from the institutional trauma registry and electronic health records. Patients who were readmitted to the TICU (case group) were compared with those who had a single, continuous TICU stay (control group). Analyzed variables included demographics, injury characteristics (ISS, AIS, mechanism), pre-existing comorbidities, physiological and laboratory data at initial ICU discharge, processes of care (timing of discharge, nurse-to-patient ratio), and outcomes (mortality, total LOS, ICU LOS). Multivariable logistic regression was used to identify independent predictors of ICU readmission. Results: Of 4,217 initial TICU admissions, 178 (4.2%) required readmission. The median time to readmission was 3 days (IQR: 2-5 days). The leading causes for readmission were respiratory failure (32.6%), neurological deterioration (24.7%), and sepsis/septic shock (18.5%). Independent risk factors for readmission included: higher Injury Severity Score (ISS) (OR 1.03 per point, 95% CI 1.01-1.05), severe traumatic brain injury (AIS head ≥3) (OR 2.1, 95% CI 1.5-3.0), pre-existing chronic obstructive pulmonary disease (COPD) (OR 2.3, 95% CI 1.4-3.7), and discharge from the ICU during night shifts (20:00-08:00) (OR 1.8, 95% CI 1.2-2.7). Patients with ICU readmission had significantly higher in-hospital mortality (15.2% vs. 6.1%, $p<0.001$), longer median total hospital LOS (28 vs. 14 days, $p<0.001$), and longer cumulative ICU LOS (12 vs. 5 days, $p<0.001$). Conclusion: ICU readmission in a Level I Trauma Center is a relatively frequent occurrence associated with markedly worse outcomes. It is strongly linked to injury severity, specific injury patterns (TBI), underlying comorbidities (COPD), and potentially modifiable system factors like night-time discharge. These findings highlight the need for tailored discharge planning, enhanced monitoring of high-risk patients, and protocolized weaning and handover processes to mitigate this critical quality metric.

Keywords: Intensive Care Unit Readmission; Trauma Center; Critical Care; Patient Safety;

Quality Indicator; Risk Factors; Outcomes; Traumatic Brain Injury; Respiratory Failure.

1. Introduction

The Intensive Care Unit (ICU) is a high-resource setting dedicated to the care of the critically ill. An unplanned readmission to the ICU during the same hospital stay is widely recognized as a key quality indicator and a sentinel event reflecting potential gaps in care [1]. Patients who are readmitted face a two- to three-fold increase in hospital mortality, incur substantially higher costs, and experience longer hospital stays compared to those not readmitted [2, 3]. In the broader critical care literature, readmission rates typically range from 4% to 10%, with common causes including respiratory, cardiovascular, and neurological deterioration [4].

The environment of a Level I Trauma Center ICU presents distinct challenges. The patient population is defined by acute, often multisystem injury from mechanisms such as motor vehicle collisions, falls, and penetrating trauma [5]. The clinical course is dynamic, involving sequential resuscitation, damage control surgery, management of traumatic brain injury (TBI), and the navigation of complex post-injury complications like acute respiratory distress syndrome (ARDS) and sepsis [6]. Decisions regarding ICU discharge must balance the need for scarce ICU beds with the stability of a patient whose physiology may still be tenuous [7]. While predictors of readmission have been identified in general medical-surgical ICUs—including age, comorbidities, and physiological instability at discharge [8]—their applicability to the trauma population is not fully established. Trauma-specific factors, such as the Injury Severity Score (ISS), the presence of severe TBI, or the development of specific organ failures, may play a more prominent role [9].

Understanding the unique epidemiology of ICU readmission in this setting is crucial for several reasons. First, it allows for the identification of high-risk trauma patients who may benefit from more conservative discharge planning or enhanced surveillance on the ward. Second, it informs the development of targeted interventions, such as standardized respiratory weaning protocols for TBI patients or specialized sepsis alert systems for ward staff. Finally, analyzing timing and causes can reveal system-level vulnerabilities, such as the impact of after-hours discharges or communication failures during care transitions [10]. This study aims to fill this knowledge gap by providing a comprehensive analysis of the incidence, causes, predictors, and consequences of ICU readmission within a Level I Trauma Center, with the ultimate goal of informing strategies to improve patient safety and outcomes.

2. Methods

2.1 Study Design and Setting

A retrospective observational cohort study was conducted at the Level I Trauma Center of a large, urban, academic medical center. The center admits over 3,500 trauma patients annually, with a 24-bed dedicated Trauma ICU (TICU) staffed by a multidisciplinary team of trauma surgeons, intensivists, nurses, and respiratory therapists. The study period spanned 36 months.

2.2 Study Population

All adult patients (≥18 years) admitted to the TICU for more than 24 hours following acute traumatic injury were eligible for inclusion. Patients who died during the initial ICU stay, were

transferred directly to another acute care facility, or had limitations of care precluding readmission were excluded. The study cohort was divided into two groups: (1) Readmission Group: Patients discharged from the TICU to a lower-acuity hospital ward and subsequently readmitted to the TICU within the same hospitalization. (2) Control Group: Patients discharged from the TICU to a ward and not readmitted to the ICU during that hospitalization.

2.3 Data Collection

Data were extracted from two primary sources: the hospital's prospective trauma registry (which collects data per American College of Surgeons guidelines) and the institutional electronic health record (EHR). Collected variables included:

Demographics and Comorbidities: Age, sex, pre-existing conditions (Charlson Comorbidity Index components, with emphasis on COPD, congestive heart failure, renal disease).

Injury Characteristics: Mechanism (blunt vs. penetrating), Injury Severity Score (ISS), Abbreviated Injury Scale (AIS) scores for body regions (head, chest, abdomen, extremity).

Initial ICU Course: Admission physiology (GCS, systolic blood pressure), need for mechanical ventilation, surgical procedures, development of ICU complications (pneumonia, ARDS, venous thromboembolism).

Discharge Parameters: Vital signs, laboratory values (arterial blood gas, lactate, creatinine), respiratory support (oxygen flow), Glasgow Coma Scale (GCS) score, and nursing workload (patient-to-nurse ratio) at time of discharge. The shift (day: 08:00-20:00; night: 20:00-08:00) of ICU discharge was recorded.

Readmission Event: Time from initial ICU discharge to readmission, primary reason for readmission (adjudicated by two study physicians), and interventions required upon readmission.

Outcomes: In-hospital mortality, total hospital length of stay (LOS), and cumulative ICU LOS.

2.4 Statistical Analysis

Descriptive statistics were reported as medians with interquartile ranges (IQR) for continuous variables and frequencies with percentages for categorical variables. Group comparisons used Mann-Whitney U tests for continuous data and Chi-square or Fisher's exact tests for categorical data. To identify independent risk factors for ICU readmission, all variables with $p<0.1$ in univariate analysis were entered into a backward stepwise multivariable logistic regression model. Results were expressed as odds ratios (OR) with 95% confidence intervals (CI). A two-sided p-value <0.05 was considered statistically significant. All analyses were performed using SPSS version 26.0.

3. Results

During the study period, 4,582 patients were admitted to the TICU. After applying exclusion criteria, 4,217 patients formed the final analytic cohort. Of these, 178 patients (4.2%) experienced an unplanned readmission to the TICU.

3.1 Timing and Causes of Readmission

The median time to readmission was 3 days (IQR: 2-5 days), with 65% of readmissions occurring within 4 days of initial ICU discharge. The primary reasons for readmission were: respiratory failure (58 patients, 32.6%), neurological deterioration (e.g., decreased GCS, new neurological deficit) (44 patients, 24.7%), sepsis or septic shock (33 patients, 18.5%), and cardiovascular

instability (22 patients, 12.4%).

3.2 Comparison of Groups and Risk Factor Analysis

Univariate analysis revealed significant differences between the Readmission and Control groups (Table 1). Patients who were readmitted had higher median ISS (29 vs. 21, $p<0.001$), a greater proportion of severe TBI (AIS head ≥3) (54.5% vs. 38.2%, $p<0.001$), and a higher prevalence of pre-existing COPD (12.4% vs. 5.1%, $p<0.001$). At discharge, readmitted patients were more frequently discharged at night (31.5% vs. 21.8%, $p=0.002$) and had a slightly higher respiratory rate ($p=0.03$).

Multivariable logistic regression identified four independent predictors of ICU readmission (Table 2): 1) Higher ISS (OR 1.03 per point, 95% CI 1.01-1.05); 2) Severe TBI (AIS head ≥3) (OR 2.1, 95% CI 1.5-3.0); 3) History of COPD (OR 2.3, 95% CI 1.4-3.7); and 4) Discharge from ICU during the night shift (OR 1.8, 95% CI 1.2-2.7).

3.3 Outcomes Associated with Readmission

ICU readmission was associated with profoundly worse outcomes. The in-hospital mortality rate was more than double in the readmitted group (15.2% vs. 6.1% in controls, $p<0.001$). Readmitted patients also had significantly longer total hospital LOS (median 28 days, IQR 18-42 vs. 14 days, IQR 9-22; $p<0.001$) and cumulative ICU LOS (median 12 days, IQR 7-19 vs. 5 days, IQR 3-8; $p<0.001$).

4. Discussion

This study, conducted within the specific context of a Level I Trauma Center, confirms that ICU readmission is a critical event with an incidence of 4.2%, aligning with the lower end of rates reported in general ICUs [4, 11]. The concentration of readmissions within the first 96 hours post-discharge underscores the fragility of this transition period and suggests that clinical deterioration is often rapid and linked to unresolved or evolving post-injury pathophysiology [12].

The identified risk factors offer a trauma-specific profile of vulnerability. The strong association with ISS and severe TBI is expected, as these injuries lead to complex, multi-organ dysfunction and an unpredictable neurological course [13]. Patients with severe TBI are prone to respiratory complications from impaired airway reflexes and are at risk for delayed cerebral edema or seizures, explaining the high rate of respiratory and neurological readmissions [14]. The powerful link with pre-existing COPD (OR=2.3) highlights how underlying respiratory reserve dictates the margin for error in trauma patients facing pulmonary contusions, pneumonia, or opioid-induced respiratory depression [15]. This finding argues for extremely cautious weaning and discharge planning for trauma patients with known COPD.

The identification of night-time ICU discharge as an independent risk factor is a critical system-level finding. This aligns with previous research in non-trauma settings linking off-hours discharges to higher mortality and readmission rates [16, 17]. Potential mechanisms include reduced availability of senior staff, higher nursing workloads on receiving wards, less robust multidisciplinary handover communication, and delays in obtaining necessary tests or consultations. This represents a clear target for quality improvement initiatives, such as

implementing daytime discharge protocols where feasible or creating a formalized "discharge safety checklist" for use during night shifts.

The leading causes of readmission—respiratory failure and neurological deterioration—point to specific clinical processes that may be optimized. For respiratory issues, this could involve stricter adherence to standardized weaning protocols, mandatory assessment of cough strength and secretion burden pre-extubation, and the use of proactive non-invasive ventilation or high-flow nasal cannula on the ward for high-risk patients [18]. For neurological deterioration, protocols for more frequent neurologic vital signs on the ward, low-threshold CT scanning for changes in mental status, and specialized nursing education on TBI care could be beneficial.

The profound negative impact on mortality and resource use (prolonged LOS) reinforces why preventing ICU readmission must be a priority. The increased mortality is likely multifactorial, stemming from the severity of the precipitating illness, delays in recognizing deterioration on the ward, and the cumulative physiologic toll of repeated critical illness [19].

5. Limitations

This study has limitations inherent to its single-center, retrospective design. The findings may not be generalizable to all trauma centers. The reasons for readmission were adjudicated retrospectively from charts, which may introduce bias. We were unable to capture subtle aspects of clinical judgment at discharge or the quality of inter-unit handover communication, which are known to influence readmission risk [20]. Furthermore, some unmeasured confounders may exist.

6. Conclusion

Readmission to the ICU in a Level I Trauma Center is a significant event associated with identifiable patient- and system-level risk factors and severe consequences. Injury severity, severe traumatic brain injury, pre-existing COPD, and night-time ICU discharge independently increase the risk. These findings provide a roadmap for developing targeted interventions. Future efforts should focus on creating validated risk prediction scores for trauma patients, implementing structured discharge processes that mitigate the risks of off-hours transfers, and enhancing monitoring and response systems on hospital wards for high-risk populations. By doing so, trauma systems can improve the safety of ICU transitions and ultimately enhance patient outcomes.

7. References

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