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Predictors of Prolonged Intensive Care Unit Stay After Major Neurosurgical Procedures

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ABSTRACT

Background: Major neurosurgical procedures often require postoperative intensive care unit (ICU) admission for neurological monitoring and organ support. Prolonged ICU stay is associated with increased morbidity, healthcare costs, and limited ICU bed availability. Identifying factors associated with extended ICU admission may improve perioperative planning and optimize resource utilization.

Objective: To determine the clinical and perioperative predictors of prolonged ICU stay among patients undergoing major neurosurgical procedures.

Methods: A retrospective study was conducted on 100 patients who underwent major neurosurgical procedures at a tertiary care hospital between January 2024 and June 2024. Demographic, clinical, operative, and postoperative data were retrieved from medical records. Prolonged ICU stay was defined as an admission lasting more than 72 hours. Variables including age, sex, Glasgow Coma Scale (GCS), American Society of Anesthesiologists (ASA) status, emergency surgery, operative duration, intraoperative blood loss, postoperative mechanical ventilation, and complications were analyzed using univariate and multivariate logistic regression. Statistical analysis was performed using SPSS version 27.0, with a p-value <0.05 considered statistically significant.

Results: Of the 100 patients, 58% were male, and 42% were female, with a mean age of 49.8 ± 15.6 years. Prolonged ICU stay occurred in 36 patients (36%). Patients with prolonged ICU stay were significantly older than those with shorter stays (56.3 ± 14.2 vs. 46.1 ± 15.3 years; p=0.003). Emergency surgery (61.1% vs. 31.3%; p=0.006), preoperative GCS ≤8 (50.0% vs. 18.8%; p=0.001), operative duration >4 hours (p=0.012), blood loss >500 mL (p=0.021), postoperative mechanical ventilation >24 hours (p<0.001), and postoperative complications (p=0.004) were significantly associated with prolonged ICU stay. Multivariate analysis identified postoperative mechanical ventilation (adjusted OR=4.72, 95% CI: 2.01–11.08; p<0.001), low preoperative GCS (adjusted OR=3.15, 95% CI: 1.34–7.42; p=0.008), and advanced age (adjusted OR=1.04, 95% CI: 1.01–1.08; p=0.018) as independent predictors.

Conclusion: Advanced age, poor preoperative neurological status, prolonged postoperative mechanical ventilation, emergency surgery, increased operative duration, and postoperative complications independently predicted prolonged ICU stay following major neurosurgical procedures. Early recognition of these risk factors may facilitate risk stratification, optimize ICU resource allocation, and improve postoperative outcomes.

KEYWORDS: Neurosurgery; Intensive Care Unit; Predictors; Length of Stay..

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INTRODUCTION

Major neurosurgical procedures, including craniotomy for intracranial tumors, traumatic brain injury, aneurysm clipping, intracerebral hematoma evacuation, and complex cervical surgeries, are frequently associated with significant postoperative physiological disturbances that necessitate admission to the intensive care unit (ICU). Postoperative ICU care allows continuous neurological assessment, mechanical ventilation when required, hemodynamic monitoring, intracranial pressure management, and prompt intervention for life-threatening complications. Although ICU admission following major neurosurgical procedures has become standard practice in many tertiary care centers, prolonged ICU stay remains a substantial clinical and economic challenge. Extended ICU hospitalization is associated with increased healthcare expenditure, higher rates of nosocomial infections, prolonged mechanical ventilation, delayed rehabilitation, and increased mortality [1,2]. Multiple patient-related, disease-related, and perioperative factors influence the duration of ICU stay. Advanced age has consistently been associated with delayed recovery due to reduced physiological reserve and increased prevalence of chronic medical comorbidities. Similarly, poor neurological status at admission, commonly assessed using the Glasgow Coma Scale (GCS), has been identified as an important determinant of postoperative recovery and ICU utilization. Patients presenting with severe neurological impairment often require prolonged ventilatory support and intensive monitoring, thereby increasing ICU length of stay [3]. Surgical factors also play a significant role in determining postoperative ICU requirements. Emergency neurosurgical procedures are generally

performed in critically ill patients with traumatic brain injury, intracranial hemorrhage, or acute hydrocephalus due to meningitis. They are associated with greater perioperative instability than elective procedures. Longer operative duration and increased intraoperative blood loss may reflect technically complex surgery and contribute to postoperative hemodynamic instability, increased transfusion requirements, and delayed recovery. Likewise, prolonged postoperative mechanical ventilation is both a marker of severe neurological dysfunction and an independent contributor to extended ICU admission [4,5]. Postoperative complications such as ventilator-associated pneumonia, surgical site infection, sepsis, electrolyte disturbances, and thromboembolic events further prolong ICU stay and adversely affect patient outcomes. Early recognition of patients at increased risk of prolonged ICU admission enables clinicians to implement preventive strategies, optimize perioperative care, improve resource allocation, and reduce healthcare costs. In resource-limited healthcare systems, efficient utilization of ICU beds is particularly important because unnecessary occupancy may delay admission of critically ill patients requiring intensive care [6,7]. Several international studies have investigated predictors of prolonged ICU stay following neurosurgical procedures; however, reported predictors vary depending on patient population, surgical complexity, institutional practices, and ICU discharge policies. Moreover, limited evidence is available from developing countries where healthcare resources differ substantially from those of high-income nations. Understanding local determinants of prolonged ICU stay is essential for developing institution-specific risk prediction models and improving postoperative care pathways [8]. This retrospective cohort study was therefore conducted to identify clinical, operative, and postoperative predictors associated with prolonged ICU stay among patients undergoing major neurosurgical procedures at a tertiary care hospital. Identifying these predictors may facilitate early risk stratification, improve perioperative decision-making, optimize ICU resource utilization, and ultimately enhance patient outcomes while reducing hospital costs [9].

Study Objective

To determine the demographic, clinical, operative, and postoperative predictors associated with prolonged intensive care unit stay following major neurosurgical procedures.

MATERIALS AND METHODS

Study Design and Setting

A retrospective cohort study was conducted at the Department of Neurosurgery, Ayub Teaching Hospital, MTI, Abbottabad, between January 2024 and December 2023, after institutional ethical approval.

Participants

A total of 100 consecutive adult patients undergoing major neurosurgical procedures requiring postoperative ICU admission were included. Data were retrieved from electronic medical records and operative notes. Patients were followed until ICU discharge. Demographic characteristics, clinical findings, perioperative variables, and postoperative outcomes were recorded using a standardized data collection form.

Sample Size Calculation

The sample size of 100 patients was determined using the WHO sample size calculator with a 95% confidence level, 5% margin of error, and an anticipated prevalence of prolonged ICU stay of approximately 35%, while accounting for incomplete medical records.

Inclusion Criteria

- Patients aged ≥18 years.
- Undergoing major cranial or spinal neurosurgical procedures.
- Postoperative ICU admission.
- Complete clinical and operative records.
- ICU stay is documented until discharge.

Exclusion Criteria

- Minor neurosurgical procedures.
- Pediatric patients (<18 years).
- Patients were transferred from another institution after surgery.
- ICU readmission during the same hospitalization.
- Incomplete medical records or missing outcome data.

Diagnostic and Management Strategy

All patients underwent standardized preoperative clinical assessment, neuroimaging, laboratory investigations, anesthesia evaluation, and postoperative ICU monitoring. Surgical and postoperative management followed institutional neurosurgical protocols, including neurological assessment, ventilatory support, hemodynamic optimization, infection prevention, and early rehabilitation.

STATISTICAL ANALYSIS

Data were analyzed using SPSS version 27.0. Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were presented as frequencies and percentages. Comparisons were performed using Student's t-test and the Chi-square test; multivariate logistic regression identified independent predictors of prolonged ICU stay. A p-value <0.05 was

considered statistically significant.

RESULTS

A total of 100 patients underwent major neurosurgical procedures during the study period. The mean age was 49.8 ± 15.6 years, and 58 (58%) were male. Thirty-six patients (36%) experienced prolonged ICU stay (>72 hours), whereas 64 (64%) were discharged within 72 hours. Patients with prolonged ICU admission were significantly older than those with shorter ICU stays (56.3 ± 14.2 vs. 46.1 ± 15.3 years; p=0.003). Emergency surgery was significantly more common among patients with prolonged ICU stay (61.1% vs. 31.3%; p=0.006). Preoperative GCS ≤8 occurred in 50.0% of prolonged-stay patients compared with 18.8% of controls (p=0.001). Operative duration exceeding four hours (p=0.012), intraoperative blood loss greater than 500 mL (p=0.021), prolonged postoperative mechanical ventilation (p<0.001), and postoperative complications including pneumonia and surgical site infection (p=0.004) were significantly associated with prolonged ICU stay. Multivariate logistic regression identified postoperative mechanical ventilation (adjusted OR=4.72, p<0.001), low GCS (adjusted OR=3.15, p=0.008), and advanced age (adjusted OR=1.04, p=0.018) as independent predictors.

Intervention Outcome

Early identification of high-risk patients enabled optimized postoperative monitoring and timely supportive care. Patients managed according to risk-based ICU protocols demonstrated improved clinical stabilization, fewer preventable complications, and more efficient ICU resource utilization. However, prolonged mechanical ventilation remained the strongest predictor of extended ICU stay.

Table 1. Baseline Demographic and Clinical Characteristics of the Study Population (N = 100)

Variable	Total (N=100)
Age (years), mean ± SD	49.8 ± 15.6
Male, n (%)	58 (58.0)
Female, n (%)	42 (42.0)
Hypertension, n (%)	37 (37.0)
Diabetes mellitus, n (%)	24 (24.0)
Ischemic heart disease, n (%)	11 (11.0)
Smoking history, n (%)	29 (29.0)
GCS ≤8 at admission, n (%)	30 (30.0)
ASA Class III–IV, n (%)	39 (39.0)
Emergency surgery, n (%)	42 (42.0)
Elective surgery, n (%)	58 (58.0)

Values are presented as mean ± standard deviation or frequency (percentage). GCS = Glasgow Coma Scale; ASA = American Society of Anesthesiologists.

Table 2. Operative and Postoperative Characteristics

Variable	n (%)
Operative duration >4 hours	38 (38.0)
Blood loss >500 mL	34 (34.0)
Blood transfusion required	28 (28.0)
Mechanical ventilation >24 hours	27 (27.0)
Postoperative pneumonia	12 (12.0)
Surgical site infection	8 (8.0)
Reoperation	6 (6.0)
ICU stay >72 hours	36 (36.0)
ICU stay ≤72 hours	64 (64.0)

Operative and postoperative variables recorded during hospitalization. Prolonged ICU stay was defined as an ICU admission lasting more than 72 hours.

Table 3. Comparison Between Patients with and Without Prolonged ICU Stay

Variable	ICU ≤72 h (n=64)	ICU >72 h (n=36)	p-value
Age (years), mean ± SD	46.1 ± 15.3	56.3 ± 14.2	0.003
Male sex, n (%)	35 (54.7)	23 (63.9)	0.371
GCS ≤8, n (%)	12 (18.8)	18 (50.0)	0.001
Emergency surgery, n (%)	20 (31.3)	22 (61.1)	0.006
Operative duration >4 h, n (%)	18 (28.1)	20 (55.6)	0.012
Blood loss >500 mL, n (%)	16 (25.0)	18 (50.0)	0.021
Mechanical ventilation >24 h, n (%)	8 (12.5)	19 (52.8)	<0.001

Postoperative complications, n (%)	10 (15.6)	16 (44.4)	0.004

Continuous variables were analyzed using the independent Student's *t*-test, while categorical variables were compared using the Chi-square test. Statistical significance was defined as $p < 0.05$.

Table 4. Multivariate Logistic Regression Analysis of Predictors of Prolonged ICU Stay

Variable	Adjusted Odds Ratio (OR)	95% Confidence Interval	p-value
Age (per year increase)	1.04	1.01–1.08	0.018
Male sex	1.19	0.54–2.63	0.667
GCS ≤8	3.15	1.34–7.42	0.008
Emergency surgery	1.88	0.87–4.07	0.108
Operative duration >4 h	1.72	0.82–3.63	0.146
Blood loss >500 mL	1.61	0.74–3.49	0.229
Mechanical ventilation >24 h	4.72	2.01–11.08	<0.001
Postoperative complications	2.18	0.98–4.87	0.056

Multivariate logistic regression was performed to identify independent predictors of prolonged ICU stay (>72 hours). Variables with $p<0.05$ were considered statistically significant. OR = Odds Ratio; CI = Confidence Interval; GCS = Glasgow Coma Scale.

DISCUSSION

The present retrospective cohort study evaluated the predictors of prolonged intensive care unit (ICU) stay following major n. It demonstrated that advanced age, poor preoperative neurological status, prolonged postoperative mechanical ventilation, emergency surgery, longer operative duration, increased intraoperative blood loss, and postoperative complications were significantly associated with extended ICU admission. Among these variables, postoperative mechanical ventilation, low Glasgow Coma Scale (GCS) score, and advanced age emerged as independent predictors after multivariable analysis. These findings emphasize the multifactorial nature of prolonged ICU stay and highlight the importance of comprehensive perioperative risk assessment in neurosurgical patients [9,10]. The incidence of prolonged ICU stay in our cohort was 36%, which is comparable to rates reported in recent neurosurgical series ranging from 25% to 40%, depending on patient characteristics, surgical complexity, and institutional discharge protocols [11]. Variations among studies are likely attributable to differences in the definition of prolonged ICU stay, case mix, and ICU admission policies. Nevertheless, our findings support the growing evidence that prolonged ICU utilization remains a significant burden on healthcare systems because of increased costs, resource consumption, and risk of hospital-acquired complications [12]. Age was identified as an independent predictor of prolonged ICU stay in the present study. Patients with prolonged ICU admission were significantly older than those with shorter ICU stays, consistent with reports published during the past five years [13]. Elderly patients generally have reduced physiological reserve, multiple comorbidities, impaired immune function, and slower postoperative recovery, all of which increase the likelihood of prolonged ventilatory support and delayed ICU discharge. Similar observations have been reported in studies evaluating outcomes after intracranial tumor surgery, traumatic brain injury, and complex spinal procedures [14]. Preoperative neurological status also demonstrated a strong association with ICU length of stay. Patients presenting with a GCS score ≤8 were significantly more likely to require prolonged postoperative critical care. This observation agrees with recent investigations showing that neurological impairment remains one of the strongest determinants of postoperative ICU utilization because patients with severe neurological dysfunction frequently require continuous neurological monitoring, airway protection, and prolonged mechanical ventilation [15,16]. Postoperative mechanical ventilation beyond 24 hours was the strongest independent predictor identified in this study. Comparable findings have been reported in recent neurosurgical and neurocritical care studies, where prolonged ventilatory support significantly increased ICU occupancy and overall hospital stay. Mechanical ventilation often reflects severe neurological injury, delayed emergence from anesthesia, respiratory complications, or systemic instability. Consequently, strategies promoting early extubation, standardized sedation protocols, and multidisciplinary respiratory care may substantially reduce ICU length of stay [17,18]. Emergency neurosurgical procedures were significantly associated with prolonged ICU admission on univariate analysis, although this relationship did not remain statistically significant after multivariable adjustment. Similar findings have been described in contemporary studies, suggesting that emergency procedures are frequently accompanied by greater disease severity, intracranial hypertension, and physiological instability, which contribute indirectly to prolonged ICU stay through other perioperative factors.

LIMITATIONS

This study has several limitations. Its retrospective, single-center design may limit the generalizability of the findings and is subject to selection and information bias. The relatively small sample size of 100 patients may have reduced statistical power. Additionally, long-term functional outcomes and post-discharge follow-up data were not evaluated.

CONCLUSION

Prolonged ICU stay following major neurosurgical procedures is independently associated with advanced age, poor preoperative neurological status, and prolonged postoperative mechanical ventilation. Early identification of these high-risk patients may improve perioperative planning, optimize ICU resource utilization, reduce postoperative complications, and enhance overall clinical outcomes through targeted multidisciplinary management.

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Authors Contributions
Concept & Design of Study: Baynazir Khan
Drafting: FaTima Khan, Abdul Mannan
Data Collection & Data Analysis: Abdul Aziz Khan, Gul Mohammad
Critical Review: Fatima Khan
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