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ORIGINAL RESEARCH

NEUROLOGICAL AND HEMODYNAMIC PROFILES OF POST CRANIOTOMY PATIENTS BASED ON SURVIVAL STATUS IN THE INTENSIVE CARE UNIT

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ABSTRACT	Keywords
Early neurological and hemodynamic assessment is important in the management of post-craniotomy patients in the intensive care unit (ICU). To describe the distribution of age, sex, MAP, and FOUR scores among post-craniotomy patients according to survival status. A descriptive cross-sectional study was conducted in the ICU of RS Islam Sakinah from 15 February to 18 March 2026. Post-craniotomy patients were enrolled using consecutive sampling. Age was summarized as mean ± standard deviation, sex as frequencies and percentages, and MAP and FOUR scores as median and interquartile range (IQR). The overall mean age was 53.48 ± 16.02 years. Non-survivors were slightly older than survivors (56.00 ± 9.14 vs. 52.52 ± 18.00 years). The cohort consisted of 55% males and 45% females, with similar survival proportions between sexes. Survivors had a median MAP of 90 (88–122) mmHg, whereas non-survivors had a median MAP of 130 (102–130) mmHg and greater hemodynamic variability. Survivors had a median FOUR score of 15 (14–16), while non-survivors had a median score of 8 (2–11). Non - survivors demonstrated higher and more variable MAP values and lower, more heterogeneous FOUR scores than survivors. These findings describe distinct hemodynamic and neurological profiles between the two groups and may support clinical assessment in ICU settings. Further longitudinal studies are needed to evaluate the clinical significance of these parameters.	**Craniotomy, FOUR Score,Mean ArterialPressure,MAP,Mortality,ICU**

INTRODUCTION

Post-craniotomy patients require intensive postoperative monitoring because neurological deterioration and hemodynamic instability frequently occur during the early recovery period in the intensive care unit (ICU) (Braksick et al., 2018). Despite advances in neurosurgical techniques, anesthetic management, and perioperative care, postoperative neurological impairment and hemodynamic disturbances remain important clinical concerns that may complicate recovery after craniotomy(Posti et al., 2021). Continuous assessment of neurological status and cerebral perfusion is therefore a fundamental component of neurocritical care.

Postoperative deterioration frequently occurs during the early neurocritical period, when patients are vulnerable to secondary brain injury and systemic complications. Mortality rates vary according to the underlying pathology and surgical urgency, with substantially higher mortality reported in critically ill and traumatic craniotomy patients (Goel et al., 2018). Because neurological deterioration may occur rapidly, continuous monitoring is essential to support timely clinical decision-making and optimize postoperative management (Posti et al., 2021).

Accurate neurological assessment is a key component of postoperative neurocritical care. The Glasgow Coma Scale (GCS) has traditionally been the standard tool for evaluating consciousness. However, its clinical utility is limited in intubated and mechanically ventilated patients because the verbal component cannot be reliably assessed (Jain et al., 2025; Schey et al., 2025).

The Full Outline of UnResponsiveness (FOUR) score was developed to overcome this limitation by incorporating assessment of eye responses, motor responses, brainstem reflexes, and respiratory patterns (Mishra et al., 2019). By including brainstem function and respiratory drive, the FOUR score provides a more comprehensive evaluation of neurological status in critically ill neurological patients (Abdallah et al., 2020; Javvaji et al., 2022)

In parallel with neurological assessment, hemodynamic monitoring plays a crucial role in maintaining cerebral perfusion and oxygen delivery during the postoperative period. Mean arterial pressure (MAP) and cerebral perfusion pressure (CPP) are important indicators of cerebral blood flow adequacy. (Rebai et al., 2025) Current neurocritical care recommendations emphasize maintaining MAP between 80 and 100 mmHg and CPP above 60 mmHg to reduce the risk of secondary brain injury (Beqiri et al., 2024). Hemodynamic instability may compromise cerebral autoregulation and contribute to neurological deterioration.

Although the FOUR score and hemodynamic parameters are widely used in neurocritical care, information describing their temporal patterns during the early postoperative period among post-craniotomy patients remains limited. A clearer description of changes in neurological status and hemodynamic stability may help clinicians better understand the clinical course of patients with different outcomes.

Therefore, this descriptive cross-sectional study aims to describe the patterns of the Full Outline of UnResponsiveness (FOUR) score and hemodynamic parameters during the early postoperative period among post-craniotomy patients and to characterize these clinical patterns according to patient outcomes.

METHOD

This descriptive cross-sectional study was carried out in the intensive care unit (ICU) of RS Islam Sakinah between 15 February and 18 March 2026. Participants were recruited using a **consecutive sampling** technique, in which all eligible post-craniotomy patients admitted to the intensive care unit (ICU) during the study period. Participants were eligible if they were aged 18 years or older, had undergone neurosurgical craniotomy for indications including traumatic brain injury or hemorrhagic stroke, and were admitted to the ICU for postoperative care. Only patients with complete documentation of the Full Outline of UnResponsiveness (FOUR) score and Mean Arterial Pressure (MAP) recorded

at a single assessment were included in the analysis.
Patients were categorized into survivor and non-survivor groups according to their clinical outcomes. Age was presented as mean ± standard deviation, while sex and survival status were summarized as frequencies and percentages. The distributions of the FOUR score and MAP were described using the median and interquartile range (Q2 [Q1–Q3]), and their variability was illustrated using box plot graphs.

RESULTS

Table 1. Baseline Demographic Characteristics of the Study Population

Variables	Non-survivors (n = 11)	Survivors (n = 29)	Overall (N = 40)
Age (Years), *Mean±SD*	56 ± 9.14	52.52 ± 18.00	53.48±16.02
Gender, *n (%)*			
Male	6 (27.3%)	16 (72.7%)	22 (55%)
Female	5 (27.8%)	13 (72.2%)	18 (45%)

A total of 40 post-craniotomy patients were included in this study, consisting of 29 survivors (72.5%) and 11 non-survivors (27.5%). The overall mean age was 53.48 ± 16.02 years. Non-survivors had a slightly higher mean age (**56.00 ± 9.14 years**) than survivors (**52.52 ± 18.00 years**).
The sex distribution was relatively balanced, with **22 male patients (55%)** and **18 female patients (45%)**. Among male patients, **16 (72.7%) survived** and **6 (27.3%) did not survive**. Similarly, among female patients, **13 (72.2%) survived** and **5 (27.8%) did not survive**. The proportions of survivors and non-survivors were comparable between men and women, indicating no marked difference in outcome distribution according to sex in this cohort.

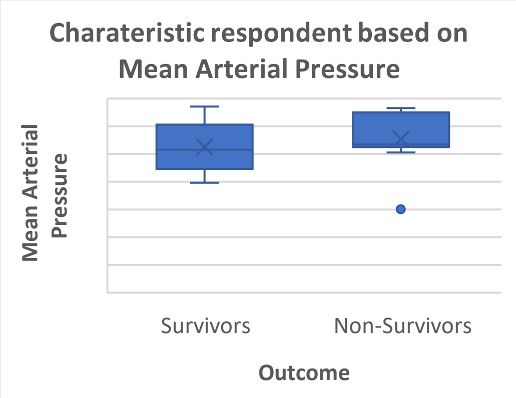

Figure 1. Characteristic respondent based on Mean Arterial Pressure

Figure 1 presents the distribution of mean arterial pressure (MAP) according to patient outcome. The non-survivor group showed generally higher MAP values than the survivor group. Survivors had a median MAP of approximately **90 mmHg**, with an interquartile range (IQR) of approximately **88–122 mmHg** and a range of **79–134 mmHg**. In contrast, non-survivors had a higher median MAP of approximately **130 mmHg**, with an IQR of approximately **102–130 mmHg** and a range of **60–133 mmHg**. Compared with survivors, non-survivors demonstrated a distribution that was concentrated at higher MAP values, although one markedly low value (60 mmHg) was observed in the non-survivor group. Survivors showed a wider spread of MAP values across the interquartile range, indicating greater variability in blood pressure measurements. Overall, the descriptive findings indicate that non-survivors tended to have higher MAP values than survivors, while the presence of both elevated and markedly reduced MAP values among non-survivors suggests greater hemodynamic disturbance in this group.

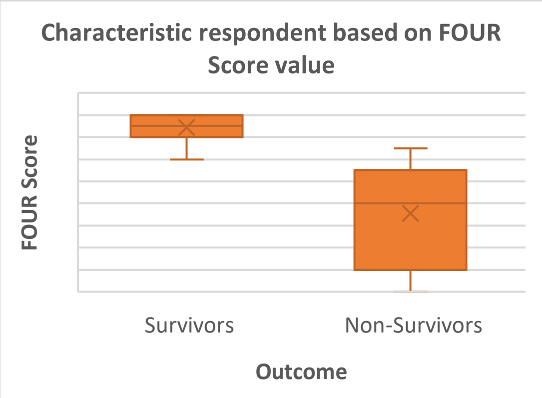

Figure 2. Characteristic respondent based on FOUR Score

Figure 2 presents the distribution of Full Outline of UnResponsiveness (FOUR) scores according to patient outcome. The survivor group had consistently higher FOUR scores than the non-survivor group. Survivors had a median FOUR score of approximately **15**, with an interquartile range (IQR) of **14–16** and a range of **12–16**. In contrast, the non-survivor group had a lower median FOUR score of approximately **8**, with a wider interquartile range of **2–11** and a range of **0–13**. Compared with survivors, non-survivors showed substantially lower FOUR scores and greater variability in neurological status.

The survivor group demonstrated a relatively narrow distribution, indicating that most patients had similarly high FOUR scores. In comparison, the non-survivor group showed a broader distribution across lower score values, suggesting more heterogeneous neurological impairment. Overall, the descriptive findings indicate that survivors tended to have higher FOUR scores and a more homogeneous neurological status, whereas non-survivors tended to have lower FOUR scores with greater variability.

DISCUSSION

Age and sex distribution according to patient outcome

The demographic characteristics of this cohort provide an overview of the age and sex distribution among post-craniotomy patients according to survival status. The overall mean age was **53.48 ± 16.02 years**, with non-survivors showing a slightly higher mean age (**56.00 ± 9.14 years**) than survivors (**52.52 ± 18.00 years**). Although non-survivors were, on average, older, the difference between the two groups was relatively small. These findings suggest that age differences were modest within this cohort and should be interpreted descriptively rather than as evidence of an independent effect on mortality.

The sex distribution was relatively balanced, with **55% male** and **45% female** patients. The proportions of survivors and non-survivors were similar in both sexes, with survival observed in **72.7% of males** and **72.2% of females**. This pattern indicates that the outcome distribution was comparable between male and female patients in the present cohort.

Our findings are consistent with Brandi et al., (2022), who reported that demographic characteristics, including age and sex, were similar between patients with and without early postoperative complications. Their study also found no significant sex-related differences in the frequency of early postoperative complications or mortality. Similarly, the relatively comparable outcome distribution observed in the present study suggests that demographic characteristics alone may not adequately describe differences in early postoperative outcomes among post-craniotomy patients.

However, our findings differ from studies evaluating longer-term postoperative outcomes. Lenga et al., (2025) identified advancing age as an independent risk factor for adverse events within 30 days after craniotomy, whereas sex was not a major predictor of postoperative complications.

Mean arterial pressure distribution according to patient outcome

The distribution of mean arterial pressure (MAP) differed between survivors and non-survivors in this cohort. Survivors had a median MAP of **90 (88–122) mmHg**, whereas non-survivors showed a higher median MAP of **130 (102–130) mmHg**. In addition, the non-survivor group demonstrated a wider distribution of MAP values, including a markedly low value of **60 mmHg**, indicating greater variability in hemodynamic status compared with the survivor group.

The higher MAP values observed among non-survivors are consistent with reports describing postoperative hypertension as a common finding during the early recovery period after craniotomy. Perez et al., (2020) reported that acute postoperative blood pressure elevation may occur following neurosurgical procedures and can accompany conditions such as cerebral edema and postoperative hemorrhage. The predominance of elevated MAP values in the non-survivor group in the present study is therefore consistent with previous observations that blood pressure disturbances frequently occur during the immediate postoperative period.

However, the current findings should be interpreted descriptively. The presence of higher MAP values among non-survivors does not indicate that elevated MAP caused mortality. Because only a single postoperative MAP measurement was analyzed, the study cannot determine whether these values represented transient postoperative hypertension, persistent hemodynamic instability, therapeutic interventions, or underlying disease severity. Consequently, the observed differences describe the hemodynamic characteristics of the two outcome groups rather than a causal or predictive relationship.

An additional finding was the presence of a markedly low MAP value (60 mmHg) within the non-survivor group. This observation suggests that non-survivors were characterized not only by elevated MAP values but also by greater hemodynamic variability. Similar patterns have been described in previous neurocritical care studies, where both hypertension and hypotension may occur during the postoperative period following craniotomy (Rebai et al., 2025; Saranti et al., 2025). The coexistence of high and low MAP values may reflect heterogeneous clinical conditions among non-survivors, including differences in cerebral autoregulation, intravascular volume status, vasopressor administration, sedation, or intracranial pressure management.

In contrast, the survivor group had a median MAP that generally fell within the range commonly recommended for maintaining cerebral perfusion in neurocritical care patients. Current literature suggests that maintaining MAP within an appropriate physiological range may support cerebral perfusion and reduce excessive pressure fluctuations (Beqiri et al., 2024; Saranti et al., 2025). The relatively narrower distribution of MAP values among survivors observed in this study is compatible with a more stable hemodynamic profile, although this interpretation should remain descriptive. Compared with previous studies, our findings are broadly consistent with the concept that postoperative blood pressure disturbances are common after craniotomy, but they also highlight the substantial variability among non-survivors. This variability may explain why a single MAP value may not fully characterize the postoperative hemodynamic condition of critically ill neurosurgical patients.

Overall, the present study found that non-survivors tended to have higher and more variable MAP values than survivors during the early postoperative period. These findings describe differences in hemodynamic distribution between the two outcome groups and suggest that hemodynamic variability may represent a clinically relevant characteristic of post-craniotomy patients that warrants further investigation in larger longitudinal studies.

Full Outline of UnResponsiveness (FOUR) score distribution according to patient outcome

The distribution of FOUR scores differed clearly between survivors and non-survivors in this cohort. Survivors had a median FOUR score of **15 (14–16)**, whereas non-survivors had a lower median score of **8 (2–11)**. In addition to the lower median value, the non-survivor group demonstrated a substantially wider distribution of scores, indicating greater variability in neurological status during the early postoperative period. The higher and more compact distribution of FOUR scores among survivors suggests that most patients in this group had relatively preserved neurological function. This finding is consistent with Jain et al., (2025), who reported higher FOUR scores among patients with favorable neurological outcomes. Similarly,Chattopadhyay et al., (2024) found that survivors generally maintained higher FOUR scores than non-survivors. The similarity between these studies and the present findings suggests that preserved neurological function is commonly observed among patients with better postoperative outcomes.

In contrast, non-survivors showed lower FOUR scores with a broad interquartile range, indicating heterogeneous neurological impairment. This wider distribution may reflect varying degrees of cortical dysfunction, brainstem involvement, and respiratory abnormalities among critically ill post-craniotomy patients. Abdallah et al., (2020) reported that lower FOUR score categories were associated with poorer clinical outcomes, while Schey et al., (2025) emphasized that the FOUR score provides additional information on brainstem function and respiratory patterns that is not captured by the Glasgow Coma Scale (GCS). These observations may help explain the broader range of FOUR scores seen among non-survivors in the present study.

Compared with previous studies, the present findings support the clinical relevance of the FOUR score as a comprehensive neurological assessment tool in ICU patients, particularly because it includes assessment of brainstem reflexes and respiratory function. Nevertheless, the wider variability observed among non-survivors also suggests that postoperative neurological status is influenced by multiple factors. The underlying diagnosis, postoperative sedation, mechanical ventilation, intracranial pressure management, anesthetic technique, and surgical complexity may all affect the FOUR score independently of patient outcome and were not evaluated in this study.

The relatively high and homogeneous FOUR scores among survivors and the lower, more variable scores among non-survivors indicate that neurological status differed between the two groups during the early postoperative period. These descriptive findings suggest that lower FOUR scores may represent clinically important markers of neurological impairment in post-craniotomy patients.

CONCLUSIONS

This descriptive cross-sectional study identified distinct demographic, hemodynamic, and neurological characteristics among post-craniotomy patients according to survival status. Age and sex distributions were generally comparable between survivors and non-survivors, indicating that demographic characteristics alone did not clearly differentiate the two outcome groups in this cohort. Non-survivors exhibited a higher and more variable distribution of mean arterial pressure (MAP) than survivors, suggesting greater hemodynamic disturbance during the early postoperative period. In addition, non-survivors had substantially lower and more heterogeneous Full Outline of UnResponsiveness (FOUR) scores, reflecting more severe neurological impairment compared with survivors.

These findings describe differences in the hemodynamic and neurological profiles of survivors and non-survivors and suggest that MAP variability and lower FOUR scores may represent clinically relevant characteristics of post-craniotomy patients requiring close neurological and hemodynamic assessment in the ICU. This study was descriptive and based on a single postoperative assessment. Larger multicenter longitudinal studies incorporating repeated measurements and multivariable analyses are needed to further clarify the clinical significance of MAP and FOUR score distributions in post-craniotomy patients.

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