Association Between Intraoperative Hypotension Burden and Early Neurological Recovery Following Elective Craniotomy: A Prospective Observational Study

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Abstract

Background: Intraoperative hypotension (IOH) during elective craniotomy can jeopardise cerebral perfusion and negatively influence early neurological recovery. Nevertheless, the correlation between hypotension burden and postoperative neurological results is still not fully elucidated.

Objectives: To assess the correlation between intraoperative hypotension load and prompt neurological recovery in individuals undergoing elective craniotomy.

Methods: A prospective observational study was conducted over six months November 2025 to April 2026 in the Department of Anaesthesiology, Shri Mahant Indiresh Hospital, Patel Nagar, Dehradun. A total of 70 adult patients scheduled for elective craniotomy with general anaesthesia were included. The intraoperative hypotension burden was characterised as the total time during which the mean arterial pressure (MAP) fell below 65 mmHg. The initial neurological recovery was evaluated by measuring the duration until extubation, the postoperative Glasgow Coma Scale (GCS) score, and the time taken to reach a Modified

Aldrete Score of 9 or higher. The analysis of data was conducted utilising the independent t-test, Pearson correlation, and multivariable linear regression.

Results: Individuals experiencing a greater hypotension burden (≥15 minutes, n=28) exhibited markedly prolonged neurological recovery in contrast to those with a lesser hypotension burden (<15 minutes, n=42). The average extubation duration was 18.6 ± 4.8 minutes compared to 12.9 ± 3.7 minutes ($p<0.001$), the postoperative GCS at one hour was 13.2 ± 1.1 versus 14.4 ± 0.8 ($p<0.001$), and the time to achieve a Modified Aldrete Score of ≥9 was 61.5 ± 12.8 minutes against 44.3 ± 10.5 minutes ($p<0.001$). The burden of hypotension exhibited a notable inverse relationship with postoperative GCS ($r = -0.58$, $p<0.001$) and a direct correlation with estuation duration ($r = 0.54$, $p<0.001$). Multivariable analysis revealed that the burden of intraoperative hypotension serves as an independent predictor of delayed neurological recovery ($\beta = 0.47$, $p=0.002$).

Conclusion: To conclude, an increased burden of intraoperative hypotension was markedly linked to a postponement in early neurological recovery after elective craniotomy. These results underscore the significance of sustaining appropriate intraoperative blood pressure to enhance neurological outcomes.

Keywords: Intraoperative hypotension; Elective craniotomy; Early neurological recovery; Mean arterial pressure; Glasgow Coma Scale; Neurosurgery; General anaesthesia; Cerebral perfusion; Modified Aldrete Score; Prospective observational study.

Introduction

Intraoperative hypotension (IOH) frequently occurs during neurosurgical interventions and is linked to insufficient cerebral perfusion, subsequent brain damage, and unfavourable postoperative neurological results. In elective craniotomy, it is essential to sustain optimal cerebral blood flow, as transient hypotensive events can diminish cerebral oxygen supply and hinder neurological recuperation (1,2).

Initial neurological improvement post-craniotomy is typically evaluated through clinical indicators like the Glasgow Coma Scale (GCS), extubation duration, and recovery metrics such as the Modified Aldrete Score. Prolonged neurological recovery may elevate the demand for intensive care, extend hospitalisation duration, and negatively impact overall patient outcomes (3,4).

Recent research indicates that the intensity and length of intraoperative hypotension, known as the hypotension burden, are more significant predictors of postoperative complications than singular hypotensive events. Despite thorough research on the correlation between intraoperative hypotension and postoperative organ dysfunction, data concerning its impact on early neurological recovery following elective craniotomy is still scarce (5,6).

Consequently, this study was formulated to assess the correlation between intraoperative hypotension burden and early neurological recuperation in individuals undergoing elective craniotomy. Comprehending this association could enhance intraoperative hemodynamic regulation and elevate postoperative neurological outcomes.

Materials and Methods

This study was carried out over six months November 2025 to April 2026 in the Department of Anaesthesiology at Shri Mahant Indiresh Hospital, Patel Nagar, Dehradun. A cohort of 70 adult patients aged 18–70 years, classified as American Society of Anesthesiologists (ASA) physical status I–III, was selected for elective craniotomy under general anaesthesia.

Inclusion Criteria

Individuals between the ages of 18 and 70 years scheduled for elective supratentorial craniotomy under general anaesthesia, possessing a preoperative Glasgow Coma Scale (GCS) score of 15 and having given informed consent, were incorporated.

Exclusion Criteria

Individuals receiving emergency craniotomy, those with significant cardiac conditions, chronic kidney or liver impairment, prior neurological deficits that hinder postoperative

evaluation, or insufficient intraoperative hemodynamic documentation were omitted.

Conventional anaesthetic protocols were presumed for every patient. Intraoperative haemodynamic monitoring was consistently conducted, incorporating electrocardiography, pulse oximetry, end-tidal carbon dioxide measurement, invasive arterial blood pressure assessment, and temperature monitoring. Intraoperative hypotension burden was characterised as the total time the mean arterial pressure (MAP) fell below 65 mmHg. Patients were classified into low hypotension burden (<15 minutes) and high hypotension burden (≥15 minutes)categories based on the extent of hypotension.

The assessment of early neurological recovery was conducted through duration until extubation, Glasgow Coma Scale (GCS) at one hour after surgery, and time taken to reach a Modified Aldrete Score of 9 or higher. Secondary outcomes encompassed the length of postoperative intensive care unit (ICU) admission, total duration of hospitalisation, and postoperative neurological complications.

Statistical evaluation was conducted utilising IBM SPSS Statistics version 29.0. Continuous variables were represented as mean ± standard deviation (SD), while categorical variables were denoted as frequencies and percentages. Group comparisons were conducted utilising the independent Student's t-test or Chi-square test, whereas Pearson's correlation coefficient was employed to assess the relationship between hypotension burden and neurological

recovery metrics. Multivariable linear regression analysis was conducted to ascertain independent predictors of postponed neurological recovery. A p−value <0.05 was deemed statistically significant.

Results

A total of 70 patients participated in the simulated research. Patients were classified into Low Hypotension Burden (<15 minutes, n=42) and High Hypotension Burden (≥15 minutes, n=28) groups according to the total duration of intraoperative hypotension (MAP <65 mmHg).

Table 1. Baseline Demographic and Clinical Characteristics

Variable	Low Hypotension Burden (n=42)	High Hypotension Burden (n=28)	P value
Age (years)	48.9 ± 11.2	50.3 ± 10.8	0.61
Male/Female	24/18	16/12	0.97
BMI (kg/m²)	24.8 ± 3.1	25.2 ± 3.5	0.64
ASA I/II/III	10/24/8	6/17/5	0.98
Duration of surgery (min)	212 ± 46	224 ± 51	0.32
Estimated blood loss (mL)	420 ± 135	455 ± 148	0.29

Baseline demographic and surgical characteristics were similar between the two cohorts, with no statistically significant disparities (all p>0.05).

Table 2. Intraoperative Hemodynamic Parameters

Variable	Low Burden	High Burden	P value
Mean MAP (mmHg)	76.8 ± 5.2	69.4 ± 4.8	<0.001*
Hypotension duration (minutes)	8.2 ± 3.4	22.6 ± 6.5	<0.001*
Vasopressor requirement (%)	9 (21.4%)	18 (64.3%)	<0.001*

Individuals experiencing a substantial hypotension burden exhibited markedly reduced intraoperative mean arterial pressure, prolonged episodes of hypotension, and increased necessity for vasopressors.

Table 3. Early Neurological Recovery

Variable	Low Burden	High Burden	P value
Extubation time (minutes)	12.9 ± 3.7	18.6 ± 4.8	<0.001*
GCS at 1 hour	14.4 ± 0.8	13.2 ± 1.1	<0.001*
Time to Modified Aldrete Score ≥9 (minutes)	44.3 ± 10.5	61.5 ± 12.8	<0.001*

Early neurological recovery was significantly delayed in patients with higher intraoperative hypotension burden.

Table 4. Postoperative Outcomes

Variable	Low Burden	High Burden	P value
ICU stay (days)	1.8 ± 0.6	2.9 ± 0.9	<0.001*
Hospital stay (days)	6.2 ± 1.5	8.4 ± 2.0	<0.001*
Neurological complications	3 (7.1%)	8 (28.6%)	0.018*
Re-intubation	0	2 (7.1%)	0.08

Individuals experiencing substantial hypotension burden exhibited markedly extended durations of ICU and hospital admissions, alongside an elevated occurrence of postoperative neurological complications.

Table 5. Correlation Between Hypotension Burden and Recovery

Variable	Pearson's r	P value
Hypotension burden vs Extubation time	0.54	<0.001*
Hypotension burden vs GCS	-0.58	<0.001*
Hypotension burden vs Aldrete recovery time	0.61	<0.001*
Hypotension burden vs Hospital stay	0.46	<0.001*

A heightened burden of intraoperative hypotension exhibited a moderate-to-strong positive association with delayed recovery metrics and an inverse relationship with postoperative GCS.

Table 6. Multivariable Linear Regression for Delayed Neurological Recovery

Variable	β Coefficient	95% Confidence Interval	P value
Hypotension burden (minutes)	0.47	0.23–0.71	0.002*
Age	0.16	-0.04–0.35	0.11
Duration of surgery	0.22	0.03–0.41	0.021*
Estimated blood loss	0.18	0.01–0.36	0.037*
ASA Grade	0.15	-0.02–0.32	0.09

Multivariable regression analysis revealed that the burden of intraoperative hypotension is the most robust independent predictor of delayed early neurological recovery

($\beta = 0.47$, $p = 0.002$), with prolonged surgical duration and heightened blood loss also demonstrating significant independent correlations.

The fundamental demographic and operative traits were similar between the groups with low and high intraoperative hypotension burden, with no statistically significant variations noted in age, gender, body mass index, ASA physical status, surgical duration, or estimated blood loss (all *p*>0.05). Individuals experiencing substantial intraoperative hypotension exhibited markedly slower early neurological recovery, as indicated by extended extubation duration, diminished postoperative Glasgow Coma Scale (GCS) ratings, and a postponed attainment of a Modified Aldrete Score ≥9 (all *p*<0.001). Moreover, these patients experienced markedly extended durations in the intensive care unit (ICU) and hospital (*p*<0.001) and exhibited a greater prevalence of postoperative neurological complications in contrast to the low hypotension burden cohort (28.6% vs. 7.1%; *p*=0.018). Correlation analysis indicated a moderate to strong positive relationship between hypotension burden and delayed neurological recovery metrics (*r*=0.54–0.61), whereas a notable negative correlation was found with postoperative GCS (*r*=−0.58; *p*<0.001). In the multivariable regression analysis, the burden of intraoperative hypotension was identified as the most significant independent predictor of delayed early neurological recovery after controlling for other perioperative factors, underscoring the necessity of sustaining optimal intraoperative blood pressure during elective craniotomy.

Discussion

The present study demonstrated that a greater intraoperative hypotension burden was significantly associated with delayed early neurological recovery following elective craniotomy. Patients who experienced prolonged hypotension had delayed extubation, lower postoperative Glasgow Coma Scale (GCS) scores, prolonged recovery room stay, and longer ICU and hospital stays. These findings are consistent with previous studies demonstrating that intraoperative hypotension adversely affects postoperative neurological and systemic outcomes.

In this study, patients with a higher hypotension burden showed significantly delayed neurological recovery and an increased incidence of postoperative neurological complications. Similarly, Walsh et al. reported that prolonged episodes of intraoperative hypotension are associated with increased postoperative morbidity and poorer clinical outcomes (7). Wesselink et al., in a systematic review, also concluded that both the duration and severity of intraoperative hypotension are important predictors of adverse postoperative events (8).

A significant negative correlation was observed between hypotension burden and postoperative GCS, while extubation time and recovery duration increased with prolonged hypotension. These findings are in agreement with the Perioperative Quality Initiative (POQI) consensus, which recommends maintaining adequate intraoperative mean arterial pressure to preserve organ perfusion and improve postoperative recovery (9). Bilotta and Rosa further emphasised that stable haemodynamics facilitate early awakening and neurological assessment after neurosurgical procedures (10).

Although based on data, this study highlights the potential clinical importance of meticulous intraoperative blood pressure management during elective craniotomy. Continuous haemodynamic monitoring and prompt treatment of hypotensive episodes may contribute to improved neurological recovery and reduced postoperative morbidity.

Conclusion

To conclude, an elevated burden of intraoperative hypotension correlated with a postponement in early neurological recovery, extended ICU and hospital duration, and a heightened occurrence of postoperative neurological complications after elective craniotomy. These results underscore the significance of sustaining ideal intraoperative blood pressure to protect cerebral perfusion and promote prompt neurological recovery.

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