Original Article

Evaluation of risk factors for postoperative neurologic intensive care admission after brain tumor craniotomy: A single-center longitudinal study

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Abstract

Background and Aims: Perioperative variable parameters can be significant risk factors for postoperative intensive care unit (ICU) admission after elective craniotomy for intracranial neoplasm, as assessed by various scoring systems such as Cranio Score. This observational study evaluates the relationship between these factors and early postoperative neurological complications necessitating ICU admission.

Material and Methods: In total, 119 patients, aged 18 years and above, of either sex, American Society of Anesthesiologists (ASA) grades I–III, scheduled for elective craniotomy and tumor excision were included. The primary objective was to evaluate the relationship between perioperative risk factors and the incidence of early postoperative complications as a means of validation of the Cranio Score. The secondary outcomes studied were 30-day postoperative morbidity/mortality and the association with patient-related risk factors.

Results: Forty-five of 119 patients (37.82%) required postoperative ICU care with the mean duration of ICU stay being 1.92 ± 4.91 days. Tumor location (frontal/infratemporal region), preoperative deglutition disorder, Glasgow Coma Scale (GCS) less than 15, motor deficit, cerebellar deficit, midline shift >3 mm, mass effect, tumor size, use of blood products, lateral position, inotropic support, elevated systolic/mean arterial pressures, and duration of anesthesia/surgery were associated with a higher incidence of ICU care. Maximum ($P = 0.035$, AOR = 1.130) and minimum systolic arterial pressures ($P = 0.022$, Adjusted Odds Ratio (AOR) = 0.861) were the only independent risk factors. Cranio Score was found to be an accurate predictor of complications at a cut-off point of >10.52%. The preoperative motor deficit was the only independent risk factor associated with 30-day morbidity (AOR = 4.66).

Conclusion: Perioperative hemodynamic effects are an independent predictor of postoperative ICU requirement. Further Cranio Score is shown to be a good scoring system for postoperative complications.

Keywords: Anesthesiology, brain neoplasm, Cranio Score, craniotomy, critical care, neurosurgery

Introduction

Intensive care admission following solid organ malignancy is increasing as a result of the increased need for organ support in these patients. Neurological malignancy accounts for about 9.9% of such admissions, indicating that the postoperative intensive care needs of this group of patients are high.[1]

Postoperative neurosurgical admission in the intensive care unit (ICU) is multifactorial, owing to neurologic, hemodynamic, metabolic, and respiratory causes. During

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craniotomy for tumor excision, the brain tissue is susceptible to injury due to incision, retraction, electrocauterization, localized neuronal death, blood–brain barrier (BBB) dysfunction, and brain edema.[2] Exaggerated physiological responses during surgery or emergence cause increased cerebral oxygen consumption, catecholamine secretion, hypercapnia, and systemic hypertension leading to a rapid increase in intracranial pressure, decreased cerebral perfusion, bleeding diatheses, or status epilepticus. The incidence of neurological complications is about 16% following such surgeries and may manifest as deterioration of consciousness, seizures, new-onset motor deficits, and dysphasia.[3] These complications may occur after a mean duration of 12 h.[4] Respiratory complications such as atelectasis, pneumonia, tracheobronchitis, re-intubation, pneumothorax, and acute respiratory distress syndrome (ARDS), as well as hemodynamic complications such as bradycardia, arterial hypertension/hypotension, and myocardial ischemia, can also present postoperatively.[3,5] In view of the above, traditional practice has been to routinely place all elective craniotomy patients in an intensive care setting postoperatively for early detection of neurologic deterioration. However, indicators of the quality of hospital management such as cost and length of hospitalization and ICU care, along with manpower utilization are expected to be significantly higher in neurosurgical patients. Therefore, the concepts of selective postoperative ICU care and preoperative risk factor assessment have influenced institutional protocols.[6,7,8] A recent systematic review derived that postoperative non-ICU care for elective craniotomies led to a reduction in the length of hospital stay ranging from up to 4 days and notable cost reductions.[9]

Preoperative scoring systems such as Acute Physiologic Assessment and Chronic Health Evaluation III score (APACHE), Karnofsky Performance Scale (KPS), and American Society of Anesthesiologists (ASA) scores have been found to have good predictive powers for these risk factors; however, these are not specific to neurosurgical patients.[10,11] Attempts toward the creation of a neurosurgical complication scoring system were made by Cinotti *et al.*[12] following analysis of a prospective as well as a retrospective multi-center database, and the score thus derived as calculated probability was termed the Cranio Score. With a value of this score at or below 3%, patients could be safely discharged from the postoperative recovery to the neurosurgical ward. Although statistically validated, we felt that a study could serve as an indicator of its applicability in the Indian scenario.

With this background, this single-centric longitudinal study was planned to evaluate the relation between perioperative variables and postoperative neurosurgical ICU requirements with a description of postoperative morbidity and mortality following elective craniotomies for brain tumors.

Material and Methods

This prospective observational study was conducted in patients aged 18 years and above, either gender, ASA grades I–III, scheduled for elective neurosurgery for intracranial tumors between February 2020 and February 2021 after obtaining Institutional Ethics clearance (ECR/736/Inst/UK/2015/RR-18 on 08/02/2020). Patients undergoing craniotomy for lesion biopsy, aneurysm clipping, arteriovenous malformation, cerebral cavernoma, central nervous system infection, awake craniotomy, or any emergent indications were excluded [Figure 1]. Written informed consent was taken from all patients/relatives.

Patients fulfilling inclusion criteria were consecutively enrolled and kept nil per oral for 8 h for solid food and 2 h for clear fluids. Medications relevant to neurosurgery such as anti-epileptics and steroids were continued perioperatively, while not administering any sedative premedication. After wheeling in and attaching standard ASA monitors, general anesthesia was induced with intravenous (IV) fentanyl 2 μg/kg, propofol 2–3 mg/kg, and vecuronium 0.1 mg/kg. After endotracheal intubation, ventilation was maintained to achieve end-tidal carbon dioxide of 32–35 mmHg. Anesthesia in all cases was maintained with either sevoflurane (0.8–1.0 minimum alveolar concentration (MAC)) with 60% air in oxygen or total intravenous technique with propofol infusion (100–150 μg/kg/min) along with boluses of vecuronium and fentanyl. Radial artery cannulation was performed for invasive monitoring, following which the solitary values of maximum as well as minimum recorded systolic and diastolic blood pressures were noted. Subclavian or internal jugular cannulation was performed with a 7 French gauge triple lumen catheter. Mannitol (0.25–1.0 mg/kg) was administered before dural opening. Fluids were administered as per the targets of goal-directed therapy while attempting to maintain stroke volume variation (SVV) values <13% and PVI values <14%, with boluses of 200 mL intravenous fluids given to achieve these targets. Blood products were administered to maintain hemoglobin of more than 10 g/dL. At the end of the surgery, the postoperative course was decided between the attending neuro anesthesiologist and the operative neurosurgeon. The intraoperative data recorded included patient position, hemodynamic parameters, blood loss, need for perioperative blood product transfusion, need for inotropic support, and urine output. Normothermic (with core temperature–36.0°C to 38.0°C), hemodynamically stable (with SBP >90 mmHg and MAP >65 mmHg without inotropic support), and alert patients with an uneventful intraoperative

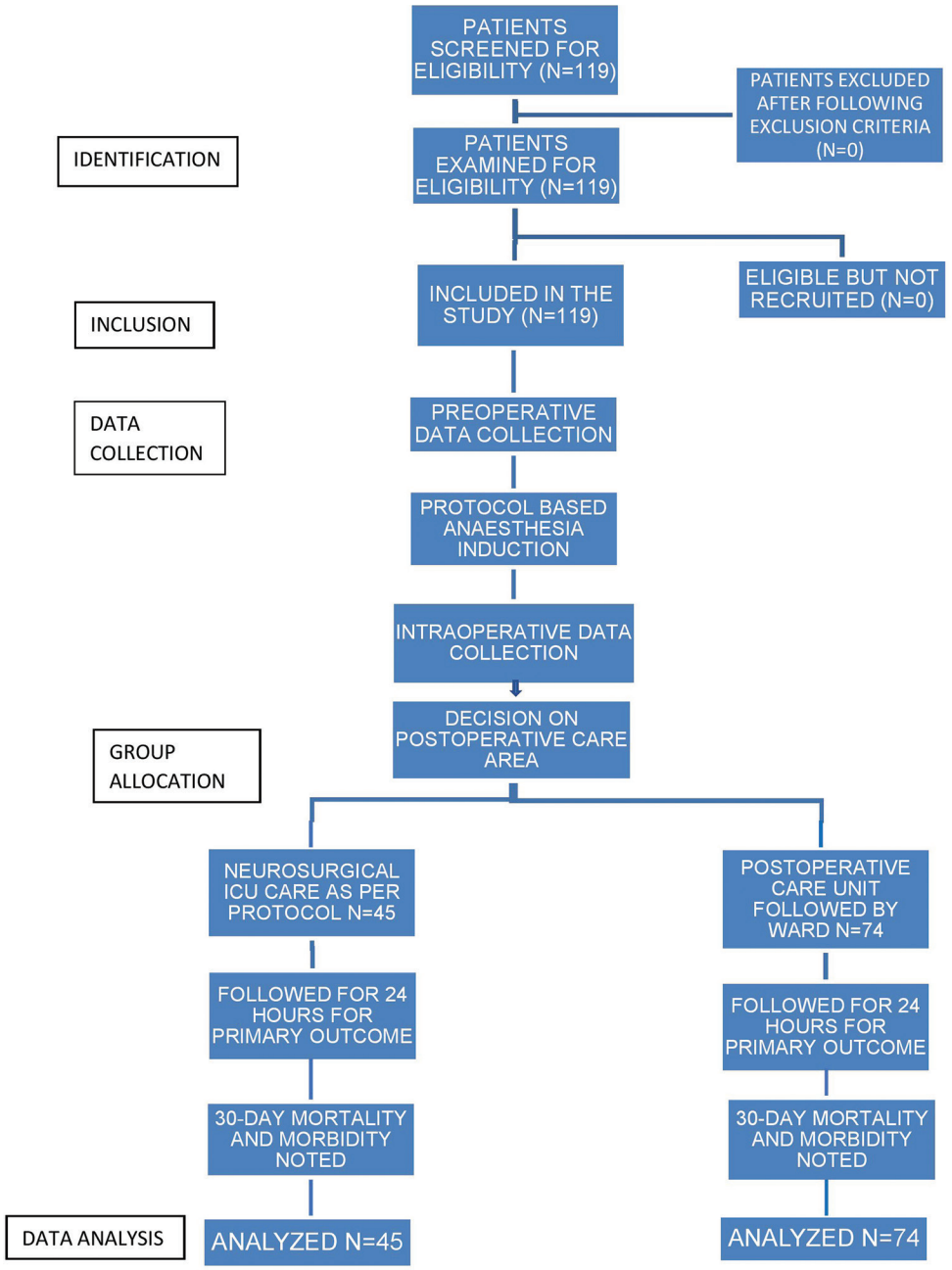

Figure 1: Study flowchart

course were administered injection neostigmine 0.05 mg/kg and glycopyrrolate 0.02 mg/kg for reversal of residual neuromuscular blockade. Patients once extubated were monitored in the postoperative care unit before shifting to the ward. However, patients with any of the following indications noted as the primary outcome were transferred to the neurosurgical ICU: patients with intracranial bleeding requiring neurosurgical evacuation (confirmed radiologically), intracranial hypertension confirmed either utilizing brain computed tomography scan or external ventricular drainage (defined as intracranial pressure at or above 20 mmHg), status epilepticus/seizures (clinically demonstrated), impaired consciousness requiring clinical monitoring (Glasgow Coma Score [GCS] at or below 13), unmanageable agitation requiring restraint or sedation, severe swallowing disorders leading to aspiration and respiratory failure, unexpected severe motor deficit (power <3/5) or a need for postoperative mechanical ventilation. These indications were not mutually exclusive, meaning that one patient could have multiple indications for ICU admission. As a subset, the indications for postoperative mechanical ventilation were as follows: hemodynamic instability (SBP <90 mmHg, MAP <65 mmHg), intraoperative brain bulge (defined as the protrusion of brain contents beyond dural margins), prolonged surgery in the prone position (more than 6 h), clinically apparent

intraoperative brainstem manipulation, or failure of extubation attempts. Each patient was then followed up for the first 24 h.

As components of the secondary outcome, length of stay in the ICU as well as in the hospital was noted, with follow-up performed either in the neurosurgical OPD or telephonically on the 30th postoperative day, and their mortality/morbidity status noted. The Cranio Score was calculated as per the formula provided, comprising the following variables: preoperative GCS, history of brain tumor surgery, greatest size of the tumor, mid-line shift ≥3 mm, transfusion of packed red blood cells/plasma/platelets, maximum and minimum operative systolic arterial pressure and duration of surgery.[11]

Assuming that 20% of the subjects in the population would require postoperative intensive care, with a population size of 220 and an expected response rate of 90%, the study would require a minimum sample size of 117 for estimating the expected proportion with 5% absolute precision and 95% confidence.[3,5,12] Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) software (Version 21.0, IBM, Chicago, IL, USA). The descriptive analyses of categorical variables are reported as frequencies and percentages (%), whereas those of continuous variables are reported as mean ± standard deviation (SD). The association of the quantitative variables was analyzed using the independent *t*-test, whereas the association of the qualitative variables was analyzed using the Chi-Square test. If any cell had an expected value of less than 5, then Fisher's exact test was used.

A receiver operating characteristic curve was used to find out the cut-off point of Cranio Score for predicting the need for postoperative ICU care. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were then calculated for the Cranio Score values. Univariate and multivariate logistic regression was used to assess significant risk factors of the primary and secondary outcomes. For statistical significance, a *P* value of less than 0.05 was considered significant for both the univariate and multivariate analyses. Because there were no missing data, no statistical adjustment was necessary.

Results

One hundred nineteen patients of either sex, aged 18 years and above, ASA grade I to III who underwent elective neurosurgery for intracranial tumors were recruited after fulfilling the eligibility criteria. Each patient was followed up for the entire study duration with no dropouts reported.

The mean age (years) of our patient demographic was 37.64 ± 14.9 years, with most patients falling in the age group of 31–50 years. The proportion of male patients was 63.03%. Concerning the ASA grading, 26 patients were ASA I grade and 93 patients were ASA grade II, with no patient falling in ASA grades III or IV. The mean body mass index (kg/m^2) was 24.56 ± 3.0. The anatomical location of intracranial tumors was supratentorial in 70 patients and infratentorial in 49. The GCS score was 15 in 86 patients (72.27%), and less than 15 in 27.73% (33/119) patients. Preoperative neurological deficit was present in 67 patients (aphasia in 5 patients, deglutition disorder in 9 patients, motor deficit in 33 patients, and cerebellar deficits in 20 patients). Preoperative comorbidities were present in 27 patients, which were hypertension in seven patients, epilepsy in seven patients, diabetes mellitus in six patients, and chronic obstructive pulmonary disease (COPD)/asthma in seven patients. Fourteen patients had a history of previous craniotomies. Tumor-related characteristics, operative positions, and histological diagnosis are shown in Table 1.

The supine position was the most frequently (48.74%) used, followed by the prone position (37.82%). The mean volume of perioperative crystalloid infused and blood loss (both in mL) were 3710.08 ± 723.39 and 704.2 ± 467.08, respectively. Intraoperative requirement of colloids (6% hydroxyethyl starch) was seen in 37.81% of patients. In all, 52.94% of patients required blood product transfusion. The mean values of maximum and minimum systolic as well as mean arterial pressures (in mmHg) were 125.01 ± 11.49, 101.5 ± 9.71, 84.34 ± 10.15, and 70.35 ± 6.89, respectively. Only

Table 1: Distribution of preoperative tumor characteristics and perioperative variables in study participants

Radiological findings	*n*=119	Percentage
Maximum tumor size (mm) (Mean±SD)	51.15±15.73	
Range of tumor size (mm)	15-85 mm	
Midline Shift (>3mm)	68	57.14%
Other Mass effect	96	80.67%
Peri-tumor edema	111	93.28%
Hydrocephalus	25	21.01%
Histological data		
Meningioma	21	17.65%
Glioma/glioblastoma	70	58.82%
Metastasis	3	2.52%
Schwanomma	11	9.24%
Craniopharyngioma	6	5.04%
Others	8	6.72%
Co-morbid conditions		
Hypertension	7	5.88%
Epilepsy	7	5.88%
Diabetes mellitus	6	5.04%
Previous craniotomy	14	11.76%
BA/COPD	7	5.88%

four patients required intraoperative inotrope support. The mean surgical and anesthesia durations (in min) were 324.96 ± 101.86 and 396.22 ± 102.95, respectively.

Postoperative neurosurgical ICU care was required in 45 out of 119 patients (37.82%). In 32.77% of patients, the indication of ICU care was the need for mechanical ventilation owing to causes such as failure to satisfy extubation criteria at emergence (38.46%), intraoperative brainstem handling (23.07%), hemodynamic instability requiring inotropic support (7.69%), intraoperative brain bulge (17.94%), and prolonged surgery in a prone position (12.82%). The incidence of other indications for ICU care was impaired consciousness (with GCS <13) (12.61%), new-onset cranial nerve deficit (7.56%), unexpected severe motor deficit (5.88%), intracranial hypertension (4.20%), status epilepticus or seizures (2.52%), moderate to severe intracerebral bleeding (1.68%), and respiratory failure following aspiration (1.68%). Unmanageable agitation requiring restraint or sedation was needed in only 1 out of 119 patients (0.84%).

On performing the univariate analysis (with significant *P* value taken as less than 0.05); tumor location (frontal/infratemporal region), preoperative deglutition disorder, GCS less than 15, motor deficit, cerebellar deficit, midline shift >3 mm, mass effect (which we defined as tumor causing ventricular compression, hydrocephalus, sulcal effacement, obliteration of basal cisterns, or local tissue pressure effects), tumor size, intraoperative use of blood products, lateral operative position, inotropic support, systolic and mean arterial pressure and duration of anesthesia and surgery were involved with a higher incidence of ICU care, as illustrated in Table 2.

On multivariate logistic regression, maximum and minimum systolic blood pressure values were the only significant independent risk factor for postoperative ICU care with an adjusted odds ratio of 1.130 (95% confidence interval [CI] bound 1.009–1.266) and 0.861 (95% CI bound 0.757–0.978), respectively, as depicted in Table 3. The mean duration of ICU stay was 1.92 ± 4.91 days (median interquartile range [IQR]-0[0–1] days), whereas that of hospital stay was 17.86 ± 9.93 days (median [IQR] of 15 [10.5–24.5]).

Follow-up on the 30th postoperative day revealed 75.22% (85/119) of patients had a GCS of 15, whereas a neurological deficit was present in 33 out of 113 patients (29.20%). Among patients in whom postoperative GCS was impaired, the GCS was 14 (15 patients), 13 (2 patients), 12 (2 patients), 11 (8 patients), and 10 (1 patient). Mortality occurred in 6 out of 119 patients (5.04%). The causes of mortality ranged from an acute coronary syndrome, refractory diabetes insipidus, lung consolidation with septic shock, and malignant cerebral edema secondary to infarction to refractory renal failure.

On performing univariate logistic regression, the factors responsible for increased 30 days morbidity were maximum tumor size, surgical/anesthesia duration, infratentorial tumor location, preoperative deglutition disorder, motor deficit, GCS less than 15, radiological features of midline shift >3 mm, hydrocephalus, and the histological diagnoses of glioma/glioblastoma and schwannoma. However, the presence of preoperative motor deficit was the only independent risk factor of 30-day morbidity following multivariate logistic regression with an adjusted odds ratio of 4.66. Perioperative risk factors causative of 30-day mortality were age, tumor size, systolic arterial pressures, GCS less than 15, and bronchial asthma, as shown in Table 4. No parameter was independently causative of higher 30-day mortality as shown in Table 5.

As shown in Figure 2, the discriminatory power of the Cranio Score (area under the curve [AUC] 0.824; 95% CI: 0.743 to 0.887) was excellent with a diagnostic accuracy of 77.31%. Cranio Score was a significant predictor of postoperative ICU care requirement at a cut-off point of 10.52%, having a positive predictive value of 75.7% and a negative predictive value of 79.3%. With this cut-off point, the sensitivity for predicting postoperative ICU care was 62.22%, whereas the specificity was 87.8%.

Discussion

In this longitudinal study, an evaluation of risk factors for postoperative neurosurgical ICU care admission was carried out in patients who underwent elective brain tumor craniotomy. This study was the first in the Indian scenario on this topic, wherein

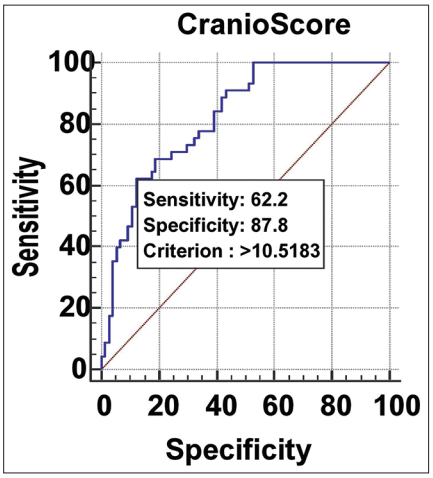

Figure 2: Receiver operating characteristics curve of calculated Cranio Score for predicting postoperative neurosurgical complications

Table 2: Univariate analysis of significant risk factors for postoperative neurosurgical ICU admission

Socio-demographic characteristics	No postoperative neurosurgical complications (*n*=74)	Postoperative neurosurgical complications (*n*=45)	Total	*P*	Testperformed
Age (years)					
≤20	15 (20.27%)	6 (13.33%)	21 (17.65%)	0.533	Chi-square test, 4.117
21–30	15 (20.27%)	9 (20%)	24 (20.17%)		
31–40	14 (18.92%)	11 (24.44%)	25 (21.01%)		
41–50	15 (20.27%)	10 (22.22%)	25 (21.01%)		
51–60	13 (17.57%)	5 (11.11%)	18 (15.13%)		
>60	2 (2.70%)	4 (8.89%)	6 (5.04%)		
Mean±SD	36.74±14.65	39.11±15.26	37.64±14.87	0.401	*t* test; 0.842
Gender					
Female	25 (33.78%)	19 (42.22%)	44 (36.97%)	0.355	Chi-square test, 0.855
Male	49 (66.22%)	26 (57.78%)	75 (63.03%)		
ASA status					
1	56 (75.68%)	37 (82.22%)	93 (78.15%)	0.402	Chi-square test, 0.702
2	18 (24.32%)	8 (17.78%)	26 (21.85%)		
Body mass index (kg/m^2)					
Mean±SD	24.65±3.01	24.42±2.93	24.56±2.97	0.688	t test; 0.402
BMI (18.5–24.99)	45 (60.81%)	32 (71.11%)	77 (64.71%)	0.346	Chi-square test, 2.12
BMI (25–29.99)	22 (29.73%)	8 (17.78%)	30 (25.21%)		
BMI(>=30)	7 (9.46%)	5 (11.11%)	12 (10.08%)		
Location					
Frontal	15 (20.27%)	1 (2.22%)	16 (13.45%)	0.005	Fisher's exact test
Frontotemporal	2 (2.70%)	4 (8.89%)	6 (5.04%)	0.198	Fisher's exact test
Frontoparietal	3 (4.05%)	1 (2.22%)	4 (3.36%)	1	Fisher's exact test
Temporoparietal	5 (6.76%)	4 (8.89%)	9 (7.56%)	0.728	Fisher's exact test
Parieto-occipital	6 (8.11%)	3 (6.67%)	9 (7.56%)	1	Fisher's exact test
Temporal	8 (10.81%)	2 (4.44%)	10 (8.40%)	0.316	Fisher's exact test
Parietal	1 (1.35%)	1 (2.22%)	2 (1.68%)	1	Fisher's exact test
Occipital	1 (1.35%)	1 (2.22%)	2 (1.68%)	1	Fisher's exact test
Infra-tentorial	23 (31.08%)	26 (57.78%)	49 (41.18%)	0.004	Chi-square test, 8.234
Sellar-suprasellar	10 (13.51%)	2 (4.44%)	12 (10.08%)	0.13	Fisher's exact test
Histological data					
Meningioma	18 (24.32%)	3 (6.67%)	21 (17.65%)	0.001	Fisher's exact test
Glioma/glioblastoma	40 (54.05%)	30 (66.67%)	70 (58.82%)		
Metastasis	3 (4.05%)	0 (0%)	3 (2.52%)		
Schwannoma	2 (2.70%)	9 (20%)	11 (9.24%)		
Craniopharyngioma	4 (5.41%)	2 (4.44%)	6 (5.04%)		
Others	7 (9.46%)	1 (2.22%)	8 (6.72%)		
Total	74 (100%)	45 (100%)	119 (100%)		
Pre-operative GCS					
GCS<15	11 (14.86%)	22 (48.89%)	33 (27.73%)	<.0001	Chi-square test, 16.164
GCS=15	63 (85.14%)	23 (51.11%)	86 (72.27%)		
Total	74 (100%)	45 (100%)	119 (100%)		
Co-morbidities					
Hypertension	5 (6.76%)	2 (4.44%)	7 (5.88%)	0.709	Fisher's exact test
Epilepsy	6 (8.11%)	1 (2.22%)	7 (5.88%)	0.251	Fisher's exact test
Diabetes mellitus	6 (8.11%)	0 (0%)	6 (5.04%)	0.082	Fisher's exact test
Previous craniotomy	8 (10.81%)	6 (13.33%)	14 (11.76%)	0.679	Chi-square test, 0.172
BA/COPD	4 (5.41%)	3 (6.67%)	7 (5.88%)	1	Fisher's exact test
Preoperative neurological deficit					
Aphasia	4 (5.41%)	1 (2.22%)	5 (4.20%)	0.649	Fisher Exact test
Deglutition disorder	1 (1.35%)	8 (17.78%)	9 (7.56%)	0.002	Fisher Exact test

Contd...

Table 2: Contd...

Socio-demographic characteristics	No postoperative neurosurgical complications (*n*=74)	Postoperative neurosurgical complications (*n*=45)	Total	*P*	Testperformed
Motor deficit	12 (16.22%)	21 (46.67%)	33 (27.73%)	0.0003	Chi-square test, 12.947
Cerebellar deficit	7 (9.46%)	13 (28.89%)	20 (16.81%)	0.006	Chi-square test, 7.555
Radiological features					
Midline shift (>3 mm)	27 (36.49%)	41 (91.11%)	68 (57.14%)	<.0001	Fisher's exact test
Hydrocephalus	12 (16.22%)	13 (28.89%)	25 (21.01%)	0.1	Chi-square test, 2.708
Mass effect	53 (71.62%)	43 (95.56%)	96 (80.67%)	0.001	Fisher's exact test
Peri-tumor edema	67 (90.54%)	44 (97.78%)	111 (93.28%)	0.256	Fisher's exact test
Maximum tumor size (mm)	44.89±12.81	61.44±14.72	51.15±15.73	<.0001	*t* test; 6.457
Position					
Prone	25 (33.78%)	20 (44.44%)	45 (37.82%)	0.245	Chi-square test, 1.352
Supine	45 (60.81%)	13 (28.89%)	58 (48.74%)	0.0007	Chi-square test, 11.413
Lateral	3 (4.05%)	9 (20%)	12 (10.08%)	0.009	Fishers' exact test
Seated	1 (1.35%)	3 (6.67%)	4 (3.36%)	0.151	Fisher's exact test
Perioperative condition					
Colloids used (mL)					
0	51 (68.92%)	23 (51.11%)	74 (62.18%)	0.092	Fisher Exact test
500	20 (27.03%)	16 (35.56%)	36 (30.25%)		
1000	3 (4.05%)	5 (11.11%)	8 (6.72%)		
1500	0 (0%)	1 (2.22%)	1 (0.84%)		
Blood products used	31 (41.89%)	32 (71.11%)	63 (52.94%)	0.002	Chi-square test, 9.59
Inotrope support	0 (0%)	4 (8.89%)	4 (3.36%)	0.019	Fisher Exact test
Minimum temperature (°C)	35.65±0.33	35.66±0.46	35.65±0.38	0.871	*t*-test; 0.163
Blood loss (mL)	635.14±412.54	817.78±530.56	704.2±467.08	0.051	*t*-test; 1.975
Crystalloids used (mL)	3500±646.38	4055.56±716.86	3710.08±723.39	<.0001	*t*-test; 4.362
Maximum systolic arterial pressure (mmHg)	122.42±11.25	129.27±10.69	125.01±11.49	0.001	*t*-test; 3.28
Minimum systolic arterial pressure (mmHg)	104.18±9.77	97.09±7.93	101.5±9.71	0.0001	*t*-test; 4.111
Maximum mean arterial pressure (mmHg)	82.45±9.99	87.47±9.72	84.34±10.15	0.008	*t*-test; 2.685
Minimum mean arterial pressure (mmHg)	71.34±6.28	68.73±7.58	70.35±6.89	0.044	*t*-test; 2.027
Total Surgical duration (min)	283.92±85.09	392.44±91.23	324.96±101.86	<.0001	*t*-test; 6.565
Total anesthesia duration (min)	353.24±85.1	466.89±90.52	396.22±102.95	<.0001	*t*-test; 6.896

multiple perioperative variables as well clinical applicability of the Cranio Score was assessed. Although our incidence of ICU care (37.82%) was comparable to the findings of Hanak *et al.* (35%),[5] there was a marked difference in our patient demographic owing to the inclusion of patients for indications apart from brain tumors. Other such studies, including the parent study devising the Cranio Score, reported much lower incidences.[12-15] Although there was a wide gap in the cut-off values of the Cranio Score between our study (10.52%) and the parent study (3%), our cut-off had a good predictive value for ICU requirement. This was despite our patients having a lower mean age (37.64 ± 14.9 years) and more female participants, with none of our patients falling into the categories of ASA grades III and IV. As reported in a systematic review by Upadhyayula *et al.*,[16] the average neurosurgeon-to-patient ratio in the United States is 1:63,000 as opposed to 1:2,500,000 in the Indian setup, indicating the disparities between the two healthcare settings. Probably, these disparities played a key role in the variation in the above cut-off values.

In agreement with the literature, we found that a significant tumor location associated with ICU care requirement was infratentorial although it was not an independent risk factor, justifying the increased perioperative vigilance in these patients.[3,6,12] In line with our findings, most previous studies have shown that preoperative neurological deficits correlate with failed extubation as well as new postoperative neurological deficits.[3,4,12,17] The comparatively larger tumor dimensions with more prevalent mass effect/edema in our patients (probably owing to the prolonged referral time in emerging nations such as ours further prolonged by COVID-19 lockdowns) also significantly correlated with neurological complications, whereas the previous literature conflicted on this issue.[5,10,12,17] Concerning the intraoperative parameters, as indicated by most studies, increased surgical duration was found by us as a significant risk factor.[5,12] In addition, Hanak *et al.*,[5]. Cata *et al.*,[18]and Cinotti *et al.*[12] obtained perioperative blood transfusion as an independent risk factor in parallel with our findings, expected because

Table 3: Multivariate logistic regression to find significant risk factors for postoperative neurosurgical ICU admission after adjusting for confounding factors

Postoperative neurosurgical complications	Beta coefficient	Standard error	*P*	Odds ratio	Odds ratio Lower bound (95%)	Odds ratio Upper bound (95%)
Maximum tumor size (mm)	0.037	0.033	0.265	1.038	0.972	1.108
Crystalloids used (mL)	0.000	0.001	0.851	1.000	0.999	1.001
Maximum systolic arterial pressure (mmHg)	0.122	0.058	0.035	1.130	1.009	1.266
Minimum systolic arterial pressure (mmHg)	-0.150	0.065	0.022	0.861	0.757	0.978
Maximum mean arterial pressure (mmHg)	-0.032	0.065	0.625	0.969	0.852	1.101
Minimum mean arterial pressure (mmHg)	0.057	0.091	0.529	1.059	0.886	1.267
Surgical duration (min)	0.027	0.016	0.107	1.027	0.994	1.061
Anesthesia duration (min)	-0.019	0.017	0.250	0.981	0.950	1.013
Preoperative GCS 15	-0.251	1.028	0.807	0.778	0.104	5.834
Deglutition disorder	-0.106	1.570	0.946	0.899	0.041	19.522
Motor deficit	0.594	0.953	0.533	1.811	0.280	11.727
Cerebellar deficit	0.147	1.012	0.885	1.158	0.159	8.425
Meningioma				1.000		
Glioma/glioblastoma	0.930	1.210	0.442	2.534	0.237	27.140
Metastasis	0.913	2.305	0.692	2.492	0.027	228.100
Schwannoma	3.335	1.747	0.056	28.084	0.914	862.775
Craniopharyngioma	4.160	3.366	0.216	64.101	0.087	46978.292
Others	1.619	2.058	0.431	5.050	0.089	285.278
Frontal location				1.000		
Frontoparietal location	0.179	2.071	0.931	1.196	0.021	69.273
Frontotemporal location	1.879	1.747	0.282	6.546	0.213	201.113
Infratentorial location	2.275	1.817	0.211	9.724	0.276	342.563
Occipital location	4.702	3.187	0.140	110.143	0.213	56867.817
Parietal location	2.692	2.649	0.309	14.758	0.082	2651.310
Parieto-occipital location	-0.494	1.972	0.802	0.610	0.013	29.112
Sellar-suprasellar location	-2.279	3.332	0.494	0.102	0.000	70.293
Temporal location	0.749	1.732	0.665	2.115	0.071	63.049
Temporoparietal location	0.432	1.507	0.775	1.540	0.080	29.553
Midline shift (>3 mm)	0.497	1.122	0.658	1.644	0.182	14.824
Mass effect	0.027	1.076	0.980	1.027	0.125	8.463
Supine position	-1.094	1.112	0.325	0.335	0.038	2.963
Lateral position	-0.593	1.453	0.683	0.553	0.032	9.535
Blood products used	0.306	0.794	0.700	1.358	0.286	6.442
Inotrope support	-0.976	2.445	0.690	0.377	0.003	45.399

increased intraoperative blood loss has been associated with postoperative hematoma formation secondary to surgical brain injury (SBI), coagulation, and complement activation. Although we did not find a relationship between excessive intraoperative fluid administration (which itself is linked to coagulation defects) and complications, some studies in the literature confirm the association, probably related to greater surgical blood loss.[15,17]

Maximum and minimum intraoperative systolic arterial pressures were the only independent risk factors of postoperative neurosurgical complications (with *P* values of 0.035 and 0.022 respectively), a result obtained by Cinotti *et al.* as well.[12] Previous studies have already shown the casual association of perioperative hypertension with postoperative intracranial hematomas, in good agreement with our findings.[19,20] Lillemäe *et al.*[21] in a retrospective study found that the incidence of post-craniotomy intracranial hematomas requiring reoperation was 0.6%, whereas our incidence was 1.68%. Purportedly, along with perioperative hypertension, other factors such as hemodynamic management and surgical hemostasis in the neurosurgical ICU could also be causative of hematoma formation. Although the presence of preoperative hypertension was a prominent risk factor for hematomas as per Seifman *et al.*,[22] it did not figure as a risk factor in our study. Nevertheless, the necessity of diligent maintenance of perioperative hemodynamics and optimization of preoperative hypertension in the neurosurgical patient remains strong as ever in light of the evidence. For example, in intracerebral hemorrhagic stroke (ICH), there is an observed relationship between

Table 4: Univariate logistic regression to find out significant risk factors of 30-day mortality

30-day mortality	Beta coefficient	Standard error	*P*	Odds ratio	Odds ratio Lower bound (95%)	Odds ratio Upper bound (95%)
Age (years)	0.059	0.03	0.048	1.06	1.001	1.124
Maximum tumor size (mm)	0.065	0.031	0.036	1.067	1.004	1.133
Minimum temperature (°C)	-1.4	1.163	0.229	0.247	0.025	2.411
Blood loss (mL)	0.001	0.001	0.395	1.001	0.999	1.002
Crystalloids used (mL)	0.001	0.001	0.2	1.001	1	1.002
Maximum systolic arterial pressure (mmHg)	0.091	0.033	0.006	1.096	1.027	1.169
Minimum systolic arterial pressure (mmHg)	-0.109	0.056	0.052	0.897	0.803	1.001
Maximum mean arterial pressure (mmHg)	0.085	0.034	0.012	1.089	1.019	1.163
Minimum mean arterial pressure (mmHg)	-0.094	0.057	0.1	0.91	0.813	1.018
Surgical duration (min)	0.005	0.004	0.222	1.005	0.997	1.012
Anesthesia duration (min)	0.005	0.004	0.239	1.005	0.997	1.012
Gender						
Female				1		
Male	0.168	0.888	0.85	1.183	0.208	6.739
ASA status						
1				1		
2	0.617	0.896	0.491	1.854	0.32	10.737
Body mass index (kg/m^2)						
Normal BMI (18.5–24.99)				1		
Overweight (25–29.99)	1.427	0.94	0.129	4.167	0.66	26.301
Obese (≥30)	1.226	1.267	0.333	3.409	0.285	40.809
Location (frontal)						
Frontal				1.000		
Frontoparietal	1.299	2.229	0.560	3.667	0.046	289.306
Frontotemporal	2.197	1.783	0.218	9.000	0.273	296.472
Infra-tentorial	0.552	1.618	0.733	1.737	0.073	41.428
Occipital	1.886	2.406	0.433	6.596	0.059	737.271
Parietal	1.886	2.406	0.433	6.596	0.059	737.271
Parieto-occipital	1.762	1.750	0.314	5.824	0.189	179.634
Sellar-suprasellar	0.278	2.108	0.895	1.320	0.021	82.171
Temporal	1.651	1.743	0.344	5.211	0.171	158.723
Temporo-parietal	1.762	1.750	0.314	5.824	0.189	179.634
Preoperative GCS>15	-2.72	1.117	0.015	0.066	0.007	0.588
Hypertension	1.272	1.173	0.278	3.567	0.358	35.543
Epilepsy	0.088	1.613	0.956	1.092	0.046	25.799
Diabetes mellitus	0.241	1.636	0.883	1.272	0.051	31.431
Previous craniotomy	-0.639	1.543	0.679	0.528	0.026	10.872
BA/COPD	2.38	0.979	0.015	10.8	1.584	73.639
Aphasia	1.696	1.208	0.16	5.45	0.511	58.159
Deglutition disorder	0.965	1.155	0.403	2.625	0.273	25.261
Motor deficit	1.018	0.844	0.228	2.767	0.529	14.462
Cerebellar deficit	0.97	0.903	0.283	2.639	0.449	15.501
Histological data						
Meningioma				1.000		
Glioma/glioblastoma	-0.639	0.845	0.449	0.528	0.101	2.763
Metastasis	0.108	1.876	0.954	1.114	0.028	44.065
Schwannoma	-1.081	1.658	0.514	0.339	0.013	8.745
Craniopharyngioma	-0.511	1.728	0.768	0.600	0.020	17.739
Others	-0.779	1.690	0.645	0.459	0.017	12.587
Midline shift (>3 mm)	2.371	1.494	0.112	10.712	0.573	200.158
Hydrocephalus	-0.299	1.119	0.789	0.742	0.083	6.653
Mass effect	1.217	1.516	0.422	3.376	0.173	65.873

Contd...

Table 4: Contd...

30-day mortality	Beta coefficient	Standard error	*P*	Odds ratio	Odds ratio Lower bound (95%)	Odds ratio Upper bound (95%)
Peri-tumour edema	0.046	1.596	0.977	1.047	0.046	23.912
Prone	-0.206	0.887	0.817	0.814	0.143	4.634
Supine	-0.675	0.886	0.446	0.509	0.09	2.891
Lateral	1.639	0.927	0.077	5.15	0.837	31.699
Seated	0.627	1.715	0.715	1.872	0.065	53.99
Colloids used (mL)						
0				1		
500	0.392	0.863	0.649	1.48	0.273	8.033
1000	1.408	1.097	0.2	4.086	0.476	35.09
1500	1.912	2.378	0.421	6.765	0.064	715.129
Blood products used	2.547	1.493	0.088	12.774	0.685	238.111
Inotrope support	1.992	1.242	0.109	7.333	0.643	83.646

Table 5: Multivariate logistic regression to find out significant risk factors of 30-day mortality

30-day mortality	Beta coefficient	Standard error	*P*	Odds ratio	Odds ratio Lower bound (95%)	Odds ratio Upper bound (95%)
Age (years)	0.04	0.04	0.314	1.041	0.963	1.125
Maximum tumor size (mm)	0.039	0.043	0.361	1.04	0.956	1.13
Maximum systolic arterial pressure (mmHg)	0.013	0.091	0.89	1.013	0.848	1.209
Maximum mean arterial pressure (mmHg)	0.081	0.092	0.376	1.085	0.906	1.298
Preoperative GCS >15	-2.364	1.36	0.082	0.094	0.007	1.351
BA/COPD	1.598	1.479	0.28	4.941	0.272	89.695

increased SBP with death and disability and an increased in-hospital mortality rate, with one study suggesting that early and aggressive control of SBP may minimize the expansion of hemorrhagic strokes.[23]

Considering our complication rates, higher mortality rates were expected by us. However, the 30-day mortality rate we obtained (5.04%) was similar to that recorded by Maria *et al.* (5.5%).[13] This could be a positive reflection upon the standards of neurosurgical ward care in our institute. Our mean duration of ICU stay (1.92 days) was comparable with the results of Laan *et al.*[14] However, our results differed from the observation of Azoulay *et al.*[24] that ICU mortality for neurosurgical patients has failed to improve despite medical advancements. Qasem *et al.*[25] also observed that most complications occur 24 h postoperatively. Further, the mean length of hospital stay in our study was relatively prolonged (17.86 days) due to COVID-19-related transfer delays within the hospital.[26,27] Although no parameter in our study independently correlated with higher 30-day mortality, this factor was advanced age for Lassen *et al.*[28] and Seicean *et al.*[29] Although we found preoperative motor deficit as the only independent risk factor of 30-day morbidity, Dasenbrock *et al.*[30] found advanced age, African, American, and Hispanic ethnicity, ASA class 3 and above, dependent functional status, diabetes mellitus, hematological comorbidities, and hypoalbuminemia as predictors.

To sum up, in addition to deriving cut-off values of the Cranio Score in the Indian setting, we were able to derive independent risk factors for neurosurgical ICU care as well as 30-day mortality/morbidity, despite the chief limitation of being single-centric with a smaller sample size and short follow-up period, thus being underpowered. As another limitation, the addition of a retrospective cohort for correlation would have added to the statistical accuracy. Logistic regression utilized for calculating the risk factors itself possesses fallacies, chiefly the assumption of linearity between dependent and independent variables in the data. Extubation of these patients on the surgical table is a multi-disciplinary decision and this could have been a confounding factor for our study. The conduct of the study during the COVID-19 pandemic influenced the derivation of risk factors as we mentioned previously. Finally, long-term neurological morbidity and mortality could have been assessed by employing longer follow-up periods.

Conclusion

We found that systolic arterial pressure was the only independent risk factor for early postoperative neurological complications requiring ICU care. Additionally, Cranio Score was found to be a valid tool for the prediction of postoperative complications following elective craniotomy for brain neoplasms with a cut-off value of 10.52%.

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Conflicts of interest

There are no conflicts of interest.

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