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Intraoperative brain relaxation strategies: Balancing intracranial pressure control and cerebral perfusion

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Abstract

Background: Elective supratentorial craniotomy remains a cornerstone of neurosurgical practice, where achieving optimal intraoperative brain relaxation is crucial for surgical exposure and neurological safety. Mannitol has long been the standard osmotic agent. Hypertonic saline (HS) offers a promising alternative by reducing brain volume while maintaining intravascular volume and cerebral perfusion pressure (CPP). This study aimed to evaluate and compare two intraoperative brain relaxation strategies during elective supratentorial craniotomy.

Methods: This prospective, randomized comparative study was conducted on 80 adult patients undergoing elective supratentorial craniotomy at the Department of Neuro-Anaesthesia, Neurosciences and Hospital (NINS), Dhaka, Bangladesh, from January, 2024 to December, 2024. Participants were randomly assigned to receive either 20% mannitol (1 g/kg) or 3% HS (5 mL/kg) for intraoperative brain relaxation. Patients with renal impairment, abnormal sodium levels, uncontrolled hypertension, heart failure, or pregnancy were excluded. Standardized general anesthesia and ventilation were maintained, with cerebrospinal fluid drainage or mild hyperventilation used as adjuncts when necessary. Data were analyzed using the Statistical Package for the Social Sciences v26, and a $P < 0.05$ was considered statistically significant.

Results: Among 80 adult patients undergoing elective supratentorial craniotomy, satisfactory brain relaxation was achieved in 80% of those receiving HS compared with 60% in the mannitol group ($P = 0.027$). HS also resulted in fewer intracranial pressure (ICP) spikes ≥20 mmHg (30% vs. 50%, $P = 0.012$) and more consistent maintenance of CPP ≥60 mmHg (85% vs. 70%, $P = 0.002$). Hemodynamic stability was better with HS, though not statistically significant, while serum sodium levels were higher as expected.

Conclusion: HS achieved superior intraoperative brain relaxation compared with mannitol during elective supratentorial craniotomy, offering better control, improved cerebral perfusion, and greater hemodynamic ICP stability without increasing adverse effects. It represents an effective and safe alternative osmotherapy for optimizing surgical conditions and patient outcomes.

Keywords: Cerebral perfusion pressure, Hypertonic saline, Intracranial pressure control, Intraoperative brain relaxation, Mannitol

Introduction

Elective supratentorial craniotomy for brain tumors and other lesions remains a standard neurosurgical procedure worldwide. Globally, an estimated 308,102 new cases of primary brain and central nervous system tumors were diagnosed in 2020, with approximately 251,000 deaths that year.[1] In South Asia, including Bangladesh, the burden of intracranial neoplasms is rising alongside improved diagnostic capabilities, but neurosurgical resources remain limited. For instance, an estimated 20,000 people develop brain tumors annually in Bangladesh, yet only about 3,000 brain tumor surgeries are performed each year.[2] These statistics underscore the need to optimize intraoperative management and outcomes for those who do receive surgical care. One critical intraoperative goal during craniotomy is achieving adequate brain relaxation, a slack brain with minimal swelling, to facilitate surgical exposure and protect neural structures. Cerebral swelling and elevated intracranial pressure (ICP) are common during craniotomies and can make surgery more difficult while increasing the risk of ischemic injury and poor neurological outcomes.[3] Practical strategies to relax the brain and control ICP are therefore essential in improving surgical safety and patient prognosis. The anesthesia and neurocritical care management of craniotomy patients involves a careful balance between lowering ICP and maintaining sufficient cerebral perfusion pressure (CPP). Guidelines generally recommend initiating interventions if ICP exceeds 20–22 mmHg or if CPP falls below around 60 mmHg, as sustained ICP >20 mmHg is associated with cerebral ischemia and herniation risk.[4] However, overly aggressive ICP reduction can impair CPP and cerebral blood flow. For instance, hyperventilation is often used to constrict cerebral vessels and reduce intracranial blood volume acutely, but prolonged hypocapnia can provoke cerebral ischemia and worsen outcomes.[4,5] Similarly, deep anesthesia or high-dose sedatives can lower ICP but may cause systemic hypotension, further jeopardizing CPP. These considerations are especially pertinent in older patients (>40 years), who may have less robust autoregulation and greater susceptibility to hypoperfusion injury. Thus, intraoperative brain relaxation strategies must not only blunt ICP spikes above 20 mmHg but also preserve adequate CPP to avoid secondary ischemic damage. Several approaches are employed to achieve a relaxed brain during craniotomy. Standard measures include head elevation to improve venous drainage, judicious anesthetic control, and, when feasible, cerebrospinal fluid (CSF) drainage. A cornerstone of medical management is the use of hyperosmolar agents to reduce brain volume. Mannitol (20%) and hypertonic saline (HS) are the two most commonly used osmotic agents for intraoperative brain relaxation and ICP control.[6] Mannitol has been a first-line therapy for decades due to its effective reduction of intracranial volume via osmotic diuresis and improved cerebral blood flow from reduced blood viscosity.[7] However, mannitol is associated with side effects, such as intravascular volume depletion, electrolyte disturbances, rebound intracranial hypertension, and acute kidney injury (AKI).[8,9] In fact, recent evidence indicates that intraoperative mannitol use may be an independent risk factor for post-operative AKI,[10] especially in older or renally vulnerable patients. Given these limitations, there has been growing interest in HS as an alternative. HS (usually 3%) exerts similar osmotic dehydration of the brain but with distinct advantages: It expands intravascular volume, increases mean arterial pressure (MAP), and supports CPP.[11] It also avoids excessive diuresis, thereby reducing hypotension and fluid shifts. The Neurocritical Care Society's 2020 guidelines recommend hypertonic sodium solutions over mannitol for managing elevated ICP, citing greater effectiveness in reducing intracranial edema.[12] However, HS can lead to hypernatremia or metabolic acidosis, and its renal impact remains debated.[5] Thus, while both agents are effective, the optimal osmotic therapy for balancing ICP reduction and CPP preservation is not fully established. Multiple randomized controlled trials (RCTs) and meta-analyses have compared HS and mannitol for intraoperative brain relaxation. Overall, HS appears at least as effective as mannitol in lowering ICP, with several

studies reporting superior brain relaxation using HS.[13,14] A meta-analysis by Shao *et al*. found HS associated with higher odds of satisfactory brain relaxation and lower peak ICP compared to mannitol.[15] Most prior studies enrolled heterogeneous age groups and often excluded older patients, leaving uncertainty about optimal management in those above 40 years, who may have reduced physiological reserves and higher renal and cerebrovascular risk. Furthermore, limited data exist from low-resource or South Asian settings, where differences in baseline health, perioperative care, and surgical complexity may alter treatment responses. Therefore, locally relevant evidence is essential to guide clinical practice. This prospective randomized comparative study aims to evaluate and compare two intraoperative brain relaxation strategies during elective supratentorial craniotomy in adults over 40 years in Bangladesh.

Methods

This study was a prospective, randomized comparative study was conducted at the Department of Neuro-Anaesthesia, Neurosciences and Hospital, Dhaka, Bangladesh from July, 2024 to June, 2025. Eighty adult patients scheduled for elective supratentorial craniotomy were randomly divided into two groups of 40 each: One group received mannitol (20%, 1 g/kg) and the other received HS (3%, 5 mL/kg) to achieve intraoperative brain relaxation. Patients with renal disease, abnormal serum sodium, uncontrolled hypertension, heart failure, or pregnancy were excluded. All patients received standard general anesthesia with propofol, opioids, and muscle relaxants, and ventilation was adjusted to maintain normal carbon dioxide levels. Additional relaxation measures, such as CSF drainage or mild hyperventilation, were used when needed. Informed consent was taken from each patient; ethical clearance was taken from Institutional Review Board.

Data were analyzed using IBM Statistical Package for the Social Sciences Statistics (version 26). Continuous variables were expressed as mean ± standard deviation and compared using the *t*-test, while categorical variables were compared using the Chi-square test. Logistic regression was used to identify factors independently associated with satisfactory brain relaxation. A $P < 0.05$ was considered statistically significant.

Results

In this study, the majority of patients were aged 40–59 years (53.8%), and the age distribution was similar between groups ($P = 0.951$). Males constituted 60% of each group, while females made up 40% ($P = 0.364$). Most participants had a body mass index <30 (70%) and American Society of Anesthesiologists I-II status (55%), again with comparable proportions between treatment arms ($P = 0.622$ and 0.498, respectively). Regarding pathology, glioma was the most common diagnosis (45%), followed by meningioma (30%) and aneurysm/vascular lesions (15%), with no significant group difference ($P = 0.399$) [Table 1].

A majority of patients in both groups had a midline shift of <5 mm (65.0%, $P = 0.241$), and most had a preoperative Glasgow coma scale score of 15 (75.0%, $P = 0.612$), indicating good neurological status before surgery. The use of preoperative steroids was identical between groups, with 60% of patients receiving them ($P = 0.9$) [Table 2].

Hyperventilation was employed in nearly half of the patients (46.2%), with similar use in both groups ($P = 0.263$). Propofol infusion was administered to 65% of patients in each group ($P = 0.54$), indicating uniform anesthetic practice. However, CSF drainage was performed more frequently in the Mannitol group (40.0%) compared to the HS group (25.0%), a difference that reached statistical significance ($P = 0.034$) [Table 3].

Satisfactory brain relaxation was observed in 80% of patients receiving HS compared to 60% in the Mannitol group ($P = 0.027$). Similarly, intraoperative ICP spikes ≥20 mmHg were less frequent in the HS group (30.0%) than in the Mannitol group (50.0%), showing a statistically significant reduction ($P = 0.012$). Furthermore,

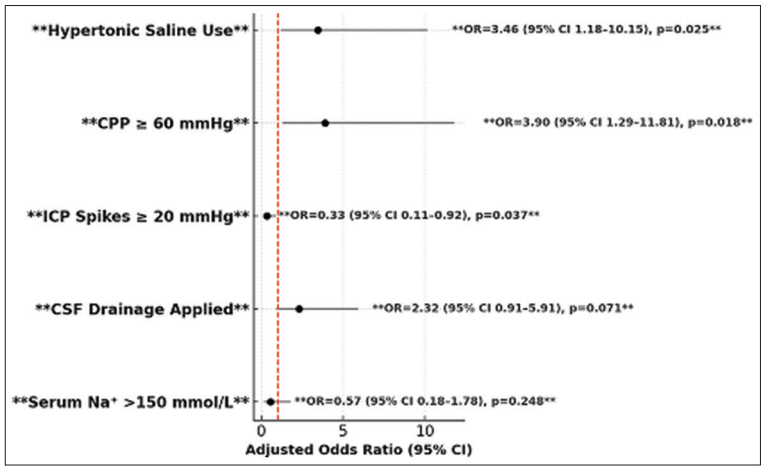

Figure 1: Forest plot of predictors of satisfactory brain relaxation. In this logistic regression analysis, hypertonic saline use and maintaining cerebral perfusion pressure ≥60 mmHg were both significantly associated with a higher likelihood of achieving satisfactory brain relaxation, with adjusted odds ratios (OR) of 3.46 ($P = 0.025$) and 3.90 ($P = 0.018$), respectively. Conversely, the presence of intracranial pressure spikes ≥20 mmHg was significantly associated with poorer brain relaxation outcomes (OR = 0.33, $P = 0.037$). Although CSF drainage showed a positive trend (OR = 2.32, $P = 0.071$), it did not reach statistical significance. Similarly, serum sodium >150 mmol/L (OR = 0.57, $P = 0.248$) was not significantly associated with satisfactory brain relaxation. Overall, these findings suggest that maintaining optimal cerebral perfusion and managing intracranial pressure effectively play key roles in promoting better intraoperative brain relaxation [Figure 1]

Table 1: Baseline demographics and clinical profile

Variable	Category	Mannitol (*n*=40) (%)	Hypertonic Saline (*n*=40) (%)	Total (*n*=80) (%)	*P*-value
Age	40–59	21 (52.5)	22 (55.0)	43 (53.8)	0.951
	<40	12 (30.0)	12 (30.0)	24 (30.0)	
	≥60	7 (17.5)	6 (15.0)	13 (16.2)	
Sex	Female	16 (40.0)	16 (40.0)	32 (40.0)	0.364
	Male	24 (60.0)	24 (60.0)	48 (60.0)	
BMI	<30	27 (67.5)	29 (72.5)	56 (70.0)	0.622
	≥30	13 (32.5)	11 (27.5)	24 (30.0)	
ASA	I–II	20 (50.0)	24 (60.0)	44 (55.0)	0.498
	III–IV	20 (50.0)	16 (40.0)	36 (45.0)	
Pathology	Aneurysm/vascular	5 (12.5)	7 (17.5)	12 (15.0)	0.399
	Glioma	20 (50.0)	16 (40.0)	36 (45.0)	
	Meningioma	12 (30.0)	12 (30.0	24 (30.0)	
	Other	3 (7.5)	5 (12.5)	8 (10.0)	

BMI: Body mass index, ASA: American Society of Anesthesiologists

maintenance of CPP ≥60 mmHg was achieved more consistently with HS (85.0%) than with Mannitol (70.0%), also demonstrating a significant difference ($P = 0.002$) [Table 4].

Intraoperative hypotension occurred in 52.5% of patients receiving Mannitol and 37.5% of those receiving HS ($P = 0.176$), suggesting a trend toward greater hemodynamic stability with HS. Serum

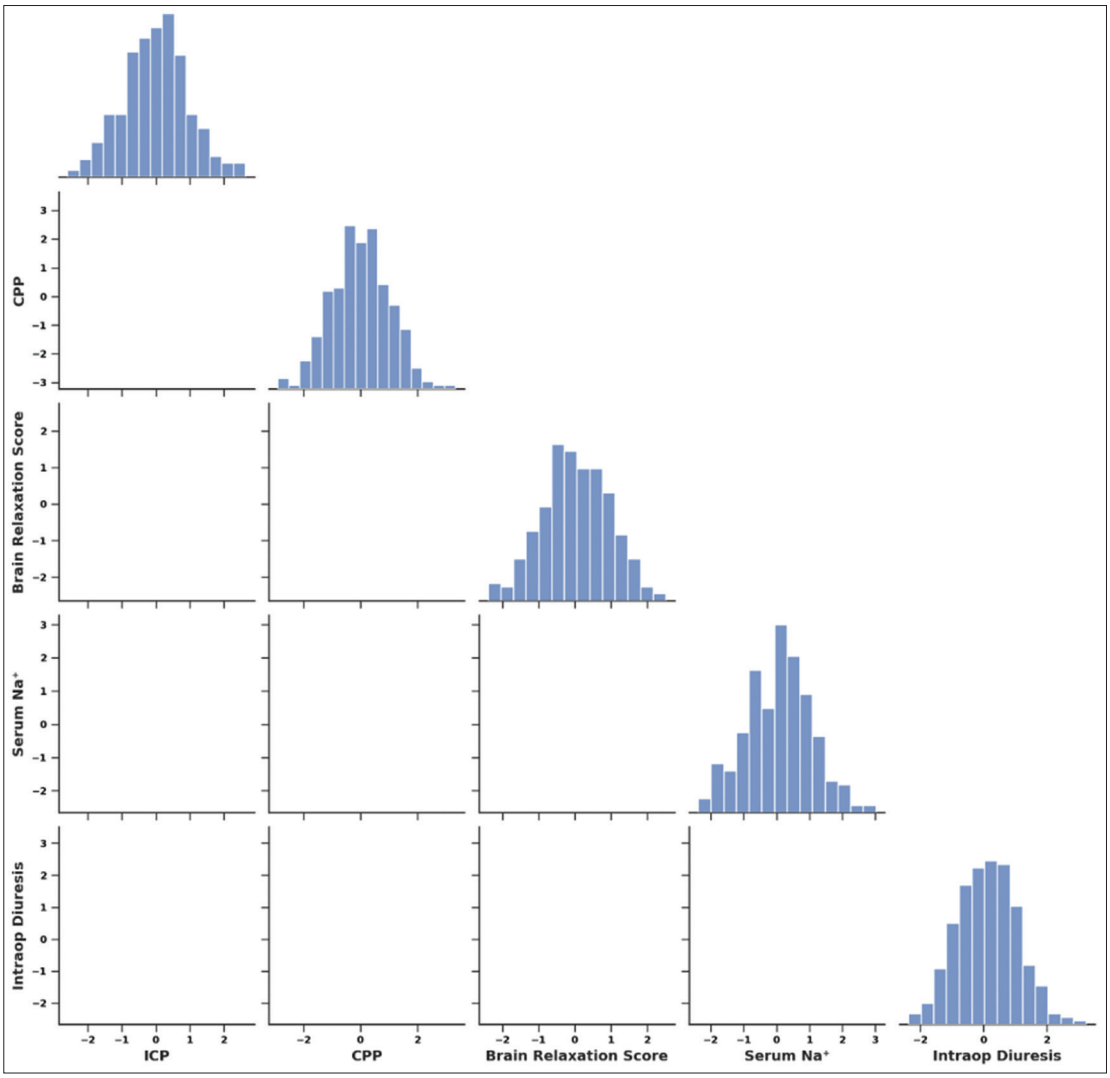

Figure 2: Scatterplot matrix of intraoperative intracranial pressure (ICP) and cerebral perfusion pressure (CPP) Parameters. The scatterplot matrix visualises pairwise relationships among intraoperative physiological variables. A strong inverse relationship is observed between ICP and CPP, and between ICP and brain relaxation score, indicating that higher intracranial pressure is associated with reduced cerebral perfusion and poorer brain relaxation. Conversely, CPP and brain relaxation score show a positive correlation, suggesting improved brain relaxation with better cerebral perfusion. Serum sodium and intraoperative diuresis demonstrate weaker associations with ICP, reflecting their lesser direct impact on intracranial dynamics in this dataset [Figure 2]

sodium levels >150 mmol/L were significantly more frequent in the HS group (30.0%) than in the Mannitol group (10.0%) ($P = 0.003$), reflecting the expected hypernatremic effect of HS. Diuresis exceeding 1000 mL occurred more often with Mannitol (55.0%) than with HS (35.0%), though this difference was not statistically significant ($P = 0.117$). Metabolic acidosis was noted in 30% of cases overall, with no meaningful difference between groups ($P = 0.161$) [Table 5].

Table 2: Preoperative status and imaging

Variable	Category	Mannitol (*n*=40) (%)	Hypertonic Saline (*n*=40) (%)	Total (*n*=80) (%)	*P*-value
Midline shift	<5 mm	23 (57.5)	29 (72.5)	52 (65.0)	0.241
	≥5 mm	17 (42.5)	11 (27.5)	28 (35.0)	
Preop GCS	15	29 (72.5)	31 (77.5)	60 (75.0)	0.612
	≤14	11 (27.5)	9 (22.5)	20 (25.0)	
Preop steroids	No	16 (40.0)	16 (40.0)	32 (40.0)	0.9
	Yes	24 (60.0)	24 (60.0)	48 (60.0)	

GCS: Glasgow coma scale

Table 3: Intraoperative measures of both groups

Variable	Category	Mannitol (*n*=40) (%)	Hypertonic saline (*n*=40) (%)	Total (*n*=80) (%)	*P*-value
Hyperventilation	No	20 (50.0)	23 (57.5)	43 (53.8)	0.263
	Yes	20 (50.0)	17 (42.5)	37 (46.2)	
Propofol infusion	No	14 (35.0)	14 (35.0)	28 (35.0)	0.54
	Yes	26 (65.0)	26 (65.0)	52 (65.0)	
CSF drainage	No	24 (60.0)	30 (75.0)	54 (67.5)	0.034
	Yes	16 (40.0)	10 (25.0)	26 (32.5)	

Table 4: Intraoperative brain relaxation and cerebral physiology outcomes

Variable	Category	Mannitol (*n*=40) (%)	Hypertonic saline (*n*=40) (%)	Total (*n*=80)	*P*-value
Brain relaxation	Borderline/Poor	16 (40.0)	8 (20.0)	24 (30.0)	0.027
	Satisfactory	24 (60.0)	32 (80.0)	56 (70.0)	
ICP spikes ≥20	No	20 (50.0)	28 (70.0)	48 (60.0)	0.012
	Yes	20 (50.0)	12 (30.0)	32 (40.0)	
CPP maintenance	<60 mmHg	12 (30.0)	6 (15.0)	18 (22.5)	0.002
	≥60 mmHg	28 (70.0)	34 (85.0)	62 (77.5)	

ICP: Intracranial pressure, CPP: Cerebral perfusion pressure

Table 5: Physiological derangements during case

Variable	Category	Mannitol (*n*=40) (%)	Hypertonic Saline (*n*=40) (%)	Total (*n*=80) (%)	*P*-value
Intraoperative Hypotension	No	19 (47.5)	25 (62.5)	44 (55.0)	0.176
	Yes	21 (52.5)	15 (37.5)	36 (45.0)	
Serum Na+	≤150	36 (90.0)	28 (70.0)	64 (80.0)	0.003
	>150	4 (10.0)	12 (30.0)	16 (20.0)	
Diuresis	≤1000 mL	18 (45.0)	26 (65.0)	44 (55.0)	0.117
	>1000 mL	22 (55.0)	14 (35.0)	36 (45.0)	
Metabolic acidosis	No	26 (65.0)	30 (75.0)	56 (70.0)	0.161
	Yes	14 (35.0)	10 (25.0)	24 (30.0)	

New neurological deficits occurred in 15% of patients in both groups ($P = 0.9$), suggesting similar neurological outcomes. AKI was rare, reported in 10% of the Mannitol group and 7.5% of the HS

group (P = 0.712). Most patients had an intensive care unit (ICU) stay of ≤24 h, with a slightly higher rate in the HS group (75.0%) compared to Mannitol (60.0%) (P = 0.465). In addition, a greater proportion of patients in the HS group were extubated in the operating room (65.0% vs. 45.0%), though this difference did not reach statistical significance (P = 0.371) [Table 6].

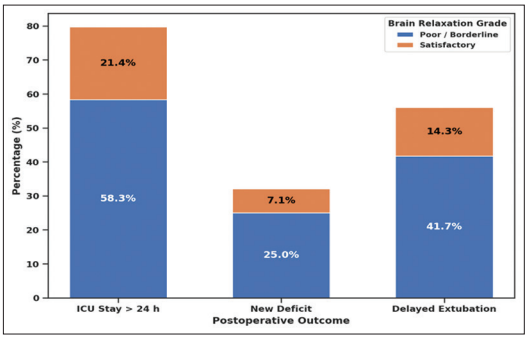

Figure 3: Stacked bar chart: Brain relaxation grade versus post-operative outcomes. The stacked bar chart illustrates the relationship between brain relaxation grade and immediate post-operative outcomes among 80 patients. Those with a poor or borderline brain relaxation grade demonstrated substantially higher rates of adverse outcomes compared to patients with a satisfactory relaxation grade. Specifically, intensive care unit (ICU) stay exceeding 24 h occurred in 58.3% of the poor/borderline group versus 21.4% of the satisfactory group, while new post-operative neurological deficits were observed in 25.0% compared to 7.1%, respectively. Similarly, delayed extubation was more frequent in the poor/borderline group (41.7%) compared to the satisfactory group (14.3%). Collectively, these findings indicate that suboptimal intraoperative brain relaxation is associated with a higher incidence of early post-operative complications, including prolonged ICU stay and delayed recovery of neurological and respiratory function, with a statistically significant overall association (P = 0.016) [Figure 3]

The analysis revealed that the use of HS and maintenance of CPP ≥60 mmHg were significant positive predictors. HS use was associated with a 3.46-fold higher likelihood of achieving satisfactory brain relaxation (P = 0.025), while maintaining CPP ≥60 mmHg increased the odds nearly fourfold (odds ratio [OR] = 3.90, P = 0.018). Conversely, the occurrence of ICP spikes ≥20 mmHg significantly reduced the likelihood of satisfactory brain relaxation (OR = 0.33, P = 0.037). Although CSF drainage showed a positive trend toward improved relaxation (OR = 2.32), it did not reach statistical significance (P = 0.071). Serum sodium >150 mmol/L had no significant effect (P = 0.248) [Table 7].

Discussion

Our findings demonstrate that intraoperative HS is highly effective for brain relaxation, with 80% of patients achieving satisfactory relaxation versus 60% with mannitol (P = 0.027). This aligns with evidence indicating HS is at least as effective as, if not superior to, mannitol for achieving a "slack" brain during craniotomy.[15-17] A meta-analysis of randomized trials (468 patients) found HS significantly increased the odds of satisfactory brain relaxation (OR ≈ 2.25) and modestly lowered peak ICP compared to mannitol.[16] Similarly, a 2024 systematic review (13 RCTs, 965 patients)

Table 6: Post-operative outcomes of both groups

Variable	Category	Mannitol (n=40) (%)	Hypertonic Saline (n=40) (%)	Total (n=80)	P-value
New neuro deficit	No	34 (85.0)	34 (85.0)	68 (85.0)	0.9
	Yes	6 (15.0)	6 (15.0)	12 (15.0)	
AKI	No	36 (90.0)	37 (92.5)	73 (91.2)	0.712
	Yes	4 (10.0)	3 (7.5)	7 (8.8)	
ICU stay	≤24 h	24 (60.0)	30 (75.0)	54 (67.5)	0.465
	>24 h	16 (40.0)	10 (25.0)	26 (32.5)	
Extubated in OR	No	22 (55.0)	14 (35.0)	36 (45.0)	0.371
	Yes	18 (45.0)	26 (65.0)	44 (55.0)	

AKI: Acute kidney injury, ICU: Intensive care unit, OR: Odds ratio

Table 7: Binary logistic regression for predictors of satisfactory brain relaxation

Predictor variable	β Coefficient	Adjusted OR (95% CI)	*P*-value
Hypertonic saline use	+1.24	3.46 (1.18–10.15)	0.025
CPP ≥60 mmHg	+1.36	3.90 (1.29–11.81)	0.018
ICP spikes ≥20 mmHg	−1.12	0.33 (0.11–0.92)	0.037
CSF drainage applied	+0.84	2.32 (0.91–5.91)	0.071
Serum Na^+ >150 mmol/L	−0.56	0.57 (0.18–1.78)	0.248
Constant	-	-	0.001

ICP: Intracranial pressure, CPP: Cerebral perfusion pressure, OR: Odds ratio, CI: Confidence interval, CSF: Cerebrospinal fluid

concluded that equiosmolar HS provides better brain relaxation and superior sodium balance.[13] Fang *et al*. reported HS roughly doubled the likelihood of good brain relaxation (OR ≈ 2.05) relative to mannitol.[18] These results support our observation that HS produced fewer "tight" brains at dural opening. However, not all studies found superiority. Raghava *et al*. reported statistically equivalent relaxation between equiosmolar 3% HS and 20% mannitol.[17] Hernández-Palazón *et al*. similarly found no difference in patients with mass effect.[6] A 2025 RCT also observed comparable outcomes when HS and mannitol were administered in equivalent doses.[15] Such discrepancies may reflect variations in dosing, baseline ICP, or small sample sizes. Smaller single-center trials often found equivalence,[6,17] while meta-analyses pooling larger datasets revealed modest but significant advantages for HS.[13,16,18] The timing of osmotherapy and the severity of intracranial hypertension also influence results. Nonetheless, our data support the broader consensus that HS provides superior or at least comparable intraoperative relaxation with additional physiological advantages. A major determinant of brain relaxation quality is the balance between ICP reduction and CPP maintenance. In our study, ICP spikes ≥20 mmHg were significantly less frequent with HS (30% vs. 50%, $P = 0.012$), and CPP ≥60 mmHg was maintained more often (85% vs. 70%, $P = 0.002$). This aligns with prior work showing HS produces a more sustained ICP reduction and greater CPP improvement than mannitol.[19] Meta-analyses in traumatic brain injury also report that HS prolongs ICP control and enhances CPP.[19] Our logistic regression identified CPP ≥60 mmHg as a strong predictor of satisfactory brain relaxation (OR ≈ 3.9), highlighting the central role of perfusion-oriented management. HS's osmotic and volume-expanding effects likely contribute to this benefit, as it increases intravascular volume and MAP.[20,21] Prior studies found HS associated with higher intraoperative MAP compared to mannitol.[21] Although our data showed a non-significant trend toward less hypotension with HS, the overall hemodynamic profile was superior. Mannitol, being a potent diuretic, can induce volume depletion and hypotension, lowering CPP.[20] Our results and previous studies indicate HS better "balances the scales" by lowering ICP without compromising systemic perfusion. We also note that while hyperventilation was used in nearly half of our cases, excessive reduction in $PaCO_2$ can risk cerebral vasoconstriction. Therefore, osmotherapy that preserves perfusion without aggressive hyperventilation, as seen with HS, is advantageous.[22] Each agent's side-effect profile was consistent with known pharmacodynamics. Mannitol caused greater diuresis (>1000 mL in 55% vs. 35% with HS), paralleling other reports.[17,18] Such diuresis can precipitate hypotension and electrolyte shifts. Conversely, HS induced transient hypernatremia (>150 mmol/L in 30% vs. 10% with mannitol, $P = 0.003$), an expected and generally benign finding. Fang *et al*. reported an average Na rise of 7–8 mmol/L with HS.[18] Importantly, our patients tolerated this without adverse neurologic or renal sequelae, consistent with reports that single-dose HS (3–5 mL/kg of 3%) rarely causes clinically significant side effects.[21] Metabolic acidosis and AKI were rare and similar between groups, paralleling other trials.[6,15,20] Previous work suggests that toxicity from mannitol (e.g., renal dysfunction, rebound ICP) occurs mainly with repeated or excessive dosing.[19] Our study confirms that single moderate doses of either

agent are safe. Neurological outcomes were also comparable, consistent with trials showing similar post-operative status, ICU duration, and mortality between HS and mannitol cohorts.[6,15,20] Overall, both agents are safe, but HS confers greater hemodynamic stability and less diuresis, which are valuable advantages intraoperatively. These findings reinforce that HS is an effective, hemodynamically favorable osmotherapy for brain relaxation during supratentorial craniotomy. It provides efficient ICP control and CPP preservation without compromising electrolyte or renal balance. Thus, HS may be preferred in patients at risk of hypotension or volume depletion. The strong predictive role of CPP ≥60 mmHg supports a perfusion-focused approach, integrating ICP reduction with hemodynamic optimization.[21,22] Using HS may facilitate extubation in the operating room and shorter ICU stays, as our data suggested trends in this direction, consistent with reports by Hernández-Palazón *et al*.[6]

Limitations of the study

This single-center study had a modest sample size, which may limit generalizability. Brain relaxation assessment relied partly on subjective surgeon evaluation, introducing possible bias. Variations in anesthetic management and surgical technique could have affected outcomes. Post-operative sodium and osmolarity were not tracked, and long-term neurological results were not assessed.

Conclusion

In adult patients undergoing elective supratentorial craniotomy, HS provided more effective intraoperative brain relaxation than mannitol, with fewer ICP spikes and better maintenance of CPP. It also showed greater hemodynamic stability and comparable safety. These results suggest that HS offers a reliable and physiologically balanced alternative to mannitol for achieving optimal surgical conditions while preserving cerebral perfusion. Integrating HS into intraoperative management protocols may enhance surgical efficiency and patient outcomes, though larger multicenter trials are warranted to confirm these benefits.

Recommendations

Based on this study's findings, HS should be considered the preferred osmotherapy for achieving intraoperative brain relaxation during elective supratentorial craniotomy, particularly in patients where maintaining cerebral perfusion and hemodynamic stability is crucial. Anesthetic teams should integrate HS into standardized brain relaxation protocols, accompanied by careful monitoring of serum sodium and osmolarity. Mannitol remains a viable alternative when hypernatremia or fluid overload are concerns. Future research should focus on optimizing dosing strategies, evaluating continuous infusion protocols, and exploring long-term neurological and recovery outcomes across diverse neurosurgical populations.

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Conflict of Interest

None declared.

Ethical Approval

The study was approved by the Institutional Ethics Committee.

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