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Perioperative Management of Pediatric Brain Tumors: A Retrospective Analysis

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Abstract

Background: Brain tumors are the second most common malignancy in childhood and the surgical excision remains the cornerstone of management. The objective of this study was to analyze the factors associated with the length of intensive care unit (ICU) and hospital stay, and postoperative outcome in such children. **Materials and Methods:** Three years of data were collected, retrospectively, by detailed review of medical records pertaining to pre-anesthetic evaluation and perioperative course of children less than 16 years of age who underwent excision of intracranial tumors. **Results:** One hundred sixty-eight medical records were analyzed. One third of the children were found to have developed various intraoperative adverse events; the most common were hemodynamic changes following brainstem handling and brain swelling. 58% of children required postoperative mechanical ventilation. 82.7% of patients had favorable neurologic outcome which was comparable between the two tumor locations (supratentorial vs infratentorial). On multivariate analysis, re-exploration surgery and electrolyte disturbances, such as serum sodium, were found to be the independent risk factors affecting hospital stay. The amount of intraoperative blood loss and postoperative pulmonary complications (POPCs) were independent risk factors affecting the neurologic outcome. **Conclusions:** Adverse events are fairly common after excision of brain tumors in children. Intraoperative complications did not affect the ICU stay or neurological outcome; however, the postoperative complications increased length of ICU and hospital stays. POPC was the single most important factor responsible for poor neurologic outcome and was more so in children who underwent infratentorial surgery, prolonged mechanical ventilation, and who had a lower cranial nerve palsy.

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Full Text

Brain tumors are the second most common malignancies in childhood,[1] constituting approximately 35% of all childhood malignancies. They remain as the leading cause of cancer-related deaths in children.[2] Surgical resection is the cornerstone of management which can be achieved with the restoration of cerebral spinal fluid (CSF) circulation by facilitating drainage, often as the first step. The neurosurgical procedures carry significant risks and potential morbidity. The perioperative complications may be related to tumor pathology, surgical approaches, intraoperative patient positioning, apart from the effect of anesthetics. A large volume of literature is available with regard to perioperative complications in adults with intracranial tumors. However, such data in relation to children are scarce. Hence, in this study, we aimed to assess the perioperative complications occurring in children who underwent excision of intracranial tumors and the effect of such complications on duration of hospital stay, intensive care unit (ICU) stay, and Glasgow outcome scale (GOS) score.

Materials and Methods

After approval from the Institute Ethics Committee, available medical records of children (aged less than 16 years) who underwent excision of intracranial tumors between January 2012 and January 2015, in our center, were analyzed. For each child, data was collected by detailed review of medical records pertaining to pre-anesthetic evaluation, intraoperative and postoperative course. Preoperative data included age, sex, weight, clinical symptoms, size, type and location of tumors, presence of midline shift and hydrocephalus (based on standard imaging criteria), presence of lower cranial nerve (LCN) involvement and the need for ventriculoperitoneal (VP) shunt. Intraoperative data related to surgical procedure, anesthetic techniques and adverse events such as blood loss, fluid and blood transfusion, brain swelling (protrusion of brain beyond the level of the dura) and the duration of surgery were noted. Postoperative data included duration of ICU and hospital stay, complications like re-exploration, postoperative pulmonary complications (POPCs) presence of hematomas on imaging after surgery, meningitis, seizures, hemodynamic fluctuations, electrolyte imbalances, presence of neurological deficits, and GOS score at the time of discharge. A GOS score of 1–2 was considered as good, whereas a score of 3–5 was considered as poor outcome. The POPC was defined as any postoperative pulmonary alteration such as atelectasis, hospital- or ventilator-acquired pneumonia, pneumothorax, bronchospasm, weaning failure or reintubation, and acute respiratory distress syndrome (ARDS) which could affect the patient outcome.

Anesthetic Technique: A standard anesthetic protocol was followed for all children. Induction of anesthesia was done by either intravenous (IV) or inhalational technique, depending on the presence or absence of an IV cannula. Anesthesia was induced with fentanyl 2 μg/kg, propofol 2–2.5 mg/kg or thiopentone 5 mg/kg or sevoflurane in 100% oxygen and rocuronium to facilitate tracheal intubation. Anesthesia was maintained with O_2:N_2O (40:60), and isoflurane, sevoflurane, or desflurane with minimum alveolar concentration (MAC) of 0.8–1.2 and intermittent boluses of rocuronium and fentanyl. N_2O was used in all children; however, it was discontinued when venous air embolism (VAE) was suspected in children who underwent sitting craniotomy. The children were mechanically ventilated without positive end-expiratory pressure (PEEP) to maintain hypo-to-normocapnia. Monitoring modalities included heart rate, electrocardiogram (ECG), pulse oximetry (SpO_2), invasive blood pressure, central venous pressure (CVP), end tidal carbon dioxide ($EtCO_2$), MAC for gases, temperature, and urine output. Central venous catheter (CVC) was inserted in cases where massive blood loss, VAE, or prolonged ICU stay was anticipated. At the end of the surgery, the trachea was extubated in the operating room (OR), else they were mechanically ventilated with further monitoring, in the ICU.

Statistical analysis was done using STATA 9.0 (College Station, TX, USA) software. Data is expressed as mean ± SD or number (percentage). The Chi-squared test, Mann–Whitney U test and Spearman's rank correlation coefficient was used to assess the strength of association between continuous factors and hospital and ICU stay, GOS, and mortality; and categorical factors were tested with hospital, ICU stay, GOS and mortality using Wilcoxon rank sum test or Fischer's exact test. For factors effecting hospital stay and GOS, a stepwise multivariate analysis with $P = 0.05$ at entry and $P = 0.10$ at removal was carried out. A P value < 0.05 was considered statistically significant.

Results

During the three-year study period, a total of 179 children underwent surgery for intracranial tumors. Data from 167 medical records were analyzed due to incomplete information in rest of the children. The mean age of presentation was 9.8 years (Range: 2 months to 16 years) with a slight male preponderance [Table 1]. Tumor was located in the supratentorial compartment in 90 children versus 77 in the infratentorial region. One hundred fifty-nine (95%) presented with mass effect, 118 (70.6%) with hydrocephalus (44 supratentorial vs 74 infratentorial tumors); 26 children (15.5%) had significant (more than 5 mm) midline shift; 73 children with supratentorial and 46 with infratentorial tumors presented with at least one neurological deficit. LCN palsy was seen in 16 children in the infratentorial group (20%) versus 5 in the supratentorial group (5.5%). Eighty-eight children underwent preoperative CSF diversion procedures for obstructive hydrocephalus. None of the children were presented with the complications of intratumoral hemorrhage or reverse herniation due to CSF diversions.{Table 1}

The most common induction agent for anesthesia was propofol followed by sevoflurane [Table 2]. Anesthesia was maintained with sevoflurane (155), isoflurane (7), desflurane (2), and propofol (3) along with oxygen and N2O mixture. CVC was inserted in 153 children (91%). Most of the children were operated in horizontal (supine, prone or lateral) position (90%); 16 underwent sitting craniotomy. The mean blood loss was 25 ± 23 ml/kg; average being 18 ml/kg in supratentorial tumors [Range 50–5000 ml]; and 14 ml/kg in infratentorial tumors [Range 100–2500 ml]. Massive blood loss of more than 40% of calculated blood volume (CBV) was seen in 39 children; 73 children (43%) required transfusion of packed red blood cells (PRBCs) and blood products [Table 2]. Twenty out of 73 children who required PRBCs transfusion were also transfused with fresh frozen plasma (FFP) and platelets. Massive transfusion (>40 ml/kg) was required in 12 patients. Perioperatively, fluids used were crystalloids with colloid boluses at the time of hypotension associated with blood loss. The average fluid requirements in the craniotomies were 93 ml/kg with the rate of fluid administration at 24 ± 11.5 ml/kg/hour. Most common tumor pathologies associated with massive blood loss were ependymomas followed by meduloblastomas and pilocytic astrocytomas. Fifty-five children (33%) developed various intraoperative complications [Table 3]; the most common were brain stem handling, brain swelling, massive blood loss, and VAE. Two children required inotropic support for hypotension; and post-extubation seizure occurred in one child. Postoperatively, 58% of children required mechanical ventilation with the common indication being brainstem handling and massive blood loss [Table 4].{Table 2}{Table 3}{Table 4}

Serum sodium disturbances were common postoperative complications in these children [Table 3]. Other complications like POPC, re-exploration surgery and new onset neurological deficit are as described in [Table 3]. The number of children requiring a second surgery was 6.6% (7.78% and 3.89% in supra and infratentorial surgeries, respectively). The most common indication was CSF diversion procedure in children having CSF leak, persistent hydrocephalus and shunt malfunction. Two cases underwent emergency decompression craniectomy. The incidence of existing and aggravated neurological deficits, POPCs, sepsis, hydrocephalus, and pneumocephalus was significantly higher after infratentorial tumor excisions. The mean duration of postoperative mechanical ventilation, ICU and hospital stay was 2.6, 5 and 12 days, respectively; they were affected by presence of postoperative complications. The factors affecting the ICU and hospital stay and GOSM were analyzed using univariate and multivariate analyses. Except for the duration of mechanical ventilation, which was significantly higher after infratentorial craniotomy [Table 5], all other outcome variables such as ICU stay, hospital stay, and GOS were comparable after the supra and infratentorial craniotomies.{Table 5}

On univariate analysis, massive blood loss, re-exploration surgery, sodium disturbances, and POPCs were found to be the risk factors affecting hospital stay [Table 6]. However, on multivariate analysis, re-exploration surgery and sodium disturbances were observed to be the independent risk factors [Table 7]. Similarly, presence of LCN palsy, massive blood loss, brainstem handling, re-exploration surgery, presence of sodium disturbances and POPCs were identified as risk factors of extended ICU stay; the re-exploration surgery was found to have an independent correlation on multivariate analysis.{Table 6}

Out of 90 patients in the supratentorial group, 78 patients had favorable and 12 had unfavorable GOSM, and in the infratentorial group, 63 children out of 77 had favorable outcomes. There was no significant difference in between the two tumor groups in terms of neurological outcome. Intraoperative massive blood loss and POPCs were found to be the independent risk factors affecting the neurologic outcome as measured by GOSM [Table 6] and [Table 7]. The incidence of mortality in this study was 3%; the most common causes were sepsis, hypothalamic and brainstem dysfunction with a 'longer duration of disease' being the single most important predictor of mortality.{Table 7}

Discussion

In this study, the influence of perioperative factors on hospital stay and neurological outcome at the time of hospital discharge were observed. Various intraoperative events affected the perioperative course of these children.

Brain stem handling was the most common intraoperative event and was observed commonly in cerebello-pontine angle (6%), skull base tumors (3%), and fourth ventricular tumors. Episodes of sudden bradycardia with or without hypotension were noticed during the handling of brainstem. Previously, the central form of TCR was shown to play an important role affecting the functional outcome, mostly after adult skull base surgeries;[3]. However, the role of TCR in children is not well-defined. In this study, the TCR episodes were not associated with any effect on postoperative outcomes. These patients may need postoperative elective ventilation so that there is gradual recovery of cardio-respiratory centers and protective reflexes over a period of time.

Massive blood loss was the second most common event observed. Bhatnagar et al.[4] reported that 31% of neurosurgical patients, including both children and adults, require allogeneic blood transfusion during neurosurgery, more so, with pediatric brain tumors. As per the literature, pediatric craniotomies have been associated with massive blood loss as high as 650%.[5],[6],[7],[8] In our study, blood loss ranged from 3%–133% of circulating blood volume (CBV), with more than 100% blood loss occurring in five patients. Blood loss in the age group of 0–2 years ranged from 20%–78% of CBV. Hemodynamic instability requiring inotropic support was observed in two cases.

Brain swelling was another common complication that occurred in 13.6% of patients. The children were given additional doses of mannitol, volatile anesthetics were withdrawn, and total intravenous anesthesia (TIVA) was utilized, and hyperventilation was instituted to maintain $PaCO_2$ of 30–32 mmHg. Despite these measures, 18 children presented with tight brain at dural closure and postoperative ventilation planned. Three of these children underwent DC in the same sitting whereas four underwent DC during the postoperative period.

Venous air embolism was seen in 31% of cases operated in sitting position. All the incidents were diagnosed by sudden fall of $EtCO_2$ more than 2 mmHg. A lower incidence of VAE was reported previously.[9],[10],[11] One out of 16 (6.3%) cases had multiple events of VAE and was associated with hypotension. All five cases were seen in children >10 years of age. Relatively high dural sinus pressures in children as compared with adults[12] might be the reason for lower incidence of VAE in children.

The overall incidence of postoperative elective ventilation was quite high, in 97 (58%) patients. Fifty-eight were extubated within 24 h (median 16 h), another eight in 48 h, and seven during the next 48–72 h. The remaining 18 children (18.5%) underwent prolonged ventilation ranging from 7 to 30 days. Out of 90 children with supratentorial tumors, seven were subjected to prolonged ventilation (>7 days). Similarly, in the infratentorial group, 17 children out of 77 required ventilation for >7 days ($P = 0.008$). The most common causes of prolonged ventilation were POPCs (12), sepsis (5), a second surgery for hydrocephalus, brain edema, venous infarct and hematoma (5), meningitis (1), and hypothalamic dysfunction (1). Prolonged mechanical ventilation was attributed to ventilator-associated pneumonia (VAP) though there is not enough literature to suggest such an association in pediatric neurosurgical patients.[13]

The most common indication for elective ventilation was brainstem handling. However, 30 out of 41 patients who had significant brainstem response after manipulation were extubated uneventfully during first 48 h after surgery. The remaining 11 patients had postoperative LCN dysfunction, were tracheostomized, and required prolonged ventilation; all of them underwent surgery for infratentorial tumors. Similarly, preoperative LCN palsy was also an indication for elective ventilation in 10 patients, out of which seven required tracheostomy and three had VAP.

Presence of brain swelling at dural closure is at risk of developing into malignant brain edema. Postoperative edema may be severe in the presence of residual tumor due to autoregulatory failure inside tumor tissue.[14] It is considered prudent to electively ventilate such patients until the edema resolves.

Patients having massive blood loss or transfusion also require elective ventilation as they may cause hemodynamic instability and dilutional coagulopathy, which increases the risk of hematoma. Seven out of 15 patients who had massive blood loss were extubated within 48 h; the rest had prolonged yet insignificant ICU and hospital stay.

Delayed awakening was observed in four children (2.4%) after anesthetic overdose was ruled out. The two causes attributed to delayed awakening were brain edema on computed tomography (CT) scan and hypothalamic dysfunction (presence of temperature fluctuations and hemodynamic changes). These children were extubated in the ICU after ascertaining satisfactory awake state.

The morbidity rate in the form of postoperative complications was 51% in this study. Previous similar observations[15],[16],[17] in pediatric neurosurgery suggested complications in the range of 30%–70%. The difference in the morbidity rates could be due to different definitions of complications, duration of observation adapted apart from the quality of surgery offered in different studies.

Postoperative seizures portend a poor outcome. The incidence in our study was about 2.4%, occurring almost equally in children who underwent either supra or infratentorial surgeries.

Sodium disturbance was another common complication seen in this study with an incidence of 16.7%. It occurred commonly in children operated for craniopharyngioma, pituitary adenoma, and ependymoma; the incidence of sodium and water imbalance in craniopharyngioma was 59% with hyponatremia being the commonest finding. Hyponatremia among children undergoing surgery for brain tumors is more common with young age, tumor located deep or spread to multiple locations (medulloblastoma), and those with hydrocephalus.[18],[19] In our study, the strongest intraoperative predictor for sodium disturbances was massive blood loss (LR 7.2, $P = 0.04$) which could be due to massive fluid shifts and the ensuing changes in serum osmolality. Belzer et al.[20] found an incidence of 55% for hyponatremia in patients undergoing first surgery for intracranial neoplasms, with a time pattern in between days 0 and 1 and days 5 and 6, postoperatively. Hyponatremia has been associated with increased morbidity in children.[20] In our study, eight out of 44 children (18%) who underwent primary resection for craniopharyngioma had a triphasic response of diabetes insipidus (DI) and hyponatremia, which is similar to that of adult data reported.[21],[22],[23]

POPCs are frequent in the early post-craniotomy period with an incidence of 23% in adults. They manifest as pneumonia, bronchitis, atelectasis and respiratory failure.[24] The incidence in this study was 8.4% (3.3% supratentorial vs 18% infratentorial). The most important predictor of POPCs was preoperative LCN palsy (LR = 3.4, $P = 0.05$). Out of the 46 patients with intraoperative brain stem handling, four developed POPCs; and six out of 21 patients with a drop in postoperative GCS had developed POPCs.

New-onset neurological deficit at discharge was seen in 15.5% of children (4% supratentorial vs 28.5% infratentorial surgery). Neurological complications have been reported to be much higher in children, in the range of 36%–54% (in infants).[25],[26] In our study, neurological complications occurred in the form of weakness in one or more limbs, LCN palsies, oculomotor weakness, vision loss and mutism. The importance of these deficits should be weighed against the benefits of radical excision of tumors. There is now convincing evidence that a greater extent of excision improves survival in most of the children with brain tumors (e.g., ependymoma),[27],[28] and hence, obviates the need of adjuvant radiotherapy. Twenty of them required postoperative ventilation, 19 stayed in ICU beyond 72 h, and 25 of them had a hospital stay of >7 days.

Meningitis, though not common, is a dreaded complication, observed in 4.8% in this series; four of them were due to shunt infection (50%). This finding was also similar to that by Drake et al.,[16] who observed meningitis after shunt infection in 58% of cases. There is good evidence that prophylactic antibiotics can reduce the incidence of meningitis, which remains >5% in most pediatric centers despite usage.[29] CSF leakage is a significant risk factor of shunt infection; therefore, meticulous attention should be paid for wound closure.[30] The other factors like presence of preoperative hydrocephalus without CSF diversion in posterior fossa tumors, development of intraventricular hemorrhage leading to hydrocephalus, and surgical site infection also lead to CSF leak.

The most common indication for a second surgery was CSF diversion procedure in children having CSF leak, persistent hydrocephalus and shunt malfunction. Two cases underwent emergency DC. Lindert et al.[17] found CSF disturbances to be the most common cause (50%) for a second surgery in pediatric neurosurgical patients.

The GOS was found to be significantly associated with massive blood loss during the intraoperative period, and also, on the incidence of POPCs, which was an independent factor for predicting the GOS. Similar findings were reported by Bharti et al.[31] Factors such as massive blood loss, sodium imbalances, re-exploration surgery, and POPCs were significantly associated with increased hospital stay; however, on multivariate analysis, sodium imbalances and re-exploration were found to be independent predictors of increased length of hospital stay in our study.

Surgical mortality in patients (aged 0–18 years) with brain tumors vary greatly (Range 0–20%).[32],[33],[34],[35] In our study, it was 3%. The common causes were postoperative sepsis and DIC in two children, hypothalamic dysfunction in two cases of craniopharyngioma, and brain stem dysfunction in one. No mortality was noticed in the age group of less than 2 years.

Conclusions

Perioperative complications are common in pediatric neurosurgical patients. Anticipation and timely intervention of such events can improve mortality and morbidity. In our study, the most common intraoperative complications were brainstem handling and brain swelling; however, none of them had any effect on hospital and ICU stay or GOS scores. In the postoperative period, sodium disturbances and pulmonary complication were the two most significant factors for extended ICU and hospital stay. Occurrence of POPCs significantly affected the neurological outcome of children in terms of GOS scores. Preoperative LCN palsy was the single most important predictor VAP. The duration of postoperative ventilation was significantly higher in children undergoing excision of infratentorial tumors. This study was limited by its retrospective nature apart from exclusion of the emergency cases; hence, further prospective studies are required to validate the above conclusions.

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Conflicts of interest

There are no conflicts of interest.

References

1 Rosemberg S, Fujiwara D. Epidemiology of pediatric tumors of the nervous system according to the WHO 2000 classification: A report of 1,195 cases from a single institution. Childs Nerv Syst 2005;21:940-4.

2 Jemal A, Siegel R, Ward E, Murray T, Xu J, Smigal C, *et al*. Cancer statistics. Cancer J Clin 2006;56:106-30.

3 Singh GP, Chowdhury T. Brain and heart connections: The trigeminocardiac reflex! J Neuroanaesthesiol Crit Care 2017;4:71-7.

4 Bhatnagar S, Udaya B, Rao GS. An audit of blood transfusion in elective neurosurgery. Indian J Anaesth 2007;51:200-4.

5 Buchbinder D, Danielpour M, Yong WH, Salamon N, Lasky J. Treatment of atypical central neurocytoma in a child with high dose chemotherapy and autologous stem cell rescue. J Neurooncol 2010;97:429-37.

6 Pencalet P, Sainte-Rose C, Lellouch-Tubiana A, Kalifa C, Brunelle F, Sgouros S, *et al*. Papillomas and carcinomas of the choroid plexus in children. J Neurosurg 1998;88:521-8.

7 Due-Tonnesen B, Helseth E, Skullerud K, Lundar T. Choroid plexus tumors in children and young adults: Report of 16 consecutive cases. Childs Nerv Syst 2001;17:252-6.

8 Matuev KB, Gorelishev SK, LubninA Yu, Lemeneva NV, Sorokin VS. Blood loss in surgery of brain tumors in infants. Zh Vopr Neirokhir Im N N Burdenko 2013;77:3-15; discussion 15.

9 Cucchiara RF, Bowers B. Air embolism in children undergoing suboccipital craniotomy. Anesthesiology 1982;57:338-9.

10 Meyer PG, Cuttaree H, Charron B, Jarreau MM, Perie AC, Sainte Rose C. Prevention of venous air embolism in pediatric neurosurgical procedures performed in the sitting position by combined use of MAST suit and PEEP. Br J Anaesth 1994;73:795-800.

11 Fuchs G, Schwarz G, Stein J, Kaltenbock F, Baumgartner A, Oberbauer RW. Doppler color flow imaging: Screening of a patent foramen ovale in children scheduled for neurosurgery in the sitting position. J Neurosurg Anesthesiol 1998;10:5-9.

12 Iwabuchi T, Sobata E, Ebina K, Tsubakisaka H, Takiguchi M. Dural sinus pressure: various aspects in human brain surgery in children and adults. Am J Physiol 1986;250:389-96.

13 Bui JQ, Mendis RL, van Gelder JM, Sheridan MM, Wright KM, Jaeger M. Is postoperative intensive care unit admission a prerequisite for elective craniotomy? J Neurosurg 2011;111:1236-41.

14 Sharma D, Bithal PK, Chouhan RS, Sookplung V, Vavilala MS. Cerebral autoregulation and CO2 reactivity before and after elective supratentorial tumor resection. J Neurosurg Anesthesiol 2010;22;132-7.

15 Neervoort FW, Van Ouwerkerk WJ, Folkersma H, Kaspers GJ, Vandertop WP. Surgical morbidity and mortality of pediatric brain tumors: A single center audit. Child Nerv Syst 2010;26:1583-92.

16 Drake JM, Riva-Cambrin J, Jea A, Auguste K, Tamber M, Lamberti-Pasculli M. Prospective surveillance of complications in a pediatric neurosurgery unit. J Neurosurg Pediatr 2010;5:544-8.

17 van Lindert EJ, Arts S, Blok LM, Hendriks MP, Tielens L, van Bilsen M, *et al*. Intraoperative complications in pediatric neurosurgery: Review of 1807 cases. J Neurosurg Pediatr 2016;18:363-71.

18 Williams CN, Belzer JS, Riva-Cambrin J, Presson AP, Bratton SP. The incidence of postoperative hyponatremia and associated neurological sequelae in children with intracranial neoplasms. J Neurosurg Pediatr 2014;13:283-90.

19 Williams C, Simon TD, Riva-Cambrin J, Bratton SL. Hyponatremia with intracranial malignant tumor resection in children. J Neurosurg Pediatr 2012;9:524-9.

20 Belzer JS, Williams MD, Cydni N, Riva-Cambrin J, Presson AB, Susan L. Timing, duration, and severity of hyponatremia following pediatric brain tumor surgery. Pediatr Crit Care Med 2014;15:456-63.

21 Hensen J, Henig A, Fahlbusch R, Meyer M, Boehnert M, Buchfelder M. Prevalence, predictors and patterns of postoperative polyuria and hyponatremia in the immediate course after transsphenoidal surgery for pituitary adenomas. Clin Endocrinol (Oxf) 1999;50:431-9.

22 Kristof RA, Rother M, Neuloh G, Klingmuller D. Incidence, clinical manifestations, and course of water and electrolyte metabolism disturbances following transsphenoidal pituitary adenoma surgery: A prospective observational study. J Neurosurg 2009;111:555-62.

23 Finken MJ, Soonawala NZ, Walenkamp MJ, Vulsma T, van Trotsenburg P, Rotteveel J. Frequent occurrence of the triphasic response (diabetes insipidus/hyponatremia/diabetes insipidus) after surgery for craniopharyngioma in childhood. Horm Res Paediatr 2011;76:22-6.

24 Sogame LC, Vidotto MC, Jardim JR, Faresin SM. Incidence and risk factors for postoperative pulmonary complication in elective intracranial surgery. J Neurosurg 2008;109:222-7.

25 Sandri A, Sardi N, Genitori L, Giordano F, Peretta P, Basso ME, *et al*. Diffuse and focal brain stem tumors in childhood: Prognostic factors and surgical outcome. Childs Nerv Syst 2006;22:1127-35.

26 Young HK, Johnston H. Intracranial tumors in infants. J Child Neurol 2003;19:424-30.

27 Morris EB, Li C, Khan RB, Sanford RA, Boop F, Pinlac R, *et al*. Evolution of neurological impairment in pediatric infratentorial ependymoma patients. J Neurooncol 2009;94:391-8.

28 Sanford RA, Merchant TE, Zwienenberg-Lee M, Kun LE, Boop FA. Advances in surgical techniques for resection of childhood cerebellopontine angle ependymomas are key to survival. Childs Nerv Syst 2009;25:1229-40.

29 Akay KM, Izci Y, Baysefer A, Atabey C, Kismet E, Timurkaynak E. Surgical outcomes of cerebellar tumors in children. Pediatr Neurosurg 2004;40:220-5.

30 Albright AL, Pollack IF, Adelson PD, Solot JJ. Outcome data and analysis in pediatric neurosurgery. Neurosurgery 1999;45:101-6.

31 Bharati SJ, Pandia MP, Rath GP, Bithal PK, Dash HH. Respiratory complications in the early post-operative period following elective craniotomies. J Neuroanaesthesiol Crit Care 2015;2:114-20.
32 Sandri A, Sardi N, Genitori L, Giordano F, Peretta P, Basso ME, *et al*. Diffuse and focal brain stem tumors in childhood: Prognostic factors and surgical outcome. Childs Nerv Syst 2006;22:1127-35.
33 Sinson G, Sutton L, Yachnis A, Duhaime A, Schut L. Subependymal giant cell astrocytomas in children. Pediatr Neurosurg 1994;20:233-9.
34 Smith E, Butler W, Barker F. Craniotomy for resection of pediatric brain tumors in the United States, 1988 to 2000: Effects of provider caseloads and progressive centralization and specialization of care. Neurosurgery 2004;54:553-65.
35 O'Kane R, Mathew R, Kenny T, Stiller C, Chumas P. United Kingdom 30-day mortality rates after surgery for pediatric central nervous system tumors. J Neurosurg Pediatr 2013;12:227-34.

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Table 1: Demographic data

Patient Characteristics	Mean±SD/Number
Age (years)	9.8±4.3
Weight (kg)	30±7.5
Sex (Male: Female)	1.8:1
Location of tumors (supra vs infratentorial)	1.2:1
Preoperative parameters:	
Neurological deficits (*n*)	125
Lower cranial nerve (LCN) palsy	21
Hydrocephalus	118
Ventriculoperitoneal (VP) shunt in situ	88

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Table 2: Intraoperative management

Parameters	Number/ Percentage (%)/Mean±SD	Supratentorial Tumors	Infratentorial Tumors
Induction agent			
Propofol	131 (78)	61	70
Thiopentone	22 (13)	16	6
Sevoflurane	14 (9)	12	2
Central venous catheter (CVC) insertion			
IJV	82 (49)	56	26
SCV	71 (51)	25	46
Position			
Supine	79 (47)	79	0
Prone	63 (38)	1	47
Lateral	9 (5.3)	0	9
Sitting	16 (9.5)	0	16
Rate of Fluid Administration (ml/kg/hr)	24±11.5	26±13	23±8.4
Blood loss			
Mild-to-moderate (< 40% of CBV)	137 (77)	78	59
Massive (> 40%)	39 (23)	20	19
Duration of surgery (hours)	4.3±1.1	4.2±1.3	4.5±0.7
Tracheal extubation in the operating room			
Yes	70 (42)	50	20
No	97 (58)	40	57

IJV=Internal jugular vein; SCV=Subclavian vein; SD=Standard deviation; CBV=Calculated blood volume

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Table 3: Intra- and postoperative complications

Parameters	Number of Cases/Percentage (%)	Supratentorial (%)	Infratentorial (%)	*P*
Intraoperative Complications				
Brainstem handling	46 (27.3)	9 (10)	32 (42)	0.00*
Massive blood loss	39 (23)	20 (22)	19 (25)	0.85
Tight brain	23 (14)	16 (18)	7 (9)	0.12
Venous air embolism	5 (3)	0	5 (6.5)	0.02*
Seizures	1 (0.6)	1 (1.1)	0	1.00
Hemodynamic instability	2 (1.2)	1 (1.1)	1 (1.3)	1.00
Postoperative Complications				
Sodium disturbances	28 (16.7)	16 (18)	12 (16)	0.756
POPCs	17 (8.4)	3 (3.3)	14 (18)	0.203
Sepsis	5 (3)	0	5 (6.5)	0.02
Re-exploration	11 (6.6)	4 (4)	7 (9)	0.009
Neurologic deficit	26 (15)	4 (4)	22 (28.5)	0.00
Hydrocephalus	7 (4.2)	2 (2.2)	5 (6.5)	0.251
CSF leak	3 (1.8)	2 (2.2)	1 (1.3)	1.00
Meningitis	9 (5.3)	5 (5.5)	4 (5.1)	1.00
Pneumocephalus	7 (4.2)	0	7 (9)	0.004
Hypothalamic dysfunction	1 (0.6)	1 (1.1)	0	1.00
DVT	1 (0.6)	1 (1.1)	0	1.00
Seizures	4 (2.4)	2 (2.2)	2 (2.6)	1.00

CSF=Cerebrospinal fluid; DVT=Deep venous thrombosis; POPCs: Postoperative pulmonary complications

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Table 4: Indications for elective postoperative ventilation

Indication	Number of Cases/Percentage (%)
Tight brain	18 (18.5)
Brainstem handling	41 (42.2)
Massive blood loss	15 (15.4)
Delayed awakening	4 (4)
Poor gag reflex	10 (10)
Preoperative poor Glasgow coma scale (GCS) score	3 (3)
Respiratory problems	2 (2.1)
Hypothalamic involvement	4 (4.1)
Seizures	1 (1.1)
Hemodynamic instability	2 (2.06)
Venous air embolism	1 (1.03)

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Table 5: Postoperative outcome variables

Postoperative Outcome	Days/Score Mean±SD	Supratentorial Tumors	Infratentorial Tumors	*P*
Duration of postoperative mechanical ventilation (Days)	2.6±5.4	1.3±3.7	3.9±7	0.04*
Intensive care unit (ICU) stay (Days)	5.1±6.4	4.2±5.2	6.7±7.9	0.34
Hospital stay (Days)	12.7±16.1	9.3±7.1	11.9±8.3	0.12
Glasgow outcome scale (GOS) score	Good 139	79*	63*	0.16
	Poor 28	11**	16**	

*Good outcome: GOS 1-2** Poor outcome: GOS 3-5

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Table 6: Factors affecting modified Glasgow outcome scale (GOSM) score

Factors	GOS (Good)	GOS (Poor)	*P*
Rate of fluid administration			
<25 ml/kg/h	81	13	0.30
>25 ml/kg/h	57	15	
Induction agent (*n*)			
Propofol	111	19	0.21
Thiopentone	11	2	
Sevoflurane	16	7	
Position (*n*)			
Supine	65	10	0.53
Prone	53	15	
Lateral	6	1	
Sitting	14	2	
Massive blood loss (*n*)			
Yes	22	10	0.03*
No	116	18	
Massive blood transfusion (*n*)			
Yes	8	4	0.12
No	130	24	
Brainstem handling (*n*)			
Yes	37	9	0.64
No	101	19	
Re-exploration surgery (*n*)			
Yes	5	2	0.19
No	63	7	
Postoperative pulmonary complications (*n*)			
Yes	6	8	0.00*
No	132	20	

GOS: Poor: 3-5; Good: 1-2. *Statistically significant

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Table 7: Factors affecting hospital stay and modified Glasgow outcome scale (GOSM) score on multivariate analysis

Factors	Odds Ratio	95% CI	*P*
Hospital Stay			
Sodium imbalances	14.3	0.7-27	0.04*
Re-exploration surgery	21	9-31	0.00*
Postoperative pulmonary complications	NS	NS	NS
Massive blood loss	NS	NS	NS
Modified Glasgow Outcome Scale (GOSM) Score			
Massive blood loss	2.5	0.9-6.6	0.05*
Postoperative pulmonary complications	8	2.4-26	0.00*

*Statistically significant