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Original Article

Neurophysiological factors associated with postoperative airway management complications after posterior fossa surgery in children

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Abstract: Objectives: The study aims were to explore whether perioperative changes in somatosensory evoked potentials (SEPs) and motor evoked potentials (MEPs) provide a reliable indicator for assessing postoperative airway management complications. Methods: The study was a retrospective analysis of patients under 18 years old who underwent posterior cranial fossa surgery between December 2019 and November 2023. Patient demographics, imaging data, surgical records, anesthesia records, neurophysiological data, and airway management complications were reviewed. The airway management complications included extubation failure, tracheostomy, and aspiration. The primary outcome of the study was the efficacy of perioperative changes in SEPs and MEPs for postoperative airway management complications. Results: A reduction in postoperative SEP amplitude was associated with postoperative airway management complications ($P = 0.018$). The combination of feasible preoperative SEP recording followed by a reduction in postoperative SEP amplitude emerged as a risk factor for complications related to postoperative airway management ($P = 0.007$). Patients with airway management complications had more days of intubation, and longer intensive care unit and hospital stays compared to negative patients. Conclusions: The combination of feasible preoperative SEP recording followed by a reduction in postoperative SEP amplitude was a significant risk factor for postoperative airway management complications.

Keywords: Evoked potentials, neuroanesthesia, pediatric anesthesia, airway management, posterior fossa tumors

Introduction

Central nervous system tumors are the most common solid tumors in children, with approximately 45% to 60% of intracranial tumors occurring in the infratentorial region (i.e., the posterior fossa) [1]. For the majority of posterior fossa tumors, surgical intervention is the preferred treatment modality. Despite this anatomic area constituting only 10% of total intracranial volume, it remains the leading cause of tumor-related mortality among children aged 0 to 14 years [1]. The posterior fossa has a complex anatomic structure that houses critical neural components, rendering surgical procedures highly risky. Furthermore, this brain region is crucial for major sensory and motor neural pathways such as the corticospinal tract and various sensory pathways responsible for the control of limb movements and sensory information transmission. Additionally, it plays an integral role in regulating consciousness, language processing, swallowing mechanisms, auditory perception, facial sensation, muscle coordination, and tongue functions [2]. However, damage to these vital structures during tumor resection may lead to cranial nerve dysfunction. Research indicates that postoperative complications are relatively common among patients with posterior fossa tumors; approximately one-third experience injuries to the lower cranial nerves [3]. These postopera-

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tive neurological impairments not only significantly diminish patient quality of life but may also worsen survival rates [1].

Over the past few decades, intraoperative neurophysiological monitoring (IONM) has become increasingly established as a crucial functional tool for posterior fossa surgery [4]. It not only facilitates a safe surgical entry zone to mitigate the risk of neurological deficits but also provides real-time insight into the functional integrity of neural pathways within the posterior fossa, thereby aiding in the prediction of neurological outcomes [5]. Common monitoring techniques of IONM include somatosensory evoked potentials (SEPs), motor evoked potentials (MEPs), brainstem auditory evoked potentials (BAEPs), and facial nerve monitoring. SEPs and MEPs are particularly important for evaluating the functional state of the brainstem during posterior fossa surgery. Relevant data have demonstrated the effect of electrophysiological monitoring in reducing the occurrence of conventional neurological complications [5]. However, at present, there is a lack of effective monitoring and early warning methods for airway complications, which makes it difficult to prevent and control them, and they still occur at an unacceptably high frequency.

Given the unique anatomic and physiologic characteristics of children, the risk of severe hypoxemia during the perioperative period is significantly higher in children than in adults [6]. It has been reported that approximately 5% of children experience severe peri-operative adverse events [7], among which respiratory-related adverse events account for 60%-75% of them [6]. Unplanned re-intubation may indicate serious postoperative complications related to the initial surgery or new medical complications, such as postoperative cardiopulmonary events [8, 9]. Failed extubation has been proven to be independently associated with a 5-fold increase in the risk of death in pediatric patients [10], and leads to an increased incidence of ventilator-associated pneumonia, a prolonged length of stay in the intensive care unit (ICU), and an extended hospital stay [11]. In addition, frequent re-intubation in children may cause long-term complications, including subglottic stenosis, palatoglossal and local airway injury [12]. Invasive procedures such as tracheotomy in children can cause irreversible damage and even put children in a permanent tracheotomy state. In children with posterior fossa lesions, airway complications such as difficulty in swallowing, choking, and coughing, which lead to difficult extubation and re-intubation, are all related to cranial nerve injury [13]. Whether the peri-operative changes in existing neuro-electrophysiological monitoring indicators can indicate in advance the risk of both airway related nerve injury and postoperative complications remains unknown. Revealing a relationship between the dynamic changes in electrophysiological monitoring and the risk of postoperative airway complications in patients would guide prediction of relevant risks and facilitate individualized postoperative airway management strategies.

Currently, there is a lack of reliable objective indicators in clinical practice to predict and identify the occurrence of postoperative airway related complications in children, such as failed extubation, tracheotomy, and aspiration. Therefore, the objectives of this study were to investigate whether the peri-operative changes in neuro-electrophysiological monitoring indicators such as SEPs and MEPs could predict the risk of airway related complications. The present study adopted a retrospective research design to explore relevant predictive indicators and risk assessment efficacy. Its aim was to maximize the postoperative airway safety of children by early detection and intervention for airway-related complications.

Patients and methods

Ethics approvals and registration

This was a single-center retrospective cohort study performed in accordance with the Helsinki Declaration. The protocol was approved by the Ethics Committee on Biomedical Research of the West China Hospital of Sichuan University on December 15, 2023 (No. 2331, 2023), and was registered at the China Clinical Trial Registry (ChiCTR2400081508, https://www.chictr.org.cn) on March 4, 2024. This study did not elicit any specific interventions and only retrospectively extracted clinical data from electronic medical records. Thus, exemption was provided from the need for informed consent from the patients or their guardians.

Patients

We conducted a retrospective analysis of all patients under 18 years of age who underwent posterior fossa surgery at West China Hospital of Sichuan University between December 2019 and November 2023. Data were extracted from the hospital's Electronic Medical Record system. Patients were included in the study if they met the following criteria: available pathology reports; high-quality preoperative magnetic resonance imaging (MRI) or computed tomography (CT) imaging; and complete and detailed electronic medical records. Exclusion criteria included: a history of prior posterior fossa tumor resection; dependence on tracheostomy; dysphagia or coughing after drinking water; a history of allergy to anesthetics; or surgical procedures involving endoscopic intraventricular, suboccipital transtentorial, or interhemispheric approaches, or biopsy-only cases. Additionally, all included patients had no history of mental illness, demonstrated good lung function and exhibited no respiratory infections prior to surgery. Patients were classified into two groups based on their postoperative outcomes. The "complication group" comprised those who experienced tracheostomy, re-intubation or aspiration during hospitalization after enrollment. The "no complications group" consisted of patients without any of the aforementioned complications.

Anesthesia procedure

The patients were strictly forbidden to drink or fast before surgery. No premedication was administered. Patients under 14 years of age were allowed to be accompanied by their parents until their consciousness disappeared. In the operation room, each patient was routinely monitored with electrocardiography and heart rate, non-invasive or invasive arterial blood pressure and pulse oximetry measurements; in addition, venous access was established. After having instituted standard monitoring and breathing of 100% oxygen, we adopted a total intravenous anesthesia program (TIVA). General anesthesia was induced with 2.5-3 mg/kg propofol, 0.05-0.1 mg/kg midazolam, 0.3 μg/kg sufentanil and 0.1 mg/kg cisatracurium, and maintained with an intravenous infusion of 200-300 μg/kg/min of propofol, and remifentanil and sufentanil were administered as required. All patients were intubated orally with a video laryngoscope. The sizes of tracheal tubes were selected according to each patient's age, based on the manufacturer's recommendations. The lungs were mechanically ventilated under a pressure-controlled mode to maintain an end-tidal CO_2 partial pressure ($P_{ET}CO_2$) of 30-40 mmHg. After induction of anesthesia, the metabolism of muscle relaxants was monitored using an accelerated muscle relaxant monitor (Neuromaster MEE-2000; Nihon Kohden). Muscle relaxants were not administered during surgery.

IONM

For patients undergoing posterior fossa surgery, SEPs are frequently measured to assess the integrity of the brainstem; usually SEPs of the upper limb are monitored [14]. The stimulation sites are typically located at the median nerve of the upper limb wrist (2 cm proximal to the transverse carpal ligament) or the ulnar nerve (at the transverse carpal ligament of the wrist flexor carpi ulnaris, or in the temporal ulnar groove). The stimulation used monophasic constant current, with an intensity of 2-3 times the threshold value (15-25 mA) and a frequency of 4.7-5.1 Hz. According to the 10-20 system established by the International Electroencephalography Society, recording electrodes and reference electrodes were positioned, and the upper limb SEPs recording leads C3-Fz and C4-Fz had a time window of 50 ms, with the averaging number being between 50 and 200 trials [15]. Traditional SEP alarm criterion is a 50% drop in its amplitude [5, 14]. All MEPs involved transcranial electrical stimulation, with the stimulation electrodes placed at C3-C4. The stimulation used monophasic or biphasic square waves, with an intensity of 80-200 V, a train of 5, 7 or 9 pulses, a pulse width of 0.2-0.5 ms and an inter-stimulus interval of 2-4 ms [16]. Recording electrodes were placed on the upper limb hand muscles (abductor pollicis brevis, abductor digiti minimi, interosseous dorsalis muscles) and lower limb anterior tibial and extensor hallucis longus muscles. The criteria for alarms were set as a 20% increase in the threshold of contralateral MEPs post-surgery, or a significant increase of 50% bilaterally compared to the preoperative values.

When the SEP and MEP monitoring alarms sounded, the surgeon immediately stopped the operation and only continued the operation after monitoring returned to normal. When the train-of-four stimulation (TOF) was carried out, measurements of the ulnar nerve in the right hand were > 0.75. The preoperative SEPs (Neuromaster MEE-2000; Nihon Kohden) and MEPs (Neuromaster MEE-2000; Nihon Kohden) were also recorded. When the mass was removed, postoperative SEPs and MEPs were measured.

Postoperative airway management

All patients included in this study were admitted to the ICU for postoperative observation and care. The patient's level of consciousness and ability to protect their airway were evaluated. If the patient showed improvement in either consciousness or airway protection, extubation was promptly performed, avoiding unnecessary deep sedation. The weaning protocol followed the European guidelines of weaning from mechanical ventilators [17]. A spontaneous breathing trial (SBT) is the major diagnostic test to determine whether patients can be successfully extubated, which should last 30 min [17]. All patients underwent a SBT with a Glasgow score (GCS) ≥ 8. Extubation failure was defined as post-extubation respiratory distress requiring reintubation within 48 h after extubation [18]. The reintubation indications were: (1) apnea and bradycardia; (2) increased work of breathing; (3) respiratory acidosis; (4) increased O_2 needs; or (5) upper airway obstruction [19]. Regarding the indications for tracheostomy, the following criteria were established: (1) low chance of definitive, spontaneous resolution within a reasonable time (weeks); (2) low probability that surgery can definitely correct the cause; (3) high risk of critical upper airway obstruction with simple respiratory tract infections or minor bleeding (epistaxis); (4) difficult-to-control gastro-esophageal reflux; (5) young age with a high risk of mid-facial deformation from mask pressure; (6) inability to cope with a mask (full face or nasal mask); or (7) recurrent aspirations (gastroesophageal reflux, laryngeal incompetence) with significant benefit from pulmonary toilet [20].

Data collection

Demographics, imaging data, surgical, anesthesia, nursing records and pathology reports were reviewed retrospectively. All records were de-identified and analyzed anonymously. The demographic data included age, sex and comorbidities. The surgery name and type, tumor size and histology, duration of surgery and surgery location were obtained from the surgical reports. The American Society of Anesthesiologists (ASA) physical status, infusion volume, and duration of anesthesia were obtained from the anesthesia records. The data of IONM, the airway management procedure and the complications (extubation failure, tracheostomy, aspiration, dysphagia and coughing after drinking water) were obtained from the patients' electronic medical records. The primary outcome of the study was the suggestive efficacy of perioperative changes in SEPs and MEPs for the detection of likely postoperative airway management complications.

Statistical analysis

Statistical analyses were performed using SPSS ver. 25 (SPSS, Chicago, Illinois, USA). All data from different groups were verified for normality and homogeneity of variance using Kolmogorov-Smirnov and Brown-Forsythe tests before analysis. Continuous variables are given as the median (interquartile range) and potential differences between groups were assessed using the Mann-Whitney U test. Categorical variables are presented as numbers (percentages) and differences between groups were compared using the Chi-square test or Fisher's exact test when appropriate. The variables of $P < 0.1$ in univariate analysis were selected for multivariate logistic regression analysis. A P-value < 0.05 (2-sided) was considered significant.

Propensity scores (PS) were computed as conditional probabilities using a logistic regression model that included baseline characteristics to achieve balance in covariates between the two groups. This was achieved using a neighbor matching algorithm with a caliper of 0.2 standard deviations. Patients were paired at a ratio of 1:4, meaning each patient who experienced postoperative airway management complica-

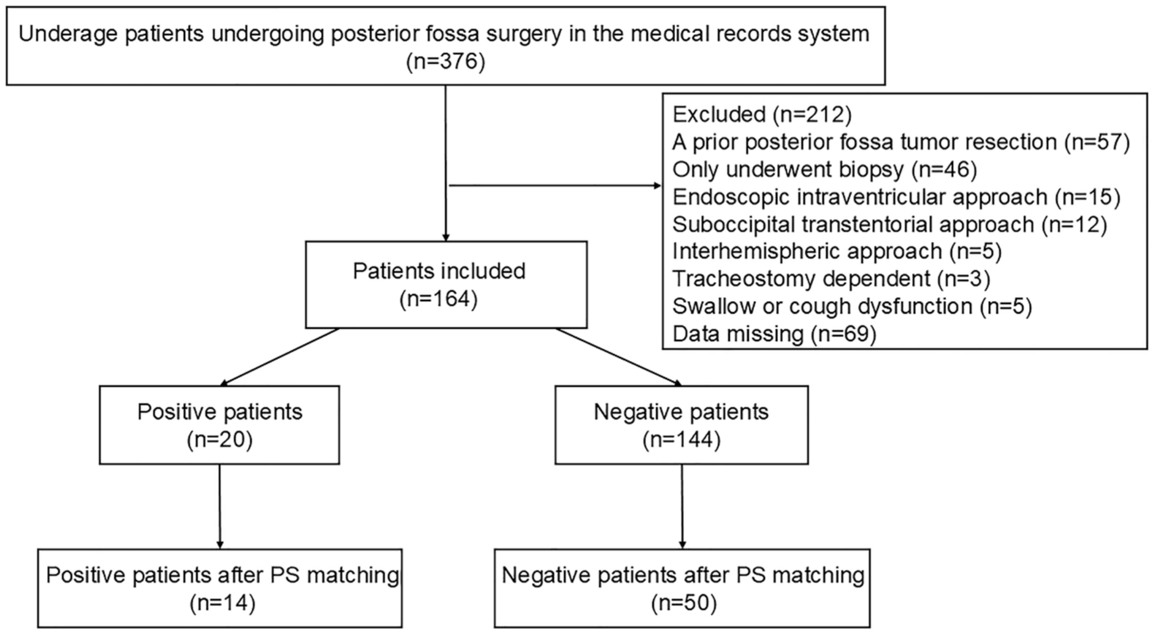

Figure 1. Flow chart of the study.

tions was matched with 4 patients who did not experience such complications.

Results

A total of 376 potentially eligible patients who underwent posterior fossa surgery were consider for enrollment. After excluding patients according to the exclusion criteria, 164 were enrolled of whom 20 patients were in the complications group and 144 were in the no complications group (**Figure 1**).

The general and clinical characteristics of the population are shown in **Table 1**. There were no significant differences in age, sex, ASA physical status, infusion volume, tumor size or histology, surgery type and location between the two groups. However, the surgery time [6.70 (4.07, 12.60) h *vs.* 4.42 (3.25, 5.97) h, $P = 0.004$] and anesthesia time [8.13 (5.81, 13.81) h *vs.* 5.77 (4.59, 7.33) h, $P = 0.004$] were significantly longer in the complications group compared to the no complications group. In order to determine whether surgical and anesthesia times were risk factors for postoperative airway management complications, multivariate logistic regression analysis was performed for factors with $P < 0.1$, and the results showed that neither the surgical time nor the anesthesia time were risk factors (Supplementary Table 1).

To adjust for potential confounding factors related to postoperative complications, we paired the cases by PS matching. In PS matching, 14 patients in the complications group were matched with 50 patients in the no complications group. Among the 14 patients in the complications group, there were 14 cases of postoperative reintubation, 3 cases of postoperative tracheostomy, and 1 case of reflux aspiration. In **Table 2**, the matched patient characteristics were compared and the baseline profiles were found to be comparable between the two groups. It is worth noting that there was no statistical difference in preoperative SEPs recording feasibility (before PS matching: $P = 0.561$, **Table 1**; after PS matching: $P = 0.485$, **Table 2**) or preoperative MEPs recording feasibility (before PS matching: $P = 0.302$, **Table 1**; after PS matching: $P = 0.299$, **Table 2**), before and after PS matching.

To determine whether IONM predicted occurrence of postoperative airway management complications in patients under 18 years old undergoing posterior fossa surgery, we analyzed both before and after PS matching cases. Similar to the results of the model before matching ($P < 0.001$), the postoperative SEP amplitude was reduced after PS matching ($P = 0.018$) and was also associated with postoperative airway management complications (**Table**

Table 1. Baseline characteristics between groups before PS matching

Variable	Complications group (n = 20)	No complications group (n = 144)	χ^2 or U value	*P* value
Age (months)	73.0 (37.5, 154.3)	79.0 (49.0, 133.8)	1424.500	0.938
Sex			0.101	0.751
Male	12 (60.00%)	81 (56.25%)		
Female	8 (40.00%)	63 (43.75%)		
ASA physical status			4.391	0.127
II	4 (20.00%)	34 (23.61%)		
III	14 (70.00%)	108 (75.00%)		
IV	2 (10.00%)	2 (1.39%)		
Surgery time (h)	6.70 (4.07, 12.60)	4.42 (3.25, 5.97)	871.000	0.004
Anesthesia time (h)	8.13 (5.81, 13.81)	5.77 (4.59, 7.33)	863.500	0.004
Fluid infusion volume (mL)	2350.0 (1062.5, 7235.0)	1700.0 (1160.0, 2700.0)	1159.500	0.159
Surgery type			0.293	0.483
Emergency surgery	1 (5.00%)	4 (2.78%)		
Selective surgery	19 (95.00%)	140 (97.22%)		
Tumor size (cm)	4.65 (3.65, 5.50)	4.45 (3.50, 5.30)	1319.500	0.545
Tumor histology			3.934	0.267
Glioma	5 (25.00%)	49 (34.03%)		
Ependymoma	6 (30.00%)	34 (23.61%)		
Medulloblastoma	2 (10.00%)	33 (22.92%)		
Others	7 (35.00%)	28 (19.44%)		
Location			5.046	0.240
Cerebellum (including vermis)	1 (5.00%)	34 (23.61%)		
Fourth ventricle	6 (30.00%)	45 (31.25%)		
Brainstem	9 (45.00%)	44 (30.56%)		
Cerebellopontine angle	2 (10.00%)	10 (6.94%)		
Pineal body	2 (10.00%)	11 (7.64%)		
Preoperative SEPs recording feasible			0.337	0.561
Yes	15 (75.00%)	116 (80.56%)		
No	5 (25.00%)	28 (19.44%)		
Preoperative MEPs recording feasible			0.894	0.302
Yes	18 (90.00%)	137 (95.14%)		
No	2 (10.00%)	7 (4.86%)		

Values are expressed as median (IQR) or numbers (percent). ASA, American Society of Anesthesiologists; PS, propensity scores.

3). However, the postoperative MEPs threshold increase (before PS matching: *P* = 0.626, after PS matching: *P* = 1.000, **Table 3**) did not predict likelihood of postoperative airway management complications.

Table 4 shows the combinations of IONM indicators, the corresponding risk ratios, and the *P*-values before and after PS matching. Before PS matching, it was found that the combination of feasible preoperative SEP recording followed by a reduction in postoperative SEP amplitude and the combination of feasible preoperative MEPs recording followed by an increase in the postoperative MEP threshold were both risk factors for postoperative airway management complications, which increased the likelihood of postoperative airway management complications by 77 times [odds ratio (OR) (95% CI) = 77.000 (8.784, 674.963), *P* < 0.001] and 5 times [OR (95% CI) = 5.000 (1.481, 16.875), *P* = 0.016], respectively. However, after PS matching, only the combination of feasible preoperative SEP recording followed

Table 2. Baseline characteristics between groups after PS matching

Variable	Complications group (n = 14)	No complications group (n = 50)	χ^2 or U value	*P* value
Age (months)	65.5 (22.5, 135.7)	72.5 (45.8, 138.5)	311.000	0.526
Sex			0.666	0.414
Male	9 (64.29%)	26 (52.00%)		
Female	5 (35.71%)	24 (48.00%)		
ASA physical status			1.575	0.454
II	2 (14.29%)	11 (22.00%)		
III	11 (78.57%)	38 (76.00%)		
IV	1 (7.14%)	1 (2.00%)		
Surgery time (h)	5.04 (3.55, 7.00)	5.13 (3.48, 6.25)	340.000	0.871
Anesthesia time (h)	6.52 (4.73, 8.79)	6.41 (4.86, 7.58)	333.000	0.782
Fluid infusion volume (mL)	1575.0 (737.5, 3325.0)	1880.0 (1157.5, 2800.0)	303.000	0.445
Surgery type			0.956	0.392
Emergency surgery	1 (7.14%)	1 (2.00%)		
Selective surgery	13 (92.86%)	49 (98.00%)		
Tumor size (cm)	4.50 (3.75, 5.13)	4.40 (3.50, 5.30)	347.000	0.961
Tumor histology			2.300	0.546
Glioma	4 (28.57%)	17 (34.00%)		
Ependymoma	5 (35.72%)	12 (24.00%)		
Medulloblastoma	1 (7.14%)	11 (22.00%)		
Others	4 (28.57%)	10 (20.00%)		
Location			2.624	0.654
Cerebellum (including vermis)	1 (7.14%)	10 (20.00%)		
Fourth ventricle	4 (28.57%)	15 (30.00%)		
Brainstem	7 (50.00%)	14 (28.00%)		
Cerebellopontine angle	1 (7.14%)	6 (12.00%)		
Pineal body	1 (7.14%)	5 (10.00%)		
Preoperative SEPs recording feasible			0.470	0.485
Yes	10 (71.43%)	40 (80.00%)		
No	4 (28.57%)	10 (20.00%)		
Preoperative MEPs recording feasible			1.043	0.299
Yes	12 (85.71%)	47 (94.00%)		
No	2 (14.29%)	3 (6.00%)		

Values are expressed as median (IQR) or numbers (percent). ASA, American Society of Anesthesiologists; PS, propensity scores.

by a reduction in postoperative SEP amplitude was a risk factor for postoperative airway management complications, which increased the likelihood of postoperative airway management complications by 19.6 times [OR (95% CI) = 19.600 (1.976, 194.406), *P* = 0.007]. Correspondingly, the feasible preoperative SEP recording with no reduction in postoperative SEP amplitude was a protective factor for postoperative airway management complications (*P* = 0.011).

Among the 14 patients in the complications group, because the number of patients with postoperative re-intubation and overall postoperative airway management complications was the same, they had exactly the same results. However, only 1 patient experienced postoperative reflux aspiration, which could not be further analyzed due to the small number of patients. We conducted further analysis on the 3 patients with postoperative tracheostomy, and the results were consistent with the overall

Table 3. Risk variables of neuro-electrophysiological indicators in postoperative airway management complications

Variable	Before PS matching				After PS matching			
	Complications group (n = 20)	No complications group (n = 144)	χ^2	*P* value	Complications group (n = 14)	No complications group (n = 50)	χ^2	*P* value
Postoperative SEPs amplitude reduction	7 (35.00%)	5 (3.47%)	25.739	< 0.001	4 (28.57%)	2 (4.00%)	7.772	0.018
Postoperative MEPs threshold increased	2 (10.00%)	9 (6.25%)	0.395	0.626	1 (7.14%)	4 (8.00%)	0.011	1.000

Values are expressed as numbers (percent). SEP, somatosensory evoked potential; MEP, motor evoked potential; PS, propensity scores.

Table 4. Neuro-electrophysiological indicators using combinations of SEPs and MEPs related to postoperative airway management complications

Combinations	Complications group	No complications group	OR (95% CI)	χ^2	*P* value
Before PS matching	(n = 20)	(n = 144)			
A-/B+	7	1	77.000 (8.784, 674.963)	44.540	< 0.001
A-/B-	8	115	0.168 (0.063, 0.449)	14.881	< 0.001
C-/D+	5	9	5.000 (1.481, 16.875)	7.907	0.016
C-/D-	13	128	0.232 (0.081, 0.667)	8.312	0.004
After PS matching	(n = 14)	(n = 50)			
A-/B+	4	1	19.600 (1.976, 194.406)	10.722	0.007
A-/B-	6	39	0.212 (0.060, 0.740)	6.471	0.011
C-/D+	1	4	0.885 (0.091, 8.615)	0.011	1.000
C-/D-	11	43	0.597 (0.132, 2.691)	0.458	0.677

Values are expressed as numbers. A-, preoperative SEPs recording feasible; B+, postoperative SEPs amplitude reduction; B-, postoperative SEPs amplitude no reduction; C-, preoperative MEPs recording feasible; D+, postoperative MEPs threshold increased; D-, postoperative MEPs threshold not increased; PS, propensity scores.

Table 5. Comparisons of other outcomes between the two groups

Variable	Complications group (n = 14)	No complications group (n = 50)	U value	*P* value
Intubation days (days)	11.5 (4.3, 20.3)	1.0 (0, 1.3)	62.500	< 0.001
ICU stays (days)	14.0 (11.0, 21.8)	4.0 (1.8, 5.0)	50.500	< 0.001
Hospital stays (days)	21.0 (18.8, 26.5)	11.0 (7.0, 17.3)	121.000	< 0.001

Values are expressed as median (IQR). ICU, intensive care unit.

postoperative airway management complications (Supplementary Tables 2 and 3). The combination of feasible preoperative SEP recording followed by a reduction in postoperative SEP amplitude was a risk factor for postoperative tracheostomy.

In addition, there were 9 cases of postoperative dysphagia and 8 cases of postoperative coughing after drinking water. We further analyzed in detail the differences in perioperative SEPs and MEPs between the two groups for various types of complications (Supplementary Tables 4, 5, 6, 7), and found that the combination of feasible preoperative SEP recording followed by a reduction in postoperative SEP amplitude was associated with postoperative dysphagia (*P* = 0.017, Supplementary Table 5) and postoperative coughing after drinking water (*P* = 0.012, Supplementary Table 7).

The patients in the complications group were more likely to have poor outcomes than those in the no complications group, with longer intubation days [11.5 (4.3, 20.3) *vs.* 1.0 (0, 1.3) days, *P* < 0.001], longer ICU stays [14.0 (11.0, 21.8) *vs.* 4.0 (1.8, 5.0) days, *P* < 0.001] and longer hospital stays [21.0 (18.8, 26.5) *vs.* 11.0 (7.0, 17.3) days, *P* < 0.001] (**Table 5**).

Discussion

In the present study, the overall incidence of airway management complications in pediatric posterior fossa surgery was 12.2%. With intraoperative neurophysiological monitoring (IONM), a significant correlation emerged between reduced postoperative SEP amplitude and postoperative airway management complications. The combination of preoperative SEP recording and reduced postoperative SEP amplitude was a also risk factor for postoperative airway management complications. Patients with airway management complications had longer intubation days and longer ICU and hospital stays compared to negative patients. Therefore, early identification and prevention of airway management complications can significantly improve the quality of life of patients.

The brainstem is a crucial area that controls basic life-sustaining functions including breathing, and it regulates fundamental reflexes such as swallowing and coughing that are essential for protecting the airways [21]. In clinical and surgical settings, maintaining the integrity of brainstem functions is critical, for which SEP and MEP measurements are indispensable monitoring tools [22]. They provide real-time feedback on the functional status of sensory and motor pathways respectively, especially those passing through the brainstem. Monitoring SEPs and MEPs not only reduces potential damage to neural pathways during surgical procedures, but also predicts the occurrence of postoperative complications, thereby enabling clinicians to identify and intervene in high-risk patients at an early stage [23].

Predicting and managing airway complications is a significant challenge in pediatric ICU settings, with extubation failure rates ranging from 6% to 15%, and even as high as 29% in high-risk cases [24]. In a retrospective study of adult craniotomy for intracranial tumors, the incidence of unplanned reintubation for infratentorial surgeries was 6.6% [25]. In the present study, the rate of postoperative reintubation for children after posterior fossa surgery was 11.6%. Previous studies found that nerve damage is the main cause of extubation failure in patients undergoing posterior fossa surgery, rather than respiratory failure [26, 27]. Therefore, assessing neurological injury in patients is crucial. While IONM has been extensively studied for preventing neurological injury, its effect on postoperative airway complications remains unexplored. By focusing on the role of IONM in postoperative complications, we introduce a new dimension to the assessment of extubation failure risk. This may lead to more precise prevention strategies and improved patient outcome.

The presence of a large amount of oropharyngeal secretions was another common reason for unplanned reintubation after craniotomy [28]. The evidence again indicated that the main reason for reintubation in patients after craniotomy was to protect the airway, rather than for respiratory disorders. Dysphagia was an important reason for the presence of large amounts of oropharyngeal secretions. Swallowing is a complex activity that requires control by neurons in the brainstem, cerebral cortex and cerebellum [29]. Swallowing can be interrupted at many levels for various reasons and one of the most common causes of dysphagia is neurological diseases [30]. Therefore, patients with posterior fossa lesions often experience dysphagia. The research by Goethe and colleagues found that the incidence of dysphagia after pediatric posterior fossa tumor surgery was 21.8% [3]. A pediatric study by Morgan et al. showed that 73% of patients who underwent posterior fossa tumor resection exhibited dysphagia in the first two weeks postoperatively [31]. However, the incidence in the present study was only 8.14%, which may be related to the heterogeneity of the patients included, the application of IONM, etc. Patients with postoperative dysphagia may also have an impaired cough reflex, significantly increasing the risk of aspiration. Therefore, neural protection during posterior fossa surgery is of great importance for the postoperative recovery of patients.

The SBT test is usually used to evaluate the withdrawal of mechanically ventilated ICU patients [17], which was also the evaluation method used in our study. However, the SBT test could not assess the adequacy of airway reflexes. Adult patients can follow the doctor's instructions to evaluate their cough and swallowing ability, but the above assessment methods are often not suitable for children. Therefore, the results of our study should help evaluate the swallowing function of children who underwent posterior cranial fossa surgery to reduce postoperative airway management complications.

Several factors during surgery may affect changes in SEPs and MEPs, including the anesthetic used, low blood pressure, and hypothermia [32]. We reviewed the anesthesia records of each patient and found that all patients were treated with a uniform TIVA anesthesia protocol. Moreover, the patients' body temperatures were routinely monitored during surgery, and warming measures were taken for children under 6 years of age. None of the children experienced hypothermia during surgery. Maintaining blood pressure is crucial during craniocerebral surgery. Routine intraoperative monitoring of blood pressure changes revealed that the blood pressure of patients remained within

± 20% of their preoperative normal level. Therefore, although the present study was retrospective in nature, it can exclude any interference by these factors.

To reduce the occurrence of postoperative airway management complications, when a decrease in SEP amplitude was identified during the operation, it was essential to inform the surgeons promptly and request them to suspend the operation and await the recovery of SEPs, thereby avoiding damage to the neural pathways of the brainstem. At the same time, it was necessary to inform the anesthesiologists that adjusting blood pressure can be considered to avoid low perfusion in patients. If the amplitude of SEPs remained decreased after surgery, the anesthesiologists and the ICU doctors were informed that the patient was at a higher risk of postoperative airway management complications. Therefore, intensified monitoring is required and the extubation indication should be carefully evaluated. Overall, the present study unequivocally showed that due to the close correlation between neurological function prognosis and postoperative management, surgeons and anesthesiologists should engage in more informative communication with the IONM team to guide postoperative airway management, which will likely help to significantly improve the patients' prognosis.

However, there were some limitations to this study. First, this was a retrospective study; a prospective study should be performed to determine the predictive value of IONM for postoperative airway management complications in the near future. Second, the study was conducted in a single center, so its findings require confirmation through larger-scale research across multiple centers. Third, the magnitude of the predictive value of the SEP change is uncertain given the wide 95% CI (1.976, 194.406), which may mean that the OR value was estimated with low accuracy, so follow-up multi-center large-scale studies or prospective studies are needed to determine further the risk factors.

Conclusion

A significant association was identified between the reduction in postoperative SEP amplitude and the occurrence of complications related to postoperative airway management. The presence of preoperative SEP recordings, combined with a decrease in postoperative SEP amplitude, emerged as a notable risk factor for complications associated with airway management following surgery. This finding not only deepens our understanding of the underlying mechanisms contributing to extubation challenges in pediatric patients but also paves the way for integrating SEP monitoring into standard perioperative care protocols for high-risk surgical procedures.

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Disclosure of conflict of interest

None.

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Supplementary Table 1. Multivariate logistic regression of preoperative factors influencing postoperative airway management complications

Factor	*P* value
Surgery time (h)	0.977
Anesthesia time (h)	0.880

Supplementary Table 2. Risk variables of neuro-electrophysiological indicators in patients with postoperative tracheotomy after PS matching

Variable	Complications group (n = 3)	No complications group (n = 61)	χ^2	*P* value
Preoperative SEPs recording not feasible	1	13	0.242	0.530
Postoperative SEPs amplitude reduction	2	4	12.160	0.021
Preoperative MEPs recording not feasible	1	4	2.846	0.220
Postoperative MEPs threshold increased	0	5	0.267	1.000

Values are expressed as numbers (percent). SEP, somatosensory evoked potential; MEP, motor evoked potential; PS, propensity scores.

Supplementary Table 3. Combinations of SEPs and MEPs related to postoperative tracheotomy after PS matching

Combination	Complications group (n = 3)	No complications group (n = 61)	OR (95% CI)	χ^2	*P* value
A-/B+	2	3	38.667 (2.688, 556.257)	15.138	0.014
A-/B-	0	45	/	7.455	0.023
C-/D+	0	5	/	0.267	1.000
C-/D-	2	52	0.346 (0.028, 4.228)	0.749	0.405
A+/C+	1	2	14.750 (0.912, 238.596)	5.781	0.136
A+/C-	0	11	/	0.653	1.000
A+/D+	0	2	/	0.102	1.000
A+/D-	1	11	2.273 (0.189, 27.347)	0.439	0.470
C+/B+	0	2	/	0.102	1.000
C+/B-	1	2	14.750 (0.912, 238.596)	5.781	0.136

Values are expressed as numbers. A+, preoperative SEPs recording not feasible; A-, preoperative SEPs recording feasible; B+, postoperative SEPs amplitude reduction; B-, postoperative SEPs amplitude not reduction; C+, preoperative MEPs recording not feasible; C-, preoperative MEPs recording feasible; D+, postoperative MEPs threshold increased; D-, postoperative MEPs threshold not increased; PS, propensity scores.

Supplementary Table 4. Risk variables of neuro-electrophysiological indicators in patients with postoperative dysphagia after PS matching

Variable	Complications group (n = 9)	No complications group (n = 55)	χ^2	*P* value
Preoperative SEPs recording not feasible	3	11	0.805	0.397
Postoperative SEPs amplitude reduction	3	3	7.075	0.032
Preoperative MEPs recording not feasible	1	4	0.158	0.544
Postoperative MEPs threshold increased	0	5	0.888	1.000

Values are expressed as numbers (percent). SEP, somatosensory evoked potential; MEP, motor evoked potential; PS, propensity scores.

Supplementary Table 5. Combinations of SEPs and MEPs related to postoperative dysphagia after PS matching

Combination	Complications group (n = 9)	No complications group (n = 55)	OR (95% CI)	χ^2	*P* value
A-/B+	3	2	13.250 (1.832, 95.810)	9.471	0.017
A-/B-	3	42	0.155 (0.034, 0.707)	6.861	0.016
C-/D+	0	5	/	0.888	1.000
C-/D-	8	46	1.565 (0.174, 14.100)	0.162	1.000
A+/C+	0	3	/	0.515	1.000
A+/C-	3	8	2.938 (0.608, 14.199)	1.918	0.177
A+/D+	0	2	/	0.338	1.000
A+/D-	3	9	2.556 (0.537, 12.152)	1.462	0.351
C+/B+	1	1	6.750 (0.383, 118.995)	2.206	0.263
C+/B-	0	3	/	0.515	1.000

Values are expressed as numbers. A+, preoperative SEPs recording not feasible; A-, preoperative SEPs recording feasible; B+, postoperative SEPs amplitude reduction; B-, postoperative SEPs amplitude not reduction; C+, preoperative MEPs recording not feasible; C-, preoperative MEPs recording feasible; D+, postoperative MEPs threshold increased; D-, postoperative MEPs threshold not increased; PS, propensity scores.

Supplementary Table 6. Risk variables of neuro-electrophysiological indicators in patients with post-operative coughing after drinking water, after PS matching

Variable	Complications group (n = 8)	No complications group (n = 56)	χ^2	*P* value
Preoperative SEPs recording not feasible	3	11	1.306	0.357
Postoperative SEPs amplitude reduction	3	3	8.512	0.022
Preoperative MEPs recording not feasible	1	4	0.279	0.499
Postoperative MEPs threshold increased	1	4	0.279	0.499

Values are expressed as numbers (percent). SEP, somatosensory evoked potential; MEP, motor evoked potential; PS, propensity scores.

Supplementary Table 7. Combinations of SEPs and MEPs related to postoperative coughing after drinking water after PS matching

Combination	Complications group (n = 8)	No complications group (n = 56)	OR (95% CI)	χ^2	*P* value
A-/B+	3	2	16.200 (2.170, 120.922)	11.188	0.012
A-/B-	2	43	0.101 (0.018, 0.561)	8.993	0.007
C-/D+	1	4	1.857 (0.181, 19.069)	0.279	0.499
C-/D-	6	48	0.500 (0.085, 2.926)	0.610	0.600
A+/C+	0	3	/	27.429	1.000
A+/C-	3	8	3.600 (0.716, 18.105)	2.650	0.131
A+/D+	1	1	7.857 (0.441, 140.143)	2.654	0.236
A+/D-	2	10	1.533 (0.269, 8.739)	0.234	0.637
C+/B+	1	1	7.857 (0.441, 140.143)	2.654	0.236
C+/B-	0	3	/	0.450	1.000

Values are expressed as numbers. A+, preoperative SEPs recording not feasible; A-, preoperative SEPs recording feasible; B+, postoperative SEPs amplitude reduction; B-, postoperative SEPs amplitude not reduction; C+, preoperative MEPs recording not feasible; C-, preoperative MEPs recording feasible; D+, postoperative MEPs threshold increased; D-, postoperative MEPs threshold not increased; PS, propensity scores.