J Surg Med. 2023;7(3):214-219.
DOI: 10.28982/josam.7731



Journal of Surgery and Medicine
e-ISSN: 2602-2079
https://jsurgmed.com/

# Pediatric neuroanesthesia experiences: A single center retrospective cohort study

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**Ethics Committee Approval**
The study was approved by Gazi University Clinical Research Ethics Committee (date: 22.06.2021, number: 2022-095).
All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

**Conflict of Interest**
No conflict of interest was declared by the authors.

**Financial Disclosure**
The authors declared that this study has received no financial support.

**Published**
2023 March 9



## Abstract

**Background/Aim:** Pediatric neuroanesthesia is a special field that requires significant experience and infrastructure because of anatomical, neurological, and pharmacological differences in the pediatric patient population. Although technological improvements provide more effective and safer neuroanesthesiological management, the principles of neuroanesthesia, neurocognitive development, and the effects of anesthetic agents on central nervous system development are well-known. The majority of pediatric neuroanesthesia articles in the literature are reviews; however, retrospective/prospective case series and controlled research are limited. In this retrospective cohort study, we aimed to contribute to the existing literature by reviewing and analyzing our single-center 10-year experiences and results addressing pediatric neuroanesthesia management.

**Methods**: After ethical committee approval, anesthetic and surgical reports from 1165 pediatric neurosurgical cases over ten years were collected. Demographic data, intra-operative vascular management, anesthesia techniques, airway management, patient positions, analgesia methods, and complications were evaluated in this retrospective cohort study. The available surgical intervention, patient positions, intra-operative neuromonitorization (IONM), and intra-operative magnetic resonance imaging (IOMR) records were also analyzed.

**Results**: Six-hundred forty-six (55.4%) girls and 519 (44.5%) boys were included in the study. The median age was 60 (0–216) months. Cranial interventions were performed in 842 (72.3%) patients, and spinal interventions were performed in 323 (27.7%) patients. Patients' American Society of Anesthesiologists (ASA) physical scales grouped as I, II, III, and IV were 718 (61.6%), 360 (30.9%), 82 (7%), and 5 (0.4%), respectively. Sevoflurane (40.3%), propofol (37.2%), and sodium thiopental (2.5%) were used for anesthetic induction. Neuromuscular block was performed with rocuronium (56.7%) and atracurium (14.4%). Neuromuscular blocking agents were not used in 337 patients (28.9%). A blood transfusion was required in 120 patients (10.3%), and 40% of these patients underwent surgery for craniosynostosis. Two-hundred twenty-two (19.1%) were monitored with IONM, and IOMR was carried out in 124 (10.6%) of the cases. The anesthesia-related complication rate was 5.15% (60 patients).

**Conclusion**: Although pediatric neurosurgical interventions involve high risks, they are becoming increasingly common in our daily practice. Neuroanesthesiologists should know the procedures, techniques, and advances for safe and effective management of pediatric neurosurgical cases. We think that these data may be helpful as a guide for the anesthetic management of pediatric neurosurgical cases.

**Keywords:** anesthesia, neurosurgery, pediatric neuroanesthesia

How to cite: Emmez G, İnan G, Pampal HK, Şıvgın V, Kılıç AG, Börcek AO, Şatırlar Özköse Z. Pediatric neuroanesthesia experiences: A single center retrospective cohort study. J Surg Med. 2023;7(3):214-219.

## Introduction

Pediatric patients undergoing neurosurgical interventions are a unique group that require special care and attention in terms of anesthesia management and surgery. Pediatric neurosurgical interventions have become more common in our daily practice as a result of recent advances in neuromonitoring, neurointensive care, and more favorable surgical outcomes [1,2]. Furthermore, as better anesthesia equipment and medications have become available, neuroanesthesia applications in premature neonates cease to be dreaded procedures and have become routine operations [3].

Despite these developments, the goal of pediatric neuroanesthesia remains the same: (1) creating optimal surgical conditions, (2) reducing intracranial pressure, (3) preserving hemodynamic stability and venous return, (4) maintaining oxygenation with cerebral and spinal perfusion, (5) effective anesthesia–analgesia management, and (6) allowing for early neurological examination with rapid recovery in the post-operative period [4]. These steps require an understanding of not only pediatric neuroanesthesia principles but also normal neurocognitive development and the impact of anesthetics on the developing nervous system [5].

Many controversial issues in the literature about pediatric neuroanesthesia management exist. The majority of pediatric neuroanesthesia articles in the literature are case reviews, whereas retrospective/prospective case series and controlled research are limited. In this retrospective cohort study, 10 years of experience at a tertiary referral center for pediatric neurosurgery and neuroanesthesia, and 1165 patients were analyzed. This study may contribute to the literature as a guide for pediatric neuroanesthesia as it reflects the approaches and philosophy of an experienced team for quite a large population.

## Materials and methods

After obtaining ethical approval from Gazi University Clinical Research Ethics Committee (Date: 22.06.2021, Number: 2022-095), a retrospective evaluation of records of pediatric patients undergoing cranial and spinal surgery between 2011 and 2020 was conducted. The data retained by the Departments of Anesthesiology, and the Department of Neurosurgery medical charts of the patients were reviewed.

Demographic characteristics, gender, age, body weight, American Society of Anesthesiologists (ASA) physical condition classification, emergency/elective surgery status, anesthesia and operation durations, and classification of surgical cases were evaluated. The patients were divided into six groups based on their age: (1) newborn (0–28 days), (2) infant (1–12 months), (3) toddler (1–3 years), (4) pre-school (3–5 years), (5) school-age (5–12 years), and (6) adolescent (12–18 years). Anesthesia duration was defined as the time interval between anesthesia induction and cessation of anesthetic agents. The surgical time was determined as the time between incision and closure of the skin. Due to the diversity of cases, the operations were classified under headings. An arteriovenous malformation was considered a supratentorial tumor if no related intracranial hemorrhage occurred, and if bleeding did occur, it was classified as a cranial trauma case. Similarly, all epilepsy surgeries, including amygdalo-hippocampectomy, were considered supratentorial tumors while vagal nerve stimulation implantation or other functional surgeries in addition to Arnold Chiari surgeries were considered " other " types of surgeries. Wound dehiscence, superficial infections requiring surgical management, and cerebral spinal fluid (CSF) fistulas due to index surgery were considered "minor surgeries". Excluding tumor resections and biopsies, all endoscopic ventricular surgeries (including suprasellar arachnoid cysts and Type III giant arachnoid cysts requiring surgery) were classified under "hydrocephalus/arachnoid cyst".

Intra-operative vascular management, anesthetic agents for induction and maintenance, preferred anesthesia techniques, airway management, patient positions, use of Mayfield head pins, post-operative analgesia strategies, intra-operative neuro-monitorization (IONM), and intra-operative magnetic resonance imaging (IOMR) applications and complications were analyzed. Patients with multiple surgeries and missing data were excluded from the study.

**Statistical analysis**

Statistical evaluation was completed using the Statistical Package For Social Sciences (SPSS Inc., Chicago, IL, USA) program version 23. Categorical variables are presented as numbers and percentages, while continuous variables are presented as mean (standard deviation). Mann–Whitney U and chi-squared tests were used for non-parametric data to search for differences and associations between groups of patients when appropriate. A $P$-value <0.05 was considered statistically significant.

## Results

During the ten-year study period, 1442 patients underwent in the department of pediatric neurosurgery. The study excluded 175 patients who had multiple surgeries and 102 patients whose data could not be accessed. A retrospective analysis of 1165 pediatric patients was performed.

Five hundred nineteen (44.5%) of the cases were girls, and the boy/girl ratio was 1.24. Eighty-four cases underwent emergency surgery, and trauma was the most common indication in 24 (28.6%) patients. Eight-hundred forty-two patients (72.3%) underwent cranial surgery, and 323 patients (27.7%) underwent spinal surgery. The most frequently performed surgical procedures were performed for hydrocephalus/arachnoid cysts, supra/infratentorial tumors, and congenital spinal anomalies. These indications comprised 69.3% of the entire cohort (Table 1).

The youngest age group underwent congenital spinal surgery, and the longest duration of anesthesia was observed in supratentorial at 285.42 (108.64) min and infratentorial tumor cases at 271.63 (108.26) min.

Central venous catheterization (CVC) was performed in 92 patients, 38 of them were inserted after 2018 and accompanied by ultrasonography (USG). Three of the central catheters were subclavian, 21 were femoral, and 68 were internal jugular veins.

The most preferred agent for induction and maintenance was sevoflurane, and the most commonly used neuromuscular blocker (NMB) was rocuronium. The agents used in the intra-operative period and the preferred anesthesia methods are summarized in Table 2.

Table 1: Demographic variables and surgery data

| | |
|---|---|
| **Gender, n (%)** | |
| **Female** | 519 (44.5) |
| **Male** | 646 (55.5) |
| **Age (months), mean (SD)** | 74.26 (65.23) |
| **Age groups, n (%)** | |
| **Newborn** | 62 (5.3) |
| **Infant** | 240 (20.6) |
| **Toddler** | 184 (15.8) |
| **Pre-school** | 102 (8.8) |
| **School age** | 355 (30.5) |
| **Adolescent** | 222 (19.1) |
| **Body weight (kg), mean (SD) (min–max)** | 23.37 (18.42) (1.20-110) |
| **ASA classification** | |
| I | 618 (53.05) |
| II | 460 (39.5) |
| III | 82 (7.04) |
| IV | 5 (0.42) |
| **Duration of anesthesia (min), mean (SD)** | 212.21 (96.98) |
| **Duration of surgery (min), mean (SD)** | 157.48 (96.35) |
| **Surgery planning, n (%)** | |
| Elective | 1081 (92.8) |
| Emergency | 84 (7.2) |
| **Types of surgery, n(%)** | |
| Hydrocephalus/ arachnoid cyst | 287 (24.6) |
| Supratentorial tumor | 184 (15.8) |
| Infratentorial tumor | 100 (8.6) |
| Craniosynocytosis | 71 (6.1) |
| Cranial trauma | 44 (3.8) |
| Head extracranial tumor | 20 (1.7) |
| Cranial infection | 13 (1.1) |
| Other | 72 (6.2) |
| Minor surgery | 72 (6.2) |
| Congenital spinal surgeries | 237 (20.3) |
| Spinal tumors | 40 (3.4) |
| Spinal trauma | 18 (1.5) |
| Discopathies | 5 (0.4) |
| Spinal infection | 2 (0.2) |

SD: standard deviation, ASA: American Society of Anesthesiologists

Table 2: Agents and methods used in the induction and maintenance of anesthesia

| | |
|---|---|
| **INDUCTION** | |
| **Anesthetic agent** | |
| Propofol | 433 (37.2) |
| Pentothal | 262 (22.5) |
| Sevoflurane | 470 (40.3) |
| **Muscle relaxant** | |
| Rocuronium | 660 (56.7) |
| Atracurium | 168 (14.4) |
| Not used | 337 (28.9) |
| **Analgesic** | |
| Remifentanil | 1103 (94.7) |
| Fentanyl | 62 (5.3) |
| **MAINTANENCE** | |
| **Anesthetic agent** | |
| TIVA | 269 (23.1) |
| Sevoflurane | 896 (76.9) |
| **Muscle relaxant** | |
| Rocuronium | 558 (47.9) |
| Atracurium | 168 (14.4) |
| Not used | 439 (37.7) |
| **Analgesic** | |
| Remifentanil | 1133 (97.3) |
| Fentanyl | 32 (2.7) |

TIVA: total intravenous anesthesia

The airway was maintained by endotracheal intubation except for 39 (3.3%) laryngeal mask airway (LMA) patients. Six hundred seventy-three (57.8%) patients were operated on in the supine position and 7 (0.6%) in the sitting position (Table 3).

Table 3: Patient positions and airway management

| | Supine | Prone | Sitting | Lateral decubitus | Total |
|---|---|---|---|---|---|
| **ETT** | 530 (85.1) | 86 (13.8) | - | 7 (1.1) | 623 (100) |
| **Spiral ETT** | 105 (20.9) | 391 (77.7) | 7 (1.4) | - | 503 (100) |
| **LMA** | 38 (97.4) | - | - | 1 (2.6) | 39 (100) |

ETT: endotracheal tube, LMA: laryngeal mask airway

In cranial and spinal surgeries, three Mayfield head pins were used in 207 children aged ≥3 years, and horseshoe gel pads were used in 24 children <3 years. No local anesthetic was applied to 51 patients who underwent neuronavigation monitoring, scalp block was applied to 49 patients, and local anesthetic infiltration was applied to 107 patients.

Paracetamol was administered in 794 (68.2%) patients, a non-steroid anti-inflammatory drug in 24 (2%) patients, morphine in 67 (5.8%) patients, a combination of paracetamol and morphine in 280 (24%) patients, and morphine patient-controlled analgesia in 52 patients for post-operative analgesia. Paracetamol was administered in the form of a suppository in 101 patients and intravenously in 973 patients.

Two hundred twenty-two (19.1%) patients were monitored with IONM, 179 (80.6%) underwent surgery for a congenital spinal anomaly, and 22 (9.9%) for spinal tumor indication. Propofol was preferred for induction in 147 (66.2%) patients, while sevoflurane was preferred in 75 (33.8%) IONM patients. Anesthesia was maintained with total intravenous anesthesia (TIVA) in all patients who had IONM. In 82.5% of the patients who had TIVA for maintenance of anesthesia, IONM was used. Neuromuscular blockers were not used in induction in 120 (54.1%) patients who underwent IONM, and rocuronium was used in 102 (45.9%) patients. Seventy-one (69.6%) of those who used NMBs were in the school-age group, and 31 (30.4%) were in the adolescent age group. In the maintenance of anesthesia, NMBs were not used.

Intra-operative magnetic resonance imaging was carried out in 124 (10.6%) of the cases, and all these cases were supratentorial malignancies. The average overall IOMR imaging time was 28 min.

Complications were investigated under two headings: (1) anesthesia-related complications (5.15%) and (2) surgical complications (1.1%). Anesthesia-related complications were found in 60 of 1165 cases in our study. The most common complication was airway related (2.4%) due to laryngospasm (17) and bronchospasm (11). As for cardiac complications, bradycardia was found in 13 (1.12%) patients and dysrhythmia in seven (0.6%). Other reported complications were allergic reactions, difficult intubation, and venous air embolism (VAE) observed in three (0.26%), eight (0.69%), and one (0.08%) patients, respectively. In 13 (1.1%) of the cases, we had intra-operative surgical complications, such as significant blood loss or VAE. Seven patients underwent surgery while in the sitting position in our study, and one of them developed VAE.

One hundred twenty-one (10.3%) cases required intra-operative blood transfusion, 48 (40%) were craniosynostosis and 42 (35%) were supra/infratentorial tumor cases. Blood transfusions were performed in 67.6% of all craniosynostosis surgeries. It was observed that those who received blood transfusions were statistically younger (45.97 [54.80] versus 78.06 [65.61] months) and had a lower body weight (15.88 [12.54] versus 24.38 [18.85] kg) compared to those who did not receive blood transfusions ($P<0.01$).

## Discussion

The neuroaesthetics management of 1165 pediatric patients over 10 years was discussed in our study. According to the best of our knowledge, this study is one of the biggest retrospective series in the literature in the field of pediatric neuroanesthesia.

The innovations in pediatric neurosurgery have led to a dramatic reduction in mortality and morbidity rates in infants and children suffering from neurosurgical diseases. Since physiological and developmental variations in pediatric patients present difficulties for both neurosurgeons and anesthesiologists, most surgical and anesthetic improvements are first applied to adults. Pediatric neuroanesthesia articles are scarce in the literature, and the findings are primarily based on adult patient studies. Although it has been noted that the sex ratios in studies evaluating adult patients are close to each other, data on gender distribution are also limited since pediatric neuroanesthesia studies are rare [6].

Our study included 55.5% boys with a boy/girl ratio of 1.24 and a mean age of 6.2 years. Another study analyzing pediatric intracranial tumor surgery cases revealed a boy/girl ratio of 1.4 and a mean age of 8.2 years [7]. As per age distribution, the highest proportion of school-aged children (30.5%), infants (20.6%), and adolescents (19.1%) underwent surgery. The distribution of surgical procedures explains this issue. While cranial procedures are more common in older children (72.3%), spinal surgical procedures, particularly for congenital spinal defects, were more common in younger children (27.7%). While craniosynostosis surgery was conducted on 6% of the patients in our study, it was discovered that surgery for hydrocephalus/arachnoid cysts was the most frequently performed procedure (24.6%) in different age groups. This finding was an expected result as hydrocephalus is one of the most common neurological diseases in children.

Optimal pre-operative evaluation is essential in the management of pediatric neuroanesthesia. Age-related differences in neurophysiology and cranial development in addition to the neurosurgical illness spectrum affect the approach to the pediatric neurosurgery patient [8]. Pre-operative evaluation should focus on age-specific symptoms, signs of increasing intracranial pressure, the Glasgow Coma Scale, and airway examination results [3].

Vascular access can be challenging in pediatric patients, and multiple interventions may have unintended consequences, such as blood loss and hypothermia, in this patient population. Access to the child through sterile surgical drapes becomes limited in neurosurgery due to both the position required by the surgery and the patient's young age. As a result, it is even more critical to maintain the safety of the vascular access, which works well before the procedure and allows blood transfusion if necessary during surgery. In our clinical practice, two large-diameter venous cannulas were used in patients who had a craniotomy for tumors, craniosynostosis surgery, spinal tumor surgery, and/or trauma surgery. Failure of vascular access attempts, the risk of bleeding, and the need for parenteral nutrition during the critical care unit are our indications for a CVC. After 2018, CVCs were inserted with the aid of USG in the study. In the literature, it has been demonstrated that USG-guided CVC applications minimize the number of attempts and complication rates while allowing successful catheterization to be achieved in a shorter time [9]. Although our clinical practice confirms this observation, statistical analysis was not possible due to insufficient records.

Sevoflurane, propofol, and sodium thiopental, which are preferred for induction, are well-known agents for pediatric neuroanesthesia [10,11]. The use of these drugs in our study was organized based on the patient's age and surgical features. As in the literature, sevoflurane was preferred in the induction of patients without vascular access, particularly in the newborn group, and propofol was preferred in the induction of patients whose airway management was provided by a laryngeal mask airway (LMA) since it blocked the upper airway reflexes better than other anesthetic agents.

In adult neuroanesthesia, the superiority of inhalation anesthesia over TIVA in anesthesia maintenance is still debated. A meta-analysis comparing the efficacy and safety of remifentanil, sevoflurane, or propofol in the maintenance of anesthesia in craniotomies found that sevoflurane led to an increase in the incidence of intra-operative hypotension and brain edema in addition to post-operative nausea and vomiting, but no difference in recovery times was noted [12]. The effects of isoflurane, sevoflurane, and desflurane on early post-operative recovery outcome, intra-operative hemodynamics, and degree of brain swelling in addition to post-operative vomiting and shivering were evaluated in a study examining 60 pediatric cases who underwent supratentorial tumor surgery, and no difference among the agents was found in terms of intra-operative brain edema, hemodynamics, post-operative shivering, or vomiting. Desflurane and sevoflurane, on the other hand, provide faster emergence than isoflurane [13]. Sevoflurane has also been found to not affect cerebral blood flow in young patients, similar to adults, and is hence the best inhalation anesthetic for neuroanesthesia [14].

In elective craniotomies, propofol was found to lower intracranial pressure while causing an increase in cerebral perfusion pressure as compared to inhalation anesthesia [15]. Therefore, administration of propofol would be beneficial, particularly in cases of high intracranial pressure and midline shift [16]. In our analysis, TIVA was used in 222 of the 269 patients because of IONM and in 35 of 269 patients due to midline shift. In addition, regarding the carbon footprint, the use of TIVA and sevoflurane as inhalation anesthetics is supported by studies in the literature [17].

In our study, the administration of NMB was determined based on the patients' age, airway device, and monitoring features. It was not used, particularly in the newborn group, when LMA was preferred, and during short-term procedures. Totonchi et al. [18] found no significant positive effect of NMB use in LMA placement, contribution to airway pressures and oxygenation, or reduction airway problems in pediatric patients.

Intra-operative neuromonitorization is a very valuable technique that is one of the main adjuncts of neurosurgical cases and it is one of the unique concerns of NMB usage. This process not only prevents adverse neurological events but also protects the surgical team from medico-legal problems. Monitorization of motor evoked potentials (MEP) and somatosensory evoked potentials (SSEP) in cranial and spinal procedures is critical for assessing the intraoperative neurological condition and preventing problems [19–22]. Unfortunately, using the approach comes with a high cost due to the required anesthesiological technology and anesthesiology time. The anesthesia team must be familiar with factors, such as blood pressure, hypoglycemia, body temperature, hematocrit, and acid-base balance, that may influence IONM responses [23].

During the anesthetic management of patients with IONM, preventing the unfavorable effects of anesthetic agents on IONM is extremely important [24]. The effects of anesthetic agents for induction have short-term effects which explains why typically IONM does not significantly affect the procedure. Maintenance anesthetic doses of TIVA can be safely used in IONM. However inhalational agents over 0.5 minimum alveolar concentrate are avoided as MEPs are highly sensitive to these agents. During maintenance, the anesthesiologist should be sure that the patient is not under a NMB-related effect [25].

The above-mentioned principles were performed in two different approaches in the presented series. These two approaches did not use NMB in induction or administer short-acting NMBs. The termination of the effect of NMBs is confirmed by the "train of four" monitorization. Sala et al. [22] reported that IONM procedures can be performed safely using propofol and fentanyl infusion (TIVA) and avoiding inhalational agents and NMBs after intubation. In the presented series the anesthetic management of cases with IONM was similar to the protocols described by Sala et al.

Airway management in our patients was provided by endotracheal tube (ETT) and LMA. Reinforced ETT was frequently used in the prone position because kinking of ETT due to neck flexion was reported in the literature [26,27]. The conventional ETT was used in the prone position only when appropriate size ETT was not available for newborns, premature patients, or the patients for whom IOMR is planned.

The different patient positions in neurosurgery present advantages and disadvantages. Before closing sterile surgical drapes, the patients should be carefully observed and checked. Dilmen et al. [28] detected VAE in 20.4% of adults and 26.3% of children who were in the sitting position in 692 cases. They also suggested CVC to aspirate the venous air embolism. In the presented series, VAE was detected in one of seven patients in the sitting position and managed with symptomatic approach.

Mayfield skull clamp was used in selected pediatric patients since it carries high risk under three years of age and may cause severe painful stimulation and major hemodynamic responses [29]. These principles were considered in the presented series also.

In pediatric cases, moderate or severe pain was previously reported [30]. Pain management in pediatric neurosurgery is extremely important and controversial. This type of pain may cause morbidity and mortality because it can lead to agitation, increased intracranial pressure, epileptic seizure, and post-operative hematoma. The pain and suppression of hemodynamic responses caused by Mayfield head fixation and post-craniotomy are important in patients with increased intracranial pressure and risk of subarachnoid hemorrhage [29,31].

In a randomized controlled study with 320 pediatric craniotomy cases, fentanyl, morphine, tramadol, and saline (placebo) were compared, and the authors found that the safest and the most effective post-operative analgesia was provided by the patient or nurse-controlled iv morphine. Although physicians do not frequently prefer opioid agents because of their adverse effects, post-operative pain can be managed without neurological impairment in pediatric neurosurgical cases [30]. Smyth et al. [32] concluded that a minor analgesia regimen (acetaminophen/ibuprofen) administered just after surgery and during the hospitalization in pediatric cases in whom suboccipital craniotomy was performed, significantly decreased the pain scores, hospitalization time, the need for narcotic and anti-emetic agents were found.

The complicated management of pain in pediatric neurosurgery requires multimodal strategies to effectively control the pain and avoid the side effects [33,34]. Scalp block is effectively used to control postoperative pain in pediatric patients with craniotomy as a part of multimodal analgesia similar to adult patients [35]. Festa et al. [36] reported that scalp block provides better pain control and limits the need for rescue analgesia when compared with conventional treatment in craniosynostosis surgery in patients under two years of age. Also, Ning et al. [37] showed that scalp block is associated with better postoperative pain control and intra-operative hemodynamic stability in comparison with the control group in pediatric craniotomy cases. Unfortunately, post-operative pain evaluation is not available in the presented study, so similar multimodal analgesia strategies based on studies in the literature were performed.

In the literature about pediatric neuroanesthesia, Van Lindert et al. [38] reported that the rate of anesthesia-related complications is 2.8%–9.6%. In our study, a rate of 5.15% was found to be consistent with the literature. Intra-operative airway complications are an important concern in pediatric neurosurgical procedures. The majority of anesthesia-related complications occur during maintenance, while airway-related complications are usually happening during the induction or extubation stages [39]. We think that difficult mask ventilation during induction and extra irritation due to head movements are the major causes of laryngospasm, which was the most frequently seen complication in our series. In our study, we observed that the second most common complication, bradycardia and dysrhythmia, occurred during brain retraction, and loss of blood and is secondary to intracranial pressure changes. Harrison et al. [40] reported 9.3% VAE in pediatric neurosurgery patients, and they concluded sitting position also applies to pediatric patients.

Seven patients underwent surgery while in a sitting position in our study, and one of them developed an air embolism. The reason for the lower ratio of air embolisms in the presented series is the very rare use of the sitting position by the surgical team. As a result, intra-operative complications could also occur in pediatric patients and are not common, but being aware of the situation is the first step to preventing it [38].

**Limitations**

The retrospective type of study is the major disadvantage of the presented research. The lack of post-operative pain records and evaluation is another pitfall in this study as it limited us to defining and suggesting better pain control methods. The management of pain in pediatric neuroanesthesia must be investigated prospectively.

### Conclusion

We tried to explain our experience, methods, and results that were obtained from 1165 patients. We conclude that although retrospective cohort studies with complete and regular anesthesia and surgical records make a significant contribution to the literature and are helpful for better management of pediatric neuroanesthesia, prospective controlled studies are required to better define the standards and provide evidence-based guidelines.

### Acknowledgements

We would like to thank Selin Erel for her invaluable assistance in editing the manuscript.

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