http://www.banglajol.info/index.php/JNINB
Review Article
DOI: https://doi.org/10.3329/jninb.v11i2.78959
Journal of National Institute of Neurosciences Bangladesh,
July 2025, Vol. 11, No. 2, pp. 186-190
ISSN (Online) 2518-6612
ISSN (Print) 2410-8030

Advancements and Safety Initiatives Paediatric Neuroanaesthesia as Safe Anaesthesia for Every Tot (SAFETOTS): A Narrative Review

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Abstract
Paediatric neuroanaesthesia is a growing and still challenging subspecialty. The term ‘safe use of anesthesia in children is ill-defined and requires definition of and focus on the ‘safe conduct of pediatric neuroanaesthesia’. In recent years, the Safe Anesthesia for Every Tot campaign was established with the goal of promoting the safe practice of pediatric neuroanaesthesia. The goal of this project is to offer recommendations for indicators of high-quality anesthetic care. National "who, where, when, and how" policies must be introduced and put into effect in order to enhance the perioperative outcomes for children who are at risk. The primary objectives of the safetots.org program is to enhance instruction, training, education, and oversight of the safe practice of pediatric anesthesia. Paediatric anesthetic neurotoxicity, management of intraoperative bleeding, and the effect of anaesthesia on tumor growth are among the most debated and researched topics in paediatric neuroanaesthesia. The well-known perioperative dangers in young children, perioperative causes of cerebral morbidity, and regulatory, educational, and research deficiencies are all addressed by this project. *[Journal of National Institute of Neurosciences Bangladesh, July 2025;11(2):186-190]*

Keywords: Conduct; Pediatric neuro anesthesia; Quality; Safety; Brain tumor

Introduction

The field of pediatric Neuro anesthesia has evolved significantly, with advances in neurosurgery, neuromonitoring, and normotensives care leading to improved outcomes for pediatric patients. However, due to the unique neurophysiological attributes of children, managing anesthesia in this population requires specialized knowledge and techniques[1]. One notable initiative in this regard is the Safe Anesthesia for Every Tot (SAFETOTS) program, which has contributed to the development of safety standards and training aimed at minimizing risks associated with pediatric neuro anesthesia. This review provides an overview of current practices, with insights from the SAFETOTS initiative and foundational approaches to pediatric Neuro anesthesia.

Neurophysiology in Paediatric patients

For safe paediatric neuro anaesthesia practice, the difference between paediatric and adult neurophysiology must be taken into account. Understanding pediatric neurophysiology is vital for effective anesthesia management. Pediatric patients have unique cerebral blood flow (CBF) dynamics, with higher cerebral metabolic rates of oxygen ($CMRO_2$) compared to adults, especially in infants and young children. Cerebral blood flow (CBF) affects the cerebral blood volume and the intracranial volume, thereby affecting the intracranial

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pressure (ICP). It varies with age in pediatric population, being lower in premature infants (12 ml/100 g/min) and full-term neonates (23 to 40 ml/100 g/min) and higher in infants and older children than in adults (50 ml/100 g/min)[2]. From 6 months to 3 years of age, CBF is 90 ml/100 g/min; and from 3 to 12 years of age, the CBF is 100 ml/100 g/min. CBF is coupled tightly with the metabolic demand known as cerebral metabolic rate of oxygen ($CMRO_2$), and both increase proportionally after birth. In children, the $CMRO_2$ is higher at 5.2 ml/100g/min than the adults (3.5 ml/100 g/min) and hence, less tolerant to hypoxia. Neonates have a lower $CMRO_2$ (3.5 ml/100 g/ min) with a relative tolerance to hypoxemia. The immature central nervous system and metabolic demands result in heightened sensitivity to hypoxia, hypercapnia, and fluctuations in blood pressure, which can lead to detrimental effects on the developing brain if not managed carefully[3].

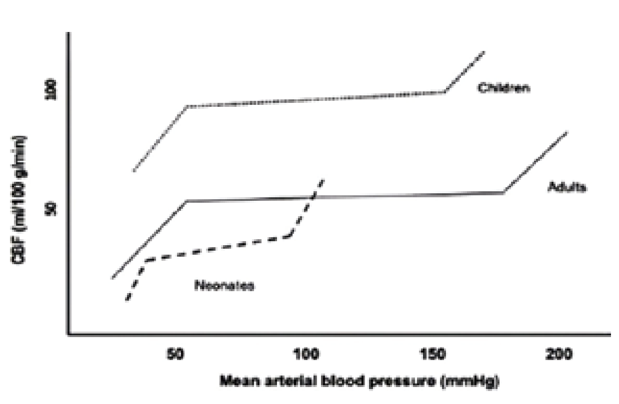

Figure I: Differences in cerebral autoregulation in adults, children and neonates[5]

Table 1: The effects of the most commonly used aesthetic agents on cerebral physiology[5].

Agent	CMR	CBF	CBV	ICP
Isoflurane	↓↓↓	↑	↑↑	↑↑
Desflurane	↓↓↓	↑	↑	↑
Sevoflurane	↓↓↓	↑	↑	↑
Nitrous oxide	↓	↑	→	↑
Propofol	↓↓↓	↓↓↓↓	↓↓	↓↓
benzodiazepines	↓↓	↓	↓	↓
Ketamine	→	↑↑	↑↑	↑↑*
Etomidate	↓↓↓	↓↓	↓↓	↓↓
Opioids	→	→	→	→
Barbiturates	↓↓↓↓	↓↓↓	↓↓	↓↓↓

↑ increase, ↓ decrease, → no or little change, CMR cerebral metabolic rate, CBF cerebral blood flow, CBV cerebral blood volume, ICP intracranial pressure.
* Ketamine does not increase ICP when patients are sedated and normocapnia is maintained with ventilation[10,11].

For instance, the autoregulation of CBF in neonates and infants is limited, making these patients more susceptible to ischemic events and intracranial hemorrhage. Therefore, maintaining stable hemodynamics during pediatric neurosurgery is crucial. The autoregulation range of blood pressure in normal newborn is narrow between 20 and 60 mmHg[4]. The autoregulatory slope drops and rises significantly at the lower and upper limits of the curve, respectively. Sudden hypotension and hypertension at either end of the autoregulatory curve places the neonate at risk for cerebral ischemia and intraventricular hemorrhage (IVH), respectively.

Table 2: The 10-Ns of Maintenance of physiological homeostasis is key for the Safe Conduct of Anaesthesia in Children[6].

10 N for Quality	
1.	No fear.
2.	Normovolemia.
3.	Normotension.
4.	Normal heart rate.
5.	Normoxemia.
6.	Normocapnia.
7.	Normonatremia.
8.	Normoglycemia.
9.	Normothermia.
10.	No postoperative discomfort.

The concept of the 10-N quality pediatric anesthesia. Quality conduct of anesthesia in children includes avoidance of fear and pain as well as maintenance of homeostasis normotension, normal heart rate (cardiac output), normovolemia, normoxemia, normocarbia, normal electrolytes, normoglycemia and normothermia.

Paediatric Anaesthetic Neurotoxicity

Multiple studies on immature animals strengthened the evidence of the neurotoxic effect of general anaesthetics. Anaesthetics can cause neuronal apoptosis and morphological changes in dendritic and glial cells, resulting in impaired neurocognitive function and abnormal behaviour in nonhuman models[7]. An increasing number of human studies, including the Mayo Anaesthesia Safety in Kids (MASK) Study, have also confirmed the negative effects of early life exposure[8,9]. Lately, a metanalysis showed that children with multiple exposures to general anaesthesia have a higher risk of neurodevelopmental disorders and the incidence of ADHD was more than twofold as high as in children with any exposure. There is no evidence that any anesthetic is less likely to cause adverse effects in the human developing brain. Currently, the only possible way to lower the risk of neuronal damage is to reduce unnecessary aesthetic exposure, especially between the third trimester and 2 to 3 years of age ("vulnerable time window").

Preoperative Consideration

Preoperative Assessment

The evaluation must include history and physical examination pertaining to the conditions requiring special anesthetic considerations. A thorough preoperative evaluation is critical in pediatric neuro anesthesia. Assessments should include neurological evaluation for signs of increased intracranial pressure (ICP), a review of electrolyte levels (as imbalances are common), and considerations for specific conditions like hydrocephalus or craniosynostosis, which may complicate anesthetic management. For children with elevated ICP, sedatives should be used cautiously to prevent further increases in pressure.

Premedication

Sedative and narcotic premedication should be avoided in all the children suspected of increased ICP as these medications decrease respiratory drive which may result in hypercapnia and further increase in ICP10. However, patients with normal ICP, such as those scheduled for repair of vascular lesions, may be sedated so as to allay preoperative anxiety and avoid hypertension, thus preventing rupture of vascular abnormality. Oral benzodiazepines (midazolam) Intraoperative Anaesthesia Management may be beneficial for small children as they provide sedation without respiratory depression and should be administered under supervision.

Intraoperative Considerations

Induction

Avoiding an increase in ICP due to related hypoxia, hypercapnia, and volatile anesthetic-induced increases in CBF is the aim of anesthetic induction. For children with elevated ICP, an intravenous (IV) induction with thiopentone or propofol with neuromuscular block to aid in endotracheal intubation is optimal. However, inhalational induction by facemask with sevoflurane should be preferable in children lacking IV access or with problematic IV access, as crying or struggle may cause the ICP to rise even more. To avoid the pressure reactions of tracheal intubation, a bolus of thiopentone (1 to 2 mg/kg) or propofol may be administered following the security of the IV access. Furthermore, the inhalational technique may subsequently be changed to an IV induction. All volatile anesthetics cause an increase in CBF, and thence the ICP.

Maintenance

Anesthesia is maintained either with low end-tidal volatile agents (minimum alveolar concentration (MAC) <1) or with total IV anesthesia (TIVA), along with short-acting opioids (fentanyl or remifentanil), inhaled nitrous oxide and controlled ventilation. Sevoflurane has almost replaced halothane as an agent for induction; isoflurane, sevoflurane or desflurane is used for maintenance of anesthesia during pediatric neurosurgical procedures. Sevoflurane provides smooth induction followed by a rapid recovery. Neuromuscular blockade with non-depolarizing muscle relaxants is given to prevent patient movement and minimize the amount of anesthetic agent required. Children on chronic anti-convulsant therapy will require large doses of muscle relaxants and narcotics due to enzymatic induction of these drugs. Muscle relaxant should be withheld when assessment of motor function is carried out, e.g. during spinal cord surgery. Intravenous induction with thiopentone or propofol is typically used to avoid increases in ICP, followed by neuromuscular blockade for intubation. In patients without intravenous access, inhalational induction with sevoflurane is preferred.

Positioning

Positioning in pediatric neurosurgery is a critical aspect of the surgical process that ensures the optimal exposure of the surgical site, minimizes complications, and maintains the safety and comfort of the child during the procedure. Proper positioning also plays a significant role in preventing neurological injuries and optimizing hemodynamics and respiratory function during surgery. Various neurosurgical positions (supine, prone, sitting, or lateral) pose specific risks in pediatric patients, such as obstructive airway challenges and pressure injuries. Proper padding and positioning are essential to ensure safety during prolonged procedures[11].

Monitoring

Monitoring during pediatric neurosurgery is essential to provide continuous assessment of the paediatric physiological, neurological and surgical parameters. Given the complexity of the procedures and the unique physiology of pediatric, the need for precise and comprehensive monitoring is heightened to prevent intraoperative complications and ensure optimal outcomes. The primary goals of intraoperative monitoring in paediatric neurosurgery are: Ensuring Safety, Protecting the Brain and Nervous System, Assessing Hemodynamic Stability, Facilitating Surgical Precision.

Fluid Management

Close hemodynamic monitoring, including arterial blood pressure and central venous access, is essential to detect complications like venous air embolism (VAE) during surgeries in the sitting position. Neurophysiological monitoring[12], including EEG and somatosensory evoked potentials, is also useful in surgeries requiring real-time feedback on neurological status. Fluid management aims to maintain normovolemia and thus hemodynamic stability. Normal saline is the most commonly administered crystalloid during pediatric neurosurgical procedures as it is mildly hyperosmolar and hence prevents cerebral oedema. However, infusion of large quantities (>60 ml/kg) of normal saline may cause hyperchloremic metabolic acidosis and hypernatraemic. Ringer's lactate is slightly hypo-osmolar and infusion of large quantities may increase cerebral oedema. avoid glucose-containing solutions to prevent hyperglycemia, a known exacerbator of reperfusion injury[13]. Glucose-containing fluids should not be used during these procedures as hyperglycemia worsens reperfusion injury.

Temperature management

In pediatric neuro anesthesia, temperature management is a crucial aspect of anesthesia care. The target temperature is typically maintained within a specific range (36°C-37.5°C) to ensure optimal brain protection and metabolic function during procedures, especially those involving the central nervous system.

Postoperative Consideration

Recovery and postoperative care: The objective is "rapid awakening" to support minimum coughing and straining during the ETT, early neurological examination, and hemodynamic stability. In youngsters, sevoflurane offers a superior recovery profile than isoflurane. When a baby opens its eyes or reacts to directions, the trachea is extubated.

Specific Conditions and Anesthetic Considerations

Hydrocephalus: Children with hydrocephalus often require ventricular shunt placement or revision. Rapid drainage of cerebrospinal fluid (CSF) should be avoided to prevent hemodynamic instability.

Craniosynostosis: Surgeries to correct cranial deformities are typically performed early in life and involve significant blood loss. Precautions against venous air embolism and careful intraoperative monitoring are required.

Brain Tumors and Encephaloceles: Pediatric brain tumors and encephaloceles pose particular challenges, as surgical manipulation may lead to respiratory or cardiovascular instability. Close postoperative monitoring is essential for prompt detection of complications such as respiratory depression.

Conclusion

Advancements in pediatric neuro anesthesia, supported by initiatives like SAFETOTS, have underscored the importance of specialized care, meticulous preoperative planning, and tailored anesthetic techniques. Ensuring safe, standardized practices in pediatric neuro anesthesia is critical for improving outcomes in this vulnerable population. Future research should focus on refining techniques and further understanding the impact of anesthesia on neurodevelopment.

Acknowledgements
None

Conflict of interest: All authors declare that they have no competing interest.

Financial Disclosure
None.

Data Availability
The datasets generated and analyzed during this study are not publicly available due to patient confidentiality and institutional data protection policies. However, anonymized data may be made available from the corresponding author upon reasonable request, subject to approval by the institutional ethics committee.

Ethics Approval and Consent to Participate
Ethical approval for the study was obtained from the Institutional Review Board. As this was a prospective study the written informed consent was obtained from all study participants. All methods were performed in accordance with the relevant guidelines and regulations. The ethical approval was obtained from July 2024 to December 2024.

How to cite this article: Rony MRR, Hasnat MA, Haque T, Mamun MA, Rahman MM, Akbor MN, Nahar F; Advancements and Safety Initiatives Paediatric Neuroanaesthesia as Safe Anaesthesia for Every Tot (SAFETOTS): A Narrative Review. J Natl Inst Neurosci Bangladesh, 2025;11(2):186-190

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Article Info
Received on: 7 April 2025
Accepted on: 24 May 2025
Published on: 1 July 2025

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