6 Anesthetizing Pediatric Neurosurgical Patients: A Practical Approach

Seelora Sahu, Amlan Swain, and Jitamitra Mishra

Key Points

- There are many challenges unique to neurosurgical pathologies in the pediatric age group, thus necessitating a specialized approach in safe anesthesia delivery.
- A focused preoperative evaluation and assessment is an essential part of the composite anesthesia regimen, which has a significant bearing on overall outcomes.
- There have been gigantic strides in neuromonitoring techniques that have considerably increased the scope of pediatric neurosurgery.
- Tailoring the perioperative management to specific neurosurgical entities, being prepared for intraoperative catastrophes, and accounting for the interactions of the anesthetic agents with immature and developing organ system are important considerations for this patient population.
- Adequate care to ensure the process of smooth emergence from anesthesia as well as comprehensive postoperative management, including judicious use of pediatric neurocritical care modalities, goes a long way in improving patient care.

6.1 Introduction

The perioperative management of a child posted for a neurosurgical intervention is based on a robust understanding of the pediatric neurophysiology, the pathophysiologic effects of myriad neurosurgical entities, and the interplay between anesthetic drugs and cerebral pathophysiology in this subset of patients. From the preoperative period, until the child is discharged to the wards, the anesthesiologist's role is paramount in achieving the harmonious amalgamation of safe neuroanesthesia principles with high-end pediatric neurocritical care. There have been giant strides in modern-day neurosurgical practice, and it is imperative to develop high-level sub-specialty pediatric neuroanesthesia and neurocritical care to improve outcome measures. The ensuing treatise attempts to present practical aspects for the hands-on management of children presenting for neurosurgical procedures.

6.2 Preoperative Preparation

While evaluating children for neurosurgery, two significant evidentiary facts should be considered in the preoperative period, especially in emer-

S. Sahu (✉) · A. Swain
Department of Anesthesia, Tata Main Hospital, Jamshedpur, Jharkhand, India
e-mail: seelora.sahu@tatasteel.com; amlan.swain@tatasteel.com

J. Mishra
Utkal Healthcare Private Limited, Bhubaneswar, Odisha, India

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Table 6.1 Conditions with special anesthetic implications

Problem	Presentation	Anesthetic implication
Syndromes with associated airway anomalies	Usually well documented and anticipated	Difficult airway plans in place prior to induction
Respiratory illness	Usually have history of previous admissions or multiple hospital visits	History of steroids and bronchodilator drugs which may affect the anesthetic plan
Autistic child	Usually documented by the anesthetist during preop visit Parents can guide regarding the coping methods	Sedative anxiolysis Nonpharmacological methods like parental presence during induction of anesthesia (PPIA)/distraction Possibility of restraint may be discussed with the parents and due consent obtained Documented plan to abort anesthesia if needed
Cardiac comorbidities	Failure to thrive Cyanotic spells Frequent lower respiratory infections	Cardiology consult and ECHO Endocarditis prophylaxis Specialized centers if needed
Trisomy 21	History of noisy breathing or excessive drooling Behavioral issues and seizures	Evaluation for coexisting cardiac and noncardiac conditions Documentation of atlantoaxial stability/instability
Prematurity	History of chronic pulmonary disease Failure to thrive Frequent seizures and developmental delays Gastroesophageal reflux disease (GERD)	Anticipate perioperative apnea and bradycardia <60 weeks' gestational age needs mandatory postoperative observation with oximetry

gency conditions. First, neonates and infants have the highest risk of mortality and morbidity during the perioperative period [1]. Second, respiratory and cardiac events account for most of the anesthetic complications in children [2]. A pediatric neuroanesthesiologist should always be wary of the neurosurgical entity necessitating surgery in the neonatal and infantile age groups and keep a careful watch for common comorbidities in the pediatric age group known to have disastrous consequences. A tabular format of such common conditions in the children presenting for surgery has been given as a ready reckoner (Table 6.1). Preoperative checks and operating room preparation have special significance in ensuring patient safety in this highly susceptible patient population. These aspects and anxiolysis in children with varied and obtunded neurological symptomatology are covered in more detail next.

6.2.1 Preoperative Checks

6.2.1.1 Preoperative Assessment

While preoperative evaluation is covered in Chap. 4, the practical points while assessing children during the preoperative period are covered consequently. Children presenting for neurosurgery essentially fall under any of the following categories: (a) those who are systemically well and require minimal assessment, (b) children with debilitating inborn diseases and rare syndromes which mandate a discrete and individualized preoperative management, and (c) otherwise fit children presenting for emergency surgery who exhibit rapid clinical deterioration—adequate care and vigilance is necessary for such children to avert catastrophes and facilitate urgent preoperative optimization and stabilization of the overall clinical condition. Also, psychosomatic issues are common in children presenting for neurosur-

gery and have a predilection toward complicating the anesthetic course, especially during induction and in the postoperative period [3–5].

As most neurosurgical procedures are emergencies, a comprehensive preoperative assessment is not always possible. Considering systemic effects of general anesthesia (GA) and the inherent stress because of surgery, it is advisable to assess the individual organ system in tandem with the developmental stage. Because some children would not have fully acquired the faculty of speech and may not fully comprehend their medical illness, in more cases than not, it becomes vital to establish meaningful communication with either their parent or primary caregiver. A detailed patient history goes a long way to identifying patients who would benefit from a focused evaluation and optimization in the preoperative period. As in standard anesthesia practice, the investigative modalities employed in the preoperative phase should be based on the history, clinical signs, and the neurosurgery planned.

A child's neurologic condition varies greatly and should dictate the specifics of the preoperative assessment. A relevant example would be wariness of latex allergy symptoms in children undergoing multiple neurosurgical procedures, especially in children with meningomyelocele [6]. Dehydration, fluid and electrolyte anomalies, obtunded upper airway reflexes, and use of steroids and antiepileptics are the specific points of interest while examining a neurologically injured child during the preoperative period. Especially in children on antiepileptic drugs (AEDs), therapeutic levels of AEDs and hematologic and hepatic systems' affliction because of long-term use and interactions with anesthetic agents assume significance [7, 8].

The preoperative examination should include a meticulous central nervous system (CNS) examination, especially because postoperative neurologic function vis-à-vis the preoperative state plays a vital role in the neurosurgical decision-making during the postoperative period. A note should be made of signs and symptoms of the brain stem and CNS dysfunction, muscle power, bulk and weakness, physical signs of dehydration, and recording an accurate body weight to facilitate judicious use of anesthetic drugs, intravenous (IV) fluids, and blood products [9].

One should be more vigilant while dealing with emergency surgery because of the unplanned nature, and consequent probability of more blind ends and a tumultuous course during the management of these cases. A neurologically deteriorated, fearful, or a child in pain may be easily mistaken for a quiet or shy child. Any signs of underlying critical illnesses like tachypnea, recession, grunting, accessory muscle use, gasping, bradycardia, or a prolonged capillary refill time should be sought after. Such a child should be resuscitated and optimized either before or during the surgery to avoid hemodynamic and cardiorespiratory catastrophe. Adhering to the ABC framework keeps things simple and ensures adequate stabilization of a decompensated critically ill child before anesthetic induction. Especially in emergent situations, a risk-benefit decision should be taken in inadequate fasting, and rapid sequence induction should be planned. Bradycardia and reduced consciousness are usually terminal signs and should herald ominous warning bells for severe intracranial hypertension and consequent herniation.

6.2.1.2 Fasting and Consent

The importance of preoperative fasting and instructions regarding regular medication cannot be overstated. There are many reasons to encourage clear fluids up to 2 h before surgery [10, 11]. These include the fact that infants and small children cannot tolerate dehydration, nausea and vomiting are more frequent in prolonged starvation, and hypoglycemia can be avoided. There is a paradoxical increase in gastric secretion after prolonged fasting, and children become more irritable at induction.

The preoperative visit should be utilized to obtain consent for the procedure from the parents, nearest blood relatives, or the legal guardians. Adequate time and effort should be devoted to explaining the surgical procedure and anesthesia techniques clearly and the potential perioperative complications [3]. The perioperative sequence of events to the parent/custodian and, if

possible, to the child should be explained clearly. All concerns and questions that the parents and guardians have should be addressed adequately. In addition to the verbal information and use of written preoperative directives, it is mandatory to reduce confusion and increase compliance [3].

6.2.1.3 Radiology and Labs

A review of the neuroradiological scans in conjunction with the neurosurgical team is important to confirm the primary pathology, associated conditions such as hydrocephalus, compressed cisterns, and midline shifts as well as to plan the intraoperative positioning and other ergonomic issues [12]. Preoperative laboratory tests should include the hematocrit, coagulation parameters, and electrolytes as these patients may be receiving decongestant therapy or may be prone to dyselectrolytemia due to intracranial pathology. Adequate blood product estimation and preparation are important preoperative steps, as is an endocrinology evaluation in children with suprasellar pathologies [12]. In children on long-term anticonvulsants, preoperative liver function tests and a coagulation profile assume significance.

6.2.1.4 Checklist

The impact of iatrogenic diseases and human error on patient safety came to the forefront in medicine only at the turn of last century with the publication of a seminal treatise by the Institute of Medicine—"To Err is Human: Building a Safer Health System" [13]. A landmark event in improving patient safety was the publication of the WHO Surgical Safety Checklist in 2009 [14].

There has been an increase in the use of checklists throughout all specialties of medicine in the last decade, especially in the realm of surgery, anesthesia, and critical care [13, 15, 16]. However, evidence on the use of preoperative checks in pediatric neurosurgical patients is less common [17, 18]. Institutions should develop pediatric checklists, especially for the common neurosurgical procedures. The aim should be to adapt universal WHO surgical safety checklist principles while including points specific to the pediatric age group (e.g., checking for parental involvement) and the aspects specific to the pathology itself (e.g., check for prior chemotherapy, radiotherapy, or dural resection in tumor surgeries). An illustrative example is given in Fig. 6.1; the utility of such checks needs to be validated further.

6.2.1.5 Anxiolysis on Day of Surgery

Confirmation of fasting, reviewing the preassessment record, and a change in the child's clinical status should be a mandatory protocol in all pediatric neurosurgical units. A child-friendly environment and allowing the child to enter the theater zone in his own clothes, if possible, go a long way in establishing a rapport between him and the anesthesiologist. Premedication, including sedatives for anxiolysis, should be considered on an individual basis [5].

An uncooperative child is frequently encountered in anesthesia practice, sometimes requiring physical restraints during anesthesia induction [19, 20]. Anxiety because of an alien environment, painful procedures, hospital personnel in scrubs, or just the fear of parental separation is at the root of this behavior. It must be addressed with due sincerity to ensure compliance during the induction of anesthesia [21].

Postoperative behavior changes may be related to these stressful experiences, which, though transient in most cases, may sometimes persist, thus being a cause of concern for both the parent and the treating neuroanaesthesiologist [22]. Apart from age, other factors predicting heightened anxiety are the child's temperament, anxious parents, a preceding morbid hospital stay, and a previous vaccination-related unpleasant experience. A shy, inhibited, dependent, and/or withdrawn child is a definite red flag [5]; contrary to popular belief, gender does not play a role in predicting anxiety.

Psychological interventions like presurgical programs, play therapy, and parental presence during induction of anesthesia (PPIA) have been tried as potential strategies to allay anxiety prior to induction along with distraction (for IV) or engagement (for inhalation) at the time of induction [22, 23]. Although parental presence may be useful in reducing their own stress, the same may not hold true for the child being anesthetized.

Fig. 6.1 Illustrative preoperative checklist to be filled by the child with the help of the caregiver

Small infants [weight < 5 kgs], anticipated airway problems, critically ill children, and emergency procedures should ideally be excluded from this approach [24].

The use of sedatives given in the preinduction period significantly reassesses the transition from the holding area into the operating room. Midazolam remains the most commonly used pharmacological agent to allay anxiety, reliably providing sedation and anxiolysis at induction and a much calmer child postoperatively. An oral dose of 0.5 mg/kg usually initiates sedation within 5–10 min (peak 20–30 min) and lasting up to 45 min to an hour. The IV route of midazolam (0.1–0.2 mg/kg) may be preferred in children with features of raised ICP, especially when such access has been established, as the response is more predictable and quicker. However, it should be administered only under monitoring as CO_2 retention may cause catastrophic decompensation, and one should watch out for paradoxical agitation, which has sometimes been reported [25].

Supervision is mandatory even with the oral route of administration of midazolam with its superior safety threshold. Hence, the drug administration is usually withheld until the child arrives in the theater's safety. Reduced crying associated with this medication is particularly beneficial in children with vascular lesions where any agitation can be catastrophic but may be a delicate issue in a child with raised ICP (decreased consciousness, irritability, lethargy, failure to feed, bulging fontanelle, and cranial enlargement) as it may potentially unleash a vicious cycle of hypercapnia and intracranial hypertension by its negative impact on the medullary respiratory center. Analgesia-sparing effects are, however, speculative. Other routes are intranasal and rectal but do not usually find favors due to poor patient compliance [12, 25, 26]. Oral lorazepam and temazepam have also been tried (Table 6.2) in older children who require doses beyond midazolam safety ceiling, especially in longer surgeries [23].

Clonidine is another sedative with an excellent therapeutic index and minimal hemodynamic changes in healthy children. Administered orally (4 μg/kg) or intranasally (2 μg/kg), it provides preoperative anxiolysis, acts as an analgesic, decreases the requirement of volatile agents (hence a favorable impact on the CBF), and improves hemodynamic stability [26]. The IV preparation is tasteless and can be administered orally. Oral transmucosal fentanyl (given as lollipops) is an approved alternative and provides excellent conditions at induction. However, its use is constrained by the frequent occurrence of pruritus and vomiting, as well as the potential risk of respiratory depression [23, 27].

6.2.2 Operating Room Preparation

Apart from the standard operating room preparation before any neurosurgical procedure, specialized modifications are required for pediatric surgery, starting from the modalities to maintain body temperature to resuscitate the child. Before receiving the child in the operating room (OR), the temperature must be maintained in the range of 25–27 °C. Adequate warming apparatuses like warm blankets, air mattresses, or forced air devices, fluid warmers, etc. need to be available and set at appropriate temperature values. It is always advisable to prepare the IV fluid of choice in the correct amount according to the body weight, especially if a neonate is to be operated on. Adequate infusion sets and infusion pumps should be available, loaded with correctly labeled syringes. The anesthetic drugs should be calculated and prepared beforehand, considering the amount of fluid in each syringe. Some anesthesiologists prefer to have a leaflet of measurements and drug dose calculations for each patient ready in the OR beforehand to avoid miscalculations in stressed conditions. It is always advisable to use low-volume syringes (1 ml, 2 ml, and 5 ml) to prepare injectable medications to limit the volume of fluid infused through them, especially in babies prone to get volume overloaded easily. Pediatric-size equipment for positioning should be present beforehand according to the surgeon's discussion regarding the surgical procedure.

The monitor parameters and alarm limits, anesthesia workstation ventilator settings, and breathing circuit should be objectively tailored to

Table 6.2 Summary of anxiolytic premedicants

Agent	Dose and route	Onset	Duration	Contraindications	Special remarks
Midazolam	0.25–0.75 mg/kg (oral) 0.05–0.15 mg/kg (IV) 0.2–0.3 mg/kg (intranasal) 0.5–1.0 mg/kg (rectal) 0.2–0.3 mg/kg (sublingual)	Approx. 20 min on oral administration	45 mins	Emergency surgery Upper airway disease Hepatic/renal derangements Respiratory depression	Paradoxical reactions on IV administration Burning sensation after intranasal spray
Lorazepam	50–100 μg/kg (oral) in children 5–12 years; 1–4 mg (oral) in children 12–18 years	60 min	8–12 h (peak at 2 h)	Respiratory depression	Preferred in bigger children and longer procedures
Temazepam	10–20 mg crushed tablet or as elixir	60 min			
Fentanyl	15–20 μg/kg (transmucosal)	15–20 min			Vomiting Pruritus Respiratory depression
Clonidine	4 μg/kg (oral) 2 μg/kg (intranasal)	30–60 min	6–10 h (peak 2–4 h)	Bradyarrhythmia	Analgesia Anesthesia sparing

IV intravenous

the weight- and surgery-specific intraoperative requirements. The airway and intubation devices should be checked and laid out properly in a separate trolley for easy access. Care should be taken that adequate-size IV cannula is available in sufficient numbers and appropriately sized adhesive tapes are available to secure them. Proper oxygenation and transport equipment/devices should be ready for the child's swift shifting to the postanesthesia care unit (PACU) or pediatric intensive care unit (PICU).

On arrival in the OR, the patient surgical safety checklist should be filled confirming the identity, surgery, surgery site, etc., and standard monitoring should be attached to the child. Anesthesia should be induced with IV medications if the venous access is in place, or one should proceed with inhalational induction in the absence of an IV line.

6.3 Intraoperative Management

6.3.1 Vascular Access

All children presenting for neurosurgery require a properly functioning peripheral IV access appropriate for the neurosurgical entity and its expected perioperative course. In an emergency, intraosseous access should be considered early [28]. Considering the difficulty in obtaining IV access in children as well as the morbid and prolonged nature of hospital stay in children, the choice and site of central venous access should be a carefully weighted one. The decision to institute central venous access in the OR should be based on issues such as expected blood loss/fluid shifts/electrolyte imbalances, procedures at high risk for venous air embolism (VAE), diabetes insipidus (DI), and severe neurological impairment (traumatic brain injury, tumors) expected to require prolonged inotropic and ventilatory support.

A crucial consideration during the placement of IV access is to be mindful of and take effective steps to allay the child's anxiety. Parental presence, breastfeeding, distraction techniques, local anesthetic (LA) creams, and oral sucrose have been shown effective in reducing anxiety and procedural pain during IV access in children [29–32]. Tourniquet, tapping over the vein, local warming, transillumination, and near-infrared devices are established aids that should be considered routine in pediatric neuroanesthesia setups [33–35].

Sedation, GA, and strict asepsis are essential for any procedure establishing central venous access [36–38]. Among the various routes, the internal jugular vein (IJV) and subclavian vein (SCV) are the most preferred central venous catheter (CVC) placements in pediatric neuroanesthesia. However, the femoral route does provide ease of access, lack of interference with cerebral venous return, and avoidance of pneumothorax [39]. In all types of vascular accesses, peripheral, central, and arterial, the role of ultrasound (USG) is well established. USG-guided cannulation is highly useful in guiding catheter placement and determining the appropriate catheter size, confirming catheter-tip placement, and preventing catheter-related complications [40].

In difficult IV access cases in critical scenarios, intraosseous (IO) access is a rapid alternative with a high success rate [29]. In younger children, the proximal tibia, anteromedial aspect, is preferred, whereas, in older children, the distal tibia is a good site [29]. The technicalities of achieving arterial access in children are the same for adults, except that in newborn babies, the umbilical artery also presents itself as a viable option [41].

6.3.2 Induction of Anesthesia

The goal of anesthetic induction is to avoid intracranial hypertension because of associated hypoxia, hypercapnia, and inhalational agent-induced increases in cerebral blood flow (CBF) while avoiding a significant decrease in blood pressure (BP) [42]. The use of thiopentone, propofol, and neuromuscular blockade is commonly practiced in neurosurgery; however, etomidate may be preferred in unstable hemodynamic states [43–45]. Except for ketamine, all IV induction agents cause a reduction in ICP [46, 47]. Inhalational induction with sevoflurane should be preferred in children without IV access or with difficult IV access. The concomitant use of hyperventilation should blunt its effect on increasing ICP. Additionally, sevoflurane has shown beneficial effects on regional cerebral oxygenation and lesser myocardial depression than less-irritant agents such as halothane [48, 49]. In full stomach scenarios with a high risk for gastric aspiration, rapid sequence anesthetic induction with thiopentone or propofol followed by rapid-acting muscle relaxants such as succinylcholine/rocuronium should be practiced. Succinylcholine is contraindicated in spinal cord injury and denervation syndromes; rocuronium is an ideal alternative for rapid sequence induction (RSI) in these cases [50, 51]. The effect of the individual anesthetic agents on neurophysiology is covered in Chap. 3.

Once IV access is secured, boluses of thiopentone (1–2 mg/kg) or propofol can be used to decrease the laryngoscopy response [38]. As all volatile anesthetics increase the CBF, and consequently, the ICP, efforts should be instituted to control ventilation as early in the course of anesthesia as possible.

6.3.3 Intubation (Airway Management)

The principles of airway management in children presenting for neurosurgical procedures have been covered in great detail in Chap. 5. However, from a practical standpoint, this crucial aspect requires an amalgamation of the knowledge of airway peculiarities in the pediatric age group and a high skill level in the use of various airway equipment. It is also imperative to consider the potential interactions of such management with the neurophysiological variables [52–55]. These challenges are further magnified by disease-related distortions of airway anatomy in children presenting for specific neurosurgical procedures (hydrocephalus, craniosynostosis, craniovertebral junction anomalies, etc.). In these patients, especially in view of intracranial hypertension, airway management should be tempered by concomitant use of opioids and hypnotics to avoid any increase in ICP stringently.

The use of cuffed endotracheal tubes (ETTs) is increasingly frequent in pediatric neurosurgery, and there is evolving evidence to suggest an association of uncuffed tubes with subglottic mucosal trauma and laryngospasm especially in

the event of selecting inappropriately larger tube not taking into account the height and weight of child [53, 56]. In cases where cuffed ETT is used, processes should be developed to monitor and adjust cuff pressure [53] routinely.

While oral and nasal routes are used for intubation, the oral route is more extensively used, and the nasotracheal route is limited exclusively to specific indications in pediatric neurosurgery. The nasal route of intubation is especially preferred in complex craniofacial surgeries and some procedures performed in the prone position in small children requiring small-size endotracheal tube. In this group of children, it offers the advantage of increased stability, comfort, and the low propensity of intraoperative kinking in their tiny oropharyngeal cavities [57]. In conditions where nasotracheal intubation is planned, use of topical vasoconstrictors (0.25% phenylephrine or oxymetazoline on cotton-tipped applicators) and gentle dilatation of nares go a long way in decreasing the risk of a nosebleed [58]. However, nasal intubation is contraindicated in the transsphenoidal procedure, choanal stenosis, basilar skull fracture, and sinusitis. Some practical tips during the use of nasotracheal routes include keeping the tube's direction toward the chin and using sutures and wires to secure the tube in prolonged complex neurosurgical and craniofacial procedures.

Especially in neurosurgical positions requiring extreme neck flexion and twisting, the tube's proper length to be fixed should be decided in conjunction with the neurosurgical team to avoid inadvertent migration of the ETT during the procedure. Notwithstanding the intubation route, it is imperative to check for bilateral equal air entry after final positioning and secure the tracheal tube with care and caution to avoid intraoperative airway disasters in a compromised position with limited airway access. In cases of inadvertent extubation, direct laryngoscopy is the go-to rescue airway technique. However, in limited-access conditions, an adequately sized LMA is an important adjunct to maintain oxygenation and ventilation [59]. In "cannot intubate, cannot ventilate" situations during induction as well as in intraoperative airway disasters, the protocols are nearly the same as for an adult population except that a surgical approach is preferred in children <5–6 years of age as the compressible nature of structures precludes a needle cricothyrotomy [60].

The process of extubation in pediatric neurosurgery presents its own set of peculiar considerations. While there is a predilection toward extubation in a deeper plane, the evidence lacks that such a process results in significantly better effects on neurophysiological variables [61–63]. Besides neurosurgical pathologies hampering respiration (e.g., posterior fossa lesions, Chiari malformations), another phenomenon interfering with extubation includes airway edema, macroglossia, and pre-existing pulmonary dysfunction [64, 65]. Generally, an awake child adhering to extubation criteria is a good candidate for the same [66]. However, in problematic cases, prolonged ventilation, head up positioning, and diuresis may need to be employed to mitigate airway edema, while tracheostomy may be needed in severe unresponsive cases [67–69].

6.3.4 Maintenance of Anesthesia

There is ample evidence showing that low exhaled inhalational agent concentration with mild hyperventilation has favorable effects on ICP [39]. There is very little to choose between the use of total IV anesthesia (TIVA) and the administration of volatile agents at the minimum alveolar concentration (MAC) less than 1 (sevoflurane, isoflurane, desflurane). More often than not, a combination of these modalities is used and is acceptable. Opioids such as fentanyl or remifentanil, with or without nitrous oxide, and ventilation with neuromuscular paralysis are part of the standard anesthetic regimen [39, 70]. Halothane, on account of being a potent cerebral vasodilator and consequent intracranial hypertension, is currently out of favor in neuroanesthesia. Sevoflurane is the established agent of choice for inhalational induction. For maintenance of anesthesia, while TIVA is commonly practiced, among inhalational agents sevoflurane and desflurane are preferred to isoflurane because of

their superior recovery profile [70, 71]. Nitrous oxide has been shown to increase ICP and cerebral metabolism, increase the propensity of postsurgery pneumocephalus as well as postoperative nausea and vomiting (PONV) and interfere with intraoperative neuromonitoring. Hence, its routine use may be discouraged in pediatric neuroanesthesia.

While choosing a muscle relaxant, train of four (TOF) monitoring is useful to maintain optimal neuromuscular blockade. The choice of the agent should be based on individual patient characteristics. However, in surgeries requiring intraoperative neuromonitoring (IONM) and intraoperative wake-up (e.g., during spinal cord surgery), the muscle relaxant regimens need to be tapered or abolished completely for a transient period. Subsets of patients on antiepileptic medications usually require larger than normal doses of non-depolarizing muscle relaxants and opioids because of hepatic enzyme induction.

Whereas fentanyl is a commonly used opioid, an increasing half-life on repeat dosing precludes its use in preterm infants with immature hepatic metabolism owing to the possibility of prolonged sedative and respiratory depressive effects. Remifentanil infusions offer the benefit of rapid recovery; however, it is associated with delirium and suboptimal analgesia. There is an increased use of α2-agonist dexmedetomidine in pediatric neurophysiologic monitoring, certain specific procedures such as awake craniotomies, and facilitation in the rapid wake-up after surgery [72–75]. For a detailed effect of anesthetic effects on CNS physiology, the reader is referred to Chap. 3.

6.3.5 Monitoring

The details of monitoring both routine and IONM are interesting and covered in detail in Chap. 8; some salient practical points are highlighted in the next few paragraphs.

An electrocardiography, pulse oximeter, noninvasive BP, sphygmomanometer, capnograph, and a thermometer comprise minimal monitoring for pediatric neuroanesthesia. While instituting neuromuscular blockade monitoring, it is important to remember that nerve stimulator should be placed at a normal neurologic function site to avoid overdosing, which might go undetected if a neurologically depressed nerve is chosen. In surgeries at high risk for venous air embolism (VAE), precordial Doppler ultrasound is recommended. A precordial Doppler, used in conjunction with capnography and arterial catheter, helps detect even minute VAEs. The site just on the right sternal border at the fourth intercostal space on the anterior chest is the best location for the Doppler probe [76]. In surgeries planned for IONM, electroencephalogram (EEG) and other electrophysiological paraphernalia need prior installation in closed coordination between neurosurgeon, neuroanesthesiologist, and neurophysiologist. Urinary output should be measured during prolonged procedures, in cases with anticipated large blood loss, and when diuretics or osmotic agents are administered [76].

6.3.5.1 Hemodynamic Monitoring

Pediatric neurosurgery warrants intense hemodynamic monitoring because of the risk of hemorrhage, VAE, herniation, or brain stem manipulation. Arterial cannulation is the cornerstone of hemodynamic monitoring in such cases. In addition to providing a real-time account of blood pressure, it allows sampling for serial measurements of blood parameters, thereby influencing appropriate metabolic, fluid, and blood component management. The arterial transducer should be ideally zeroed at the level of the head (lateral corner of the eye or the external auditory meatus) to provide an accurate mirror of cerebral perfusion pressure (CPP) [57].

The use of central venous catheters as a vascular access device has already been discussed. The fact that neither do they reliably predict intravascular volume, nor do they seem to be effective in aspiration of air in the event of VAE, has discouraged routine use of a central venous catheter (CVC) in children [77]. However, as reiterated before, CVC (subclavian, IJV, or femoral) might be required in certain neurosurgical scenarios, especially in surgeries expected to have significant blood loss and hemodynamic perturbations [78–80].

6.3.5.2 Neurophysiologic Monitoring

Advanced neurophysiologic monitoring, monitors of cerebral oxygenation, and seizure detection modalities (electrocorticography (ECoG), EEG, electromyography (EMG), transcranial Doppler (TCD), somatosensory evoked potentials (SSEP), motor evoked potentials (MEPs), etc.) are an important cog in increasing the safety profile in cranium and spine surgeries. These are dealt with in more detail elsewhere (Chap. 8). The ergonomic considerations of instituting such monitoring and interaction of anesthetic regimens with such monitoring are important in the perioperative period.

6.3.6 Positioning

The small size of children and the intricacies of neurosurgical access make positioning in pediatric neurosurgery a challenging paradigm. The physiologic effects, indications, and salient points of different neurosurgery positions are similar to those in adults and are elucidated in detail in Chap. 7. Specific implications of positioning in children include generous use of padding, avoidance of head pinning systems in the neonate and small infants, proper positioning of instruments and grounding wires, pinpoint positioning of the tracheal tube in the airway, access to the airway and vascular ports under drapes, and avoidance of extreme head positions with a propensity for brain stem compression and cervical spinal cord ischemia [57, 81]. Positioning is an integral part of neuroanesthesia care and is covered in detail in Chap. 7.

6.3.7 Fluid and Blood Component Therapy

Blood component therapy in pediatric neurosurgery should elicit close cooperation between the anesthesiologist and the neurosurgeon. Important factors to consider would be the preoperative hematocrit, the child's weight, the location and type of surgical pathology, and comorbidities affecting tissue oxygenation. Especially in surgeries where life-threatening bleeding is expected, a clear management plan encompassing blood conservation strategy, an accurate estimation of ongoing blood loss, and keeping blood products ready and accessible are critical to the overall outcome of the surgery [82]. Assessing ongoing blood loss in neurosurgery, especially in children, is an onerous task because of drapes and use of Mayo trolley. Use of overhead cameras, monitoring of suctioned blood in calibrated containers, serial hematocrit estimations on arterial blood gas (ABG) analysis, and monitoring of coagulation parameters on thrombo-elastography (TEG) are recommended to guide blood component therapy [57]. There is no definite transfusion threshold. Factors enumerated before should be used to decide when to transfuse. However, blood product administration usually commences at a hematocrit of 21–25%, to which point of time losses should be managed by crystalloids and colloids [39].

The intricacies of fluid management will be covered in Chap. 10. However, it is important to understand that perioperative fluid management affects cerebral blood flow, potentially worsens brain edema, and affects electrolyte and glucose homeostasis. Generally speaking, normal saline is a common fluid in perioperative pediatric neurosurgery, barring premature infants in whom glucose-containing solutions assume significance [83]. However, certain caveats to the routine use of normal saline are beyond the scope of this chapter. Especially in lesions affecting the pituitary, such as craniopharyngioma, alternative IV fluids may need to be considered [84]. The routine use of cerebral decongestant therapy in mannitol and hypertonic saline also greatly affects perioperative fluid therapy. Simultaneously, loop diuretics have a place only in the scenario of fluid overload [57].

6.3.8 Glucose Homeostasis

Children are at significant risk of developing and suffering the disastrous effects of hypoglycemia. These are more pronounced in premature infants and sick neonates due to their limited gluconeo-

genesis and scarce glycogen reserves. The increased vulnerability of children to perioperative hypoglycemia necessitates stringent monitoring of glucose levels and may mandate continuous infusions of glucose at a rate of 5–6 mg/kg/min if blood glucose levels drop below 60 mg/dl [85]. At the other end of the spectrum, the relative insulin resistance caused by the stress response to surgery and critical illnesses has a high propensity to cause hyperglycemia with deleterious effects in the neurologically injured patients in the setting of cerebral ischemia [86, 87]. There is no doubt that hyperglycemia causes significant secondary damage to the already neurologically compromised brain, but a tight glycemic control with resultant hypoglycemia has shown no advantage either [88]. More recently, there has been a trend to steer clear of tight glycemic control practice because of significant evidence of the detrimental effects of resultant hypoglycemia [89]. In the present scenario, it is pertinent to diligently monitor and maintain the blood glucose levels at a conservative value of less than 180 mg/dl in an attempt to thwart the disastrous effects of hypoglycemia resulting from tight glycemic control, keeping in mind the vulnerabilities of the pediatric age group.

6.3.9 Temperature Regulation

Whereas thermoregulation is discussed in Chap. 9, preserving body heat in children during anesthesia is vital to decrease oxygen consumption and prevent hypoxemia. Maintenance of OR temperature of 25–27 °C, warm air convection blankets, heater humidifiers in the breathing circuit, overhead heaters, heating mattresses, and fluid warmers are effective strategies to regulate body temperature [90].

On the other end of the spectrum, despite favorable effects in traumatic brain-injured children, the incidence of complications such as coagulation abnormalities prevents the routine use of hypothermia in pediatric neurosurgical practice [91]. Hence, normothermia using active warming modalities is the intraoperative temperature goal [91].

6.3.10 Intraoperative Complications

Major adverse events in children undergoing neurosurgery are an important cause of morbidity and mortality associated with these procedures. The intraoperative complications might be surgical, anesthesia-related, pathology-related, or a result of the underlying critical illness. These complications are reported in up to 40–50% of cases. The most commonly encountered are hemorrhage, seizures, fluid and electrolyte disturbances, and coagulation disorders besides anesthesia-related complications specific to children [92]. Various factors like the urgent nature of these procedures, inherently associated comorbidities (such as prematurity), difficulty in establishing vascular access, and problems specific to the neurosurgical subgroup like impaired communication, sedation, and neurological deficits have been shown to increase morbidity and mortality in these patients [93].

Anesthesia-related complications might be mild, such as vomiting, laryngitis, and mild oral cavity lesions, or have serious ramifications. These include hypoxia, bradycardia, cardiac arrhythmia after anesthetic induction, dental fractures (intubation), bronchospasm, aspiration pneumonia, postoperative apnea, and anaphylaxis [94]. Besides the demographics like age, physiological, immunological, and laboratory conditions, a major contributor to these complications is the duration of anesthesia and surgery [95].

Every possible precaution should be taken to avoid an increase in ICP during the anesthetic and surgical maneuvers in these subsets of patients who are already at the edge of intracranial decompensation due to the underlying pathology. Steps should be tailored to prevent catastrophic consequences like mass effect and brain herniation as a result of even the smallest hemodynamic or ventilatory change. Pharmacological intervention should be preemptively undertaken at the time of ICP elevating procedures like laryngoscopy, rapid sequence orotracheal intubation, pin insertion, periosteum elevation, etc. [93, 96].

At all points of time in the intraoperative period, a meticulous awareness of the volume losses and prompt replacement with fluids and blood component therapy as necessary go a long way in preventing complications related to anemia and dehydration, especially in high-risk cases like craniosynostosis repairs, craniopharyngiomas, meningiomas, and vascular neurosurgeries. Intraoperative hypothermia and hyperthermia contribute to secondary brain injury and should be watched out for [93, 97].

A notorious intraoperative complication closely associated with intracranial surgeries is VAE. Augmented by the pressure discrepancy between the operative site and the heart (the heart is lower than the operative field) and a low central venous pressure (hypovolemia), it results in significant air entrainment in the central circulation. The inability of dural venous sinuses to collapse and the presence of spinal epidural and bridging veins predispose these children to the consequences of VAE. The management of VAE is largely based on actions to identify the problem, stop further air entrainment, and support the circulation, the details of which are explained in Chap. 7.

6.3.11 Emergence

Needless to say, the process of emergence and extubation is highly critical to the outcome of neurosurgery because of effects on ICP and postsurgical bleeding inside close cavities (cranium and spinal canal). PONV in neurosurgery is multifactorial, but in general, it is mostly because of the high emetic potential of blood in CSF compounded by headache and use of opioids. Multimodal techniques should be used to ameliorate the same and are discussed in great detail in Chap. 37. Among intravenous agents explored to control the extubation reflex in children undergoing neurosurgery, fentanyl, lignocaine, and dexmedetomidine have shown promise as effective agents. Autonomic blockers such as labetalol are effective in adolescents. However, while shown to be effective in the adult population, esmolol does not fulfill the safety criteria for use in children because of its predominant effect on the heart rate, a vital cog of the cardiac output in children. Adequate pharmacological reversal of neuromuscular blockade, confirmation of spontaneous ventilation and oxygenation, and an awake child are prerequisites for extubation in a child who has undergone neurosurgery. In cases of a stormy intraoperative course or children not meeting respiratory and neurological criteria for extubation, it is advisable to shift the child to a facility for postoperative ventilation while simultaneously employing methods to monitor intracranial hypertension (ICP monitoring and CT evaluation) [57].

6.4 Postoperative Care

6.4.1 PACU Considerations

Postanesthesia care should address concerns of the pediatric age group and oversee the recovery of the CNS. It should be viewed as a high specialty continuum of care from the intraoperative period [98, 99]. For clarity, practical recommendations for the organization of neurosurgical PACUs, care during the transition of these children from the operating room to these PACUs, and the specific entities requiring specialized care have been presented.

6.4.1.1 Organization of PACU

The pediatric neurosurgical PACU should be designed keeping in view the following factors [100]—(1) pediatric age group anthropometrics and relevant infrastructure in terms of monitoring, beds, drugs, airway, and other equipment and drug cards detailing pre-calculated drug dosage [101], (2) provisions to include the child's family in the postoperative care of these patients [100], and (3) a team having expertise in pediatric neurocritical care with evolving competencies in pediatric and neonatal advanced life support [102, 103].

6.4.1.2 Transport and Handover

Ideally, the PACU should be located as close to the operating room as possible. Before transport

to the PACU, a clear chain of communication with certain specific points should be established like patient specifics, the perioperative course, and specific concerns, if any. The postoperative plan, including clinical decision regarding extubation and need for mechanical ventilation, should also be clearly communicated to the PACU team [100, 104]. Important considerations should be ensured while shifting (Table 6.3).

6.4.2 Specific Entities in PACU

6.4.2.1 Emergence Delirium

A thrashing, disoriented, crying, screaming, and inconsolable child in the PACU is common, especially in the age group of 2–6 years [105, 106]. It has shown an association with the newer inhalation anesthetics, and it is usually a one-off self-limiting episode [107, 108]. In neurosurgical subsets, it has the potential to increase ICP. Several drugs such as dexmedetomidine, propofol, ketamine, magnesium, and midazolam and modalities such as regional anesthesia and acupuncture have shown efficacy in prophylaxis. IV agents may at times be required to treat intractable cases albeit with parental consent [100].

Table 6.3 Important considerations during ICU handover

• Detailed monitoring preferably under the direct supervision of the anesthesia team in the operating room
• Lines and catheters should be ensured to be in working condition; emergency drugs should be handy
• Keep the child warm during transit
• Keep transit times as a short as possible in children
• Adequate provisions for ventilatory, hemodynamic, and other emergency supports
• Effective pre-shifting communication to the patient receiving team
• In children who are awake and extubated—a high index of suspicion for hypoxic events, adherence to stringent monitoring protocols as well as safety in the form of guard rails, padding, and lateral decubitus position
• A detailed handover with the incorporation of checklist and protocols—efforts to decrease human error while shifting are warranted in pediatric PACUs [99]
• Advisable for the operating room team to remain with the child during the initial stabilization and handover in the PACU the receiving team has comfortably assumed responsibility of the child

6.4.2.2 Pain Management

Till not so long ago, pain perception in children was highly trivialized, to the point of being virtually nonexistent. However, in the past two decades, there has been a burgeoning amount of evidence that neonates and young children perceive and react to pain just the same as adults [109]. Another postulate that has been challenged recently is intracranial structures being pain insensitive. Post-craniotomy pain is a significant entity and requires optimum management in the postoperative period, especially in children [110]. In pediatric neurosurgery, the present pain management method is a multimodality approach targeting pain at various peripheral, spinal, and supraspinal sites. This approach results in better pain management than targeting only one site and is the underlying principle of treating pain in a multimodal fashion [110, 111]. It offers the advantage of utilizing various drugs described in the subsequent text to obtain maximum pain relief and minimize drug-related adverse effects on the CNS in children. The intricacies, routes, and dosages of postoperative pain management in children undergoing neurosurgeries will be covered in Chap. 38. Here, the general considerations of the two major pharmacological groups for postoperative pain, i.e., opioids and non-opioids, are elaborated.

Opioids

Opioids have been the mainstay of postoperative pain management. Still, their common side effects like nausea, vomiting, and sedation have deleterious effects on cerebral physiology in the form of increased $PaCO_2$ and cerebral vasodilation, consequently leading to cerebral edema and a disastrous increase in ICP. Despite these potential pitfalls, they continue to remain an integral part of perioperative pain management. The choice of opioid, dose, and administration route is based on practitioner preference, institutional protocol, and drug availability.

However, IV route should be preferred in the contiguous postoperative period. For IV therapy, drugs found efficacious are morphine, fentanyl, and hydromorphone. Among oral opioids, oxycodone is preferred over codeine. One should always be aware of the common side effects of opioid use like nausea, vomiting, pruritus, constipation, and urinary retention while being vigilant of the more ominous respiratory depression necessitating increased monitoring such as capnography and integrated acoustic sensors [111, 112].

Non-opioids

The non-opioid analgesics, even though exhibiting lesser efficacy than their opioid counterparts, have effectively reduced opioid requirements. They are a quite diverse and heterogeneous group of anesthetic adjuvants. The most common non-opioids used in postoperative pediatric neurosurgery are acetaminophen (paracetamol) and nonsteroidal anti-inflammatory drugs (NSAIDs) such as diclofenac, ibuprofen, naproxen, and the selective cyclooxygenase (COX-2) inhibitors (celecoxib) [113]. They have myriad actions of analgesia, antiplatelet, and antipyretic effects. They also have anti-inflammatory action by blocking peripheral and central prostaglandin and thromboxane production by inhibiting cyclooxygenase types 1, 2, and 3 and can be administered through various routes. A significant limitation of this class of drugs is a ceiling effect, which has led to an offshoot of combination forms with opioids such as codeine, oxycodone, or hydrocodone. However, inadvertent liver toxicity, especially with acetaminophen formulation, is a real concern and must be avoided [114]. The major non-opioids in addition to those enumerated above are used as adjuncts and are corticosteroids, α2 adrenergic agonists (clonidine, dexmedetomidine, tizanidine), local anesthetics (lignocaine, bupivacaine, ropivacaine), nerve blocks (scalp block), and NMDA receptor antagonists (methadone). Details about mechanisms, routes, dosages, efficacy, side effects, and practical implications of these adjunct pharmacological agents in pediatric neurosurgical practice are covered in Chap. 38.

6.4.2.3 Adverse Respiratory Events and Mechanical Ventilation

Adverse respiratory events are common and represent an alarming two-thirds of critical events during the perioperative period in children [115]. The affliction of the CNS, which houses the vital respiratory centers, complicates matters manifold. A very close watch is mandated for respiratory insufficiency in neurosurgical children extubated, whether on the OR table or in the PACU.

A number of pediatric neurosurgical patients require ventilatory support, the period of ventilation is within 24–48 h to allow for effects of surgery to wear off, and assisted modes of ventilation are recommended to allow for ongoing neurological assessment. In children with poor lung mechanics, the effects of a conventional lung-protective strategy of low tidal volume, pressure-limited approach should be weighed against the effects of carbon dioxide retention and intracranial hypertension [39]. Effects on ICP are absent as long as the sutures and fontanelles are open [116]. A sizeable number of neonates and infants require controlled ventilation and sedation with muscle relaxants primarily because of severe neurological injury. The multiple systemic effects of the same, however routine use, are not advocated [117].

6.4.2.4 ICP Monitoring and Management

In children presenting with trauma and tumors, ICP monitoring is a routine of care at many centers and signifies ongoing intracranial hypertension even in CT changes [118]. Among the modalities available, intraventricular catheters offer therapeutic options and are the most widely used [39]. The methods used to manage intracranial hypertension include hypertonic saline (beware of hypernatremia), crystalloid therapy, use of steroids, and limited hyperventilation. Hyperventilation has been associated with reversible ischemia in children and should always be done in conjunction with monitoring blood gas and end-tidal carbon dioxide values [100].

6.4.2.5 Fluid and Electrolyte Disturbances

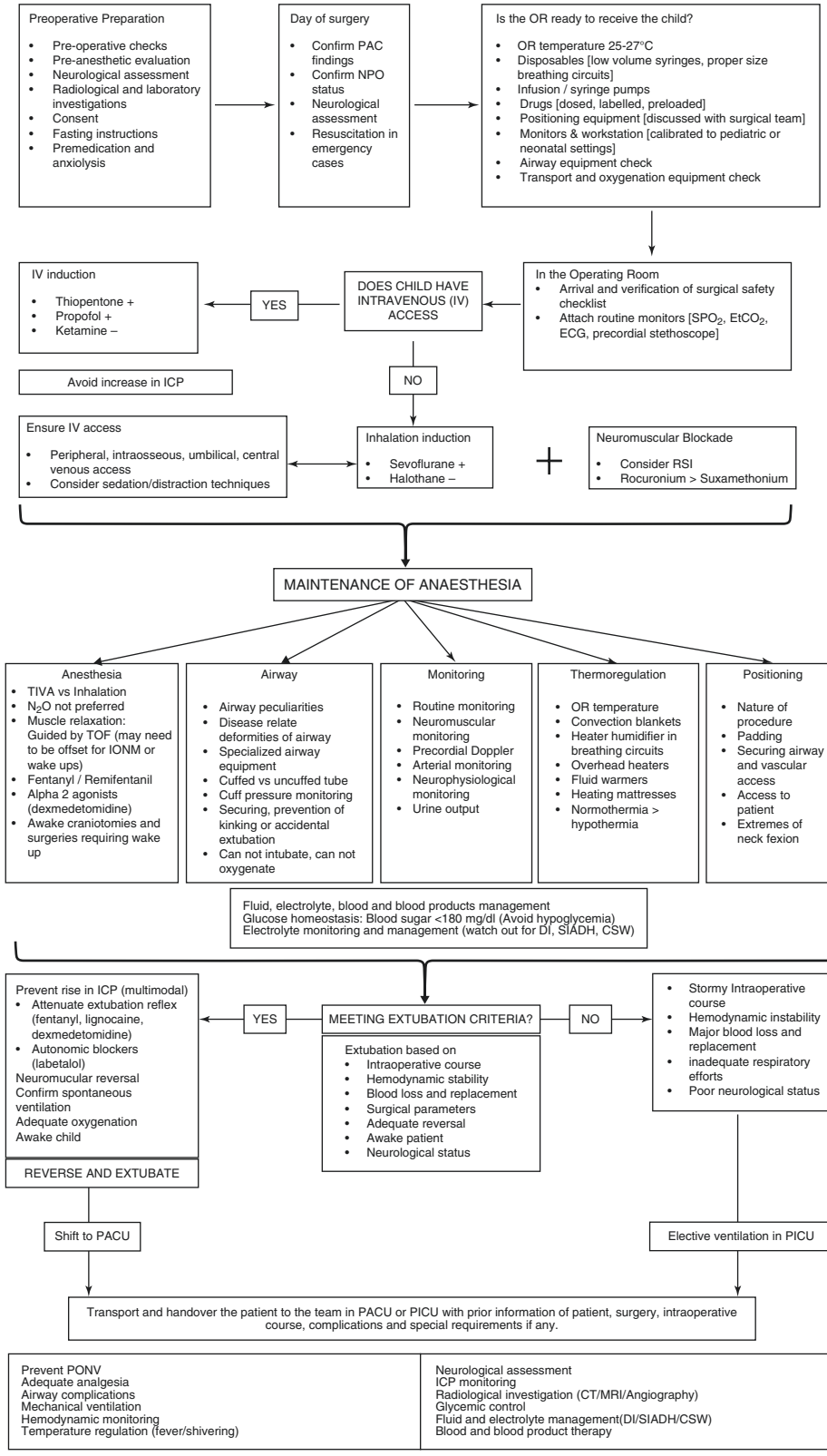
Inherent physiological considerations of pediatric neurosurgical patients like minuscule size, immature renal function, and impaired or varied intake of fluids, magnified by the effects of existing pathology and surgery on the brain, disrupt electrolyte fluid control mechanisms. This leads to severe disturbances in serum sodium and osmotic pressures in up to 10% of children undergoing neurosurgery and usually results in one of the three essential perioperative fluid and electrolyte disorders—viz., SIADH, diabetes insipidus, and CSW [119]. The details of these disorders are presented in Chap. 10. However, it is important to be very watchful for their timely diagnosis during the perioperative period as well as take timely and prompt corrective measures to mitigate evolving systemic and neuronal injury. Protocol-based diagnosis is especially important, especially because treatment modalities of these disturbances are radically different and should combine lab values of electrolytes and osmolarity in conjunction with urine output and subtle clinical signs such as hyponatremic seizures. The importance of having a strong suspicion for and dismissing and treating these disorders timely cannot be overstated, and they have a significant effect on the neurosurgical outcome.

6.5 Conclusion

Anesthetizing children for neurosurgery is challenging; nonetheless, applying sound pediatric neuroanesthesia principles in conjunction with effective postoperative neurocritical care should go a long way in delivering state-of-the-art, safe anesthesia care. An attempt to schematically represent children's care presenting for brain tumor surgery has been made as a case in point (Fig. 6.2). The aim should be to develop evidence-backed protocol-based processes involving multiple disciplines to improve outcomes and decrease morbidity in children undergoing neurosurgical procedures.

Conflict of Interest Nil.

Fig. 6.2 Schematic flow diagram of the entire perioperative management of a pediatric neurosurgical patient. Abbreviations: *PAC* pre-anesthetic checkup, *NPO* nil per oral, *OR* operating room, *IV* intravenous, SPO_2 pulse oximetry, $EtCO_2$ end-tidal carbon dioxide, *ECG* electrocardiogram, *ICP* intracranial pressure, *RSI* rapid sequence intubation, *TIVA* total intravenous anesthesia, N_2O nitrous oxide, *TOF* train of four, *IONM* intraoperative neurophysiologic monitoring, *DI* diabetes insipidus, *SIADH* syndrome of inappropriate antidiuretic hormone secretion, *CSW* cerebral salt wasting, *PICU* postanesthesia care unit, *PONV* postoperative nausea and vomiting, *CT* computed tomography, *MRI* magnetic resonance imaging


Preoperative Preparation
Pre-operative checks
Pre-anesthetic evaluation
Neurological assessment
Radiological and laboratory investigations
Consent
Fasting instructions
Premedication and anxiolysis
Day of surgery
Confirm PAC findings
Confirm NPO status
Neurological assessment
Resuscitation in emergency cases
Is the OR ready to receive the child?
OR temperature 25-27°C
Disposables [low volume syringes, proper size breathing circuits]
Infusion / syringe pumps
Drugs [dosed, labelled, preloaded]
Positioning equipment [discussed with surgical team]
Monitors & workstation [calibrated to pediatric or neonatal settings]
Airway equipment check
Transport and oxygenation equipment check
In the Operating Room
Arrival and verification of surgical safety checklist
Attach routine monitors [SPO2, EtCO2, ECG, precordial stethoscope]
DOES CHILD HAVE INTRAVENOUS (IV) ACCESS
YES
IV induction
Thiopentone +
Propofol +
Ketamine –
Avoid increase in ICP
NO
Ensure IV access
Peripheral, intraosseous, umbilical, central venous access
Consider sedation/distraction techniques
Inhalation induction
Sevoflurane +
Halothane –
Neuromuscular Blockade
Consider RSI
Rocuronium > Suxamethonium
MAINTENANCE OF ANAESTHESIA
Anesthesia
TIVA vs Inhalation
N2O not preferred
Muscle relaxation: Guided by TOF (may need to be offset for IONM or wake ups)
Fentanyl / Remifentanil
Alpha 2 agonists (dexmedetomidine)
Awake craniotomies and surgeries requiring wake up
Airway
Airway peculiarities
Disease relate deformities of airway
Specialized airway equipment
Cuffed vs uncuffed tube
Cuff pressure monitoring
Securing, prevention of kinking or accidental extubation
Can not intubate, can not oxygenate
Monitoring
Routine monitoring
Neuromuscular monitoring
Precordial Doppler
Arterial monitoring
Neurophysiological monitoring
Urine output
Thermoregulation
OR temperature
Convection blankets
Heater humidifier in breathing circuits
Overhead heaters
Fluid warmers
Heating mattresses
Normothermia > hypothermia
Positioning
Nature of procedure
Padding
Securing airway and vascular access
Access to patient
Extremes of neck fexion
Fluid, electrolyte, blood and blood products management
Glucose homeostasis: Blood sugar <180 mg/dl (Avoid hypoglycemia)
Electrolyte monitoring and management (watch out for DI, SIADH, CSW)
MEETING EXTUBATION CRITERIA?
YES
Prevent rise in ICP (multimodal)
Attenuate extubation reflex (fentanyl, lignocaine, dexmedetomidine)
Autonomic blockers (labetalol)
Neuromuscular reversal
Confirm spontaneous ventilation
Adequate oxygenation
Awake child
REVERSE AND EXTUBATE
Shift to PACU
NO
Extubation based on
Intraoperative course
Hemodynamic stability
Blood loss and replacement
Surgical parameters
Adequate reversal
Awake patient
Neurological status
Stormy Intraoperative course
Hemodynamic instability
Major blood loss and replacement
inadequate respiratory efforts
Poor neurological status
Elective ventilation in PICU
Transport and handover the patient to the team in PACU or PICU with prior information of patient, surgery, intraoperative course, complications and special requirements if any.
Prevent PONV
Adequate analgesia
Airway complications
Mechanical ventilation
Hemodynamic monitoring
Temperature regulation (fever/shivering)
Neurological assessment
ICP monitoring
Radiological investigation (CT/MRI/Angiography)
Glycemic control
Fluid and electrolyte management(DI/SIADH/CSW)
Blood and blood product therapy

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