Perioperative patient management in pediatric neurosurgery

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Summary

Objectives: To describe the main pathophysiological differences in neurosurgical procedures between children and adults; the main complications and adverse events resulting from pediatric neurosurgery reported in studies; the singularities in anesthetic and intraoperative management in several neurosurgical diseases; the more specific and common complications and their management in the most frequent pediatric neurosurgical procedures, as well as causes and treatment for the main complications found in children undergoing neurosurgery. **Methods:** A non-systematic review in literature databases PubMed, EMBASE, and SciELO was performed by using the keywords "pediatrics", "children", "neurosurgery", "risk factors", "intraoperative complications", and "postoperative period", as well as their matches in Portuguese and Spanish from January 2001 to January 2011, in addition to using important references from the selected material over any period of time. **Results:** The three procedures most commonly performed in children are hydrocephalus, craniostenosis repair, and brain tumor resection. Complications as fever, bleeding, metabolic disturbances (hyponatremia and hyperglycemia), brain swelling, and transient focal deficits (limb weakness, speech and swallowing disorders) are frequent but their course is often towards prompt improvement. Up to 50% of children may have an uneventful evolution over the postoperative period. Special attention must be given to the prevention of postoperative infections and seizures with the use of a drug therapy that suits each case. **Conclusion:** The complexity of neurosurgical procedures in children is increasing, and observation and recognition of complications in pediatric intensive care units are fundamental. Anticipating complications in order to achieve an early treatment and adverse event prophylaxis can contribute to reduced morbidity and mortality and increased patients' safety.

Keywords: Neurosurgery; pediatrics; risk factors; morbidity; postoperative care.

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Introduction

The increased complexity and improvement of care and monitoring for children undergoing neurosurgical procedures has been marked over last years. Neurosurgical patients are usually complex, and in almost all cases, need postoperative monitoring in an intensive care unit. The most frequent complications reported in medical literature are bleeding, seizures, sodium disturbances, and coagulation disorders. Case studies find a mean of 40% to 50% of cases with no postoperative complications[1]. Most patients referred to a pediatric neurosurgeon have already obtained a baseline diagnosis. The widespread use of computed tomography (CT) and magnetic resonance imaging (MRI) has reduced diagnostic difficulty; consequently, as in other surgical specialties, pediatric neurosurgeons often see the investigational process inversely from diagnosis[2].

In this setting, it is relevant to list a number of important characteristics distinguishing procedures performed by pediatric surgeons from those performed by adult neurosurgeons. Rekate, in a review article published in 2009[3], discusses the anatomophysiologic particularities of pediatric neurosurgical patients. The types of brain tumors treated by pediatric neurosurgeons are different from those treated by general neurosurgeons. Craniocerebral trauma experimented by children tends to progress with less brain mass injury compared with adult trauma. Spinal cord development features in children and congenital and inherited diseases of these patients make the decision process for how to act during surgical procedures different from the process in adults. Congenital defects in central nervous system are seldom corrected by a single surgery – indeed, they are usually lifetime challenges. In addition, hydrocephalus, which might occur in any age, is much more challenging from a clinical and surgical prospective, when its onset is in infancy or childhood. These conditions stress the unique surgical challenges for the pediatric age group these patients face.

With increasing demand and complexity of neurosurgical patients over the last years and ongoing technological advances in the area, there is an increased need to develop measures to improve care and assure uniform patient management. Technological and therapeutic advances have increased over the last decades, including alteplase use in ischemic stroke, hypothermia for neuroprotection after a cardiac arrest, improvement in monitoring craniocerebral trauma, and use of devices for intravascular cooling in cases of intracranial bleeding[4].

Thus, the need for knowledge of the major adverse events in children undergoing neurosurgery is increasingly important in the development of preventive measures and prompt treatment, in order to reduce the morbidity and mortality associated with these procedures. This review aims to:

- Describe the main surgical management of neurological diseases during childhood and present the causes and management of major complications, general and specific, of the more frequent procedures in children undergoing neurosurgery, according to the latest publications
- Describe the recommendations for prophylaxis of infections and seizures in the postoperative period
- List and discuss the most common general complications in pediatric neurosurgical patients, as well as submit proposals for each specific therapeutic complication.

Surveillance of adverse events and mortality in pediatric neurosurgery

In pediatric neurosurgery, the assessment of adverse events and risk factors of morbidity and mortality is rare, and little is known about the complications of surgical events. Children undergoing neurosurgical procedures may presumably have more complications when compared to adults. Factors such as need for emergency procedures, severe associated comorbidities (such as prematurity), and other complications inherent to the age group as communication difficulties, sedation, and intravenous access can significantly increase morbidity and mortality in these patients.

The risks and complications associated with anesthesia can be divided into minor or serious. Minor risks include inflammation of the oropharynx, nausea and vomiting, laryngitis, and mild lesions of the oral cavity, which are frequent but present low morbidity and short duration. More serious complications include dental fractures at the time of intubation for airway aspiration, aspiration pneumonia, postoperative apnea, anaphylaxis, hypoxia, bradycardia, and cardiac arrhythmia after anesthetic induction[5]. Factors that may contribute to increased incidence of anesthetic complications in children include age; physiological, immunological and laboratorial conditions; duration of anesthesia and surgery; and urgency of the surgical procedure[6].

Drake et al.[7] studied complications associated with 1,082 pediatric neurosurgical procedures. Among the procedures listed, the most frequent were cerebrospinal fluid shunts (38.4%) and brain tumor surgeries (17.5%). Overall, complications were described in 16.4% of total procedures, a significantly lower rate compared with previous studies. Among the complications, fistula (17.5%), new focal neurologic deficit (15.3%), obstruction shunt (15.3%), infected shunt (13.6%), postoperative bleeding (6.8%), wound infection (5.6%), postoperative bleeding (5.1%), and pneumonia or respiratory complications (4%) were reported.

Aleksic et al.[8] retrospectively studied anesthetic complications in 705 children up to 15 years of age undergoing elective neurosurgical procedures or after severe craniocerebral trauma. Anesthetic complications occurred in 68 patients, with 29 of them occurring during induction and 39 during surgery and anesthesia maintenance. Reported complications were bradycardia (2.69%); cardiac arrhythmias (0.71%); other complications, such as spontaneous breathing cessation, high blood pressure, air embolism, bleeding, bronchospasm, and hypoxemia were observed in less than 1% of patients.

Anesthesia in the pediatric neurosurgery patient

Every pediatric anesthetic procedure is a challenge for the anesthesiologist. It is important to have in mind that children are unique from a pathophysiological and psychological perspective. Moreover, the selection of appropriate anesthetic techniques and drugs will positively impact the postsurgical outcome, minimizing the risk of future neurological complications and sequelae[9].

Preoperative preparation and intraoperative management features

High intracranial pressure (ICP) is one of the main features to be assessed prior to surgery, although the emergency characteristic of the procedure associated with this condition frequently may not allow for an appropriate preparation[10]. Patients with behavior, speech or eating disorders, as well as vomiting not preceded by nausea, lethargy, or irritability are at risk for high ICP. Older children may complain of headache and double vision. An irregular respiratory rate (Cheyne-Stokes) may develop in the presence of severe high ICP, as well as a Cushing triad (bradycardia, high blood pressure, and irregular respiratory pattern) in the presence of uncal herniation. Even in the absence of clinical decompensation signs, an intracranial injury with mass effect can impair brain parenchyma elasticity, so that a small hemodynamic or ventilatory change could cause rapid increases in ICP and severe complications.

Preoperative anamnesis is of paramount importance and must assess ICP, possible difficulties in orotracheal intubation, and cardiorespiratory conditions which might be associated with handling tumors in the posterior cranial fossa. Other problems, such as changes in cardiac anatomy increasing the risk for thromboembolic events and stroke should be identified; anemia and dehydration must be promptly corrected. Appropriate monitoring and apparatus are key for conducting anesthesia.

Drugs reducing high ICP peaks associated with laryngoscopy, as well as reducing the brain metabolic rate so that the organ oxygen consumption can be reduced should be employed in specific high ICP contexts, such as rapid sequence orotracheal intubation. Among drugs, lidocaine (1 mg/kg) and thiopental (3-5 mg/kg) use is advocated in order to reach targets, as illustrated in Figure 1[11]. Another fundamental feature is intraoperative fluid management. The anesthesiologist must be aware of volume losses over the procedure, particularly in craniostenosis repairs, where blood transfusions are almost universally required. Hypoosmolar solutions (such as lactated Ringer's, whose osmolality is 273 mOsm/L) must be avoided, in order to prevent interstitial edema. Perioperative corticosteroid use is controversial, even though they are often used; they can have an anti-hypertensive action, reducing brain swelling and consequently ICP. Among authors advocating their use during surgical procedure, dexamethasone 0.1 to 1.0 mg/kg is preferred.

Body temperature control is key, and both extremes must be avoided – fever is known to worsen brain injury secondary to ischemia or trauma, and hypothermia has metabolic and cardiovascular effects[12]. Hypothermia causes many important deleterious physiological consequences, which increase perioperative morbidity, namely[13]:

- Increased myocardial ischemia in adult patients at risk;
- Increased incidence of coagulation disorders and need for blood components transfusion;

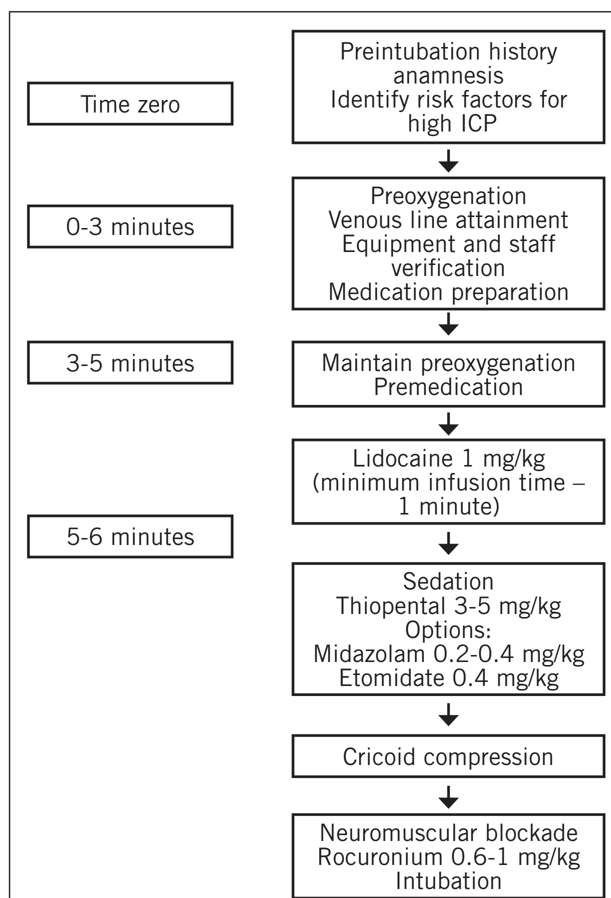

Figure 1 – Flow chart for a rapid sequence intubation in patients with high intracranial pressure (ICP).

- Damaged cell and humoral immunity function, with increased risk for infections and postoperative hospitalization;
- Alterations in the pharmacokinetics of general anesthetics, extending postanesthetic distress.

Despite the fact that hypothermia reduces metabolism rate and brain oxygen consumption, its use must be cautious in pediatrics, since children can develop severe hypothermia due to their larger body surface area compared with adults. Just after anesthetic induction, body temperature undergoes an internal redistribution to peripheral compartments, followed by a stage of heat loss to the external environment. It is not rare for a patient to have hypothermia shortly after arriving at the operating room, and heating methods, such as warm blankets and preheated crystalloid solutions infusion should be promptly available.

Most frequent conditions in pediatric neurosurgical patients

Surgical care in patients with hydrocephalus: ventriculoperitoneal shunt and third ventricle endoscopic ventriculostomy

Hydrocephalus is a clinical syndrome with different definitions. It is clinically defined as an abnormal CSF accumulation in the intracranial cavity; it is radiologically defined as a ventricular dilatation, or increased diameter of both lateral ventricle temporal horns ≥ 2 mm; it is anatomically defined as a lateral ventricle frontal horn extending beyond the genu of the *corpus callosum*[14].

This syndrome may be congenital or acquired and one of the most commonly found conditions in neurosurgical centers across all age groups. Clinical presentation depends on the age of onset and the most deleterious effects result from neuronal and glial cell injury due to increased ICP. In some cases, an emergency neurosurgical intervention may be required to minimize neuronal injury.

Hydrocephalus with an early onset is significantly different from the adult-onset form. In adults, there are a few hydrocephalus causes, such as tumors, meningitides, and bleeding, and the site of ventricular drainage obstruction can be observed with great accuracy and represents a specific obstruction point[15]. In the pediatric age group, potential causes of hydrocephalus are not only related to the three main causes seen in adults (tumor, bleeding, and infection), but are also related to brain development abnormalities causing CSF drainage obstruction. In addition, radiological definition of these obstructions can be difficult[16]. Thus, it is often difficult to determine which obstruction points are the origin of the hydrocephalus, and the same patient can have many obstruction points, which makes the surgical approach of the condition much more difficult[17].

Hydrocephalus diagnosis is based on imaging studies, currently head CT or MRI. However, diagnosis was formerly made by using ventriculography and angiography, and later, by transfontanelar ultrasound.

Main postoperative complications

Currently, ventriculoperitoneal shunt placement, either by an open procedure or an endoscopic ventriculostomy, is the main aspect of hydrocephalus treatment. The latter requires higher technical ability and superior materials; however, it presents lower complication and morbidity rates due to fewer postoperative infections.

Sepsis has been reported as one of the most frequent and severe complications in ventriculoperitoneal shunting, with most cases arising intraoperatively. Coagulase-negative *Staphylococcus* bacteria (especially *Staphylococcus epidermidis*) are frequent, but infections from Gram-negative organisms, such as *Bacillus* sp., can also occur. Infection remains the most significant early complication in ventriculoperitoneal shunting, with a reported incidence ranging from 3% to 20%, and a mean between 5% and 10%[18]. Shunt-related infections not only imply longer hospitalization but they can also result in severe neurological complications, especially if the infection is caused by a gram-negative organism.

A widely studied practice in the United States and Europe, which is not current used in Brazil, is the antibiotic-impregnated ventricular shunt catheters, which can be related to reduced infection rates and consequent benefits, as infection is the main complication resulting from ventriculoperitoneal shunting[19].

The child with craniostenosis

The premature closure of cranial sutures results in craniostenosis (or craniosynostosis) and may cause craniofacial dysmorphism with brain growth impairment and cognitive development retardation if not appropriately treated[20]. The estimated incidence of this condition is approximately 0.6 per 1,000 births. Syndromic craniostenoses occur in approximately 20% of cases and usually affect two or more sutures. Over 150 syndromes that can include craniostenosis as part of their clinical presentation have been identified; Apert and Crouzon syndromes are the most frequent. In these conditions, both coronal sutures are usually affected (an abnormality termed brachycephaly); in addition, patients may present with midline hypoplasia and obstructive sleep apnea resulting from airway anatomical defects[21].

The main complication of operative management in patients with craniostenosis is coping with the inevitable and often significant blood losses occurring during these procedures. This becomes even more important if the fact that the majority of these surgeries are performed on infants is taken into account. Koh[22], in a non-systematic review on craniostenosis surgical management, identified studies estimating surgery blood loss. Meyer and et al.[23] found a perioperative blood loss of 91 ± 66% of the estimated blood volume. Kearney et al.[24] reported a mean loss of 24% of the blood volume in sagittal suture repair, 21% for unicoronal repair, 65% for bicoronal repair, and 42% in metopic suture repair; indeed, blood transfusion is almost inevitable in craniostenosis surgery, estimated to be necessary in 96.3% of cases.

The child with a central nervous system tumor

Brain tumors in children are great surgical challenges, mainly because they are located in areas difficult to reach in the central nervous system, have large dimensions, and are at risk for sequelae from injury of important brain structures, despite the benign histological character of many of these lesions. On the other hand, the survival of children with brain tumors has significantly increased in the last years, with most of the patients reaching an adult age[25]. Thus, patients with neurological sequelae resulting from the tumor or the surgical procedure itself have higher morbidity over longer periods of time, including cognitive and psychological conditions, epilepsy, strokes, endocrine deficiencies (such as diabetes insipidus and panhypopituitarism) or tumor relapses. The most frequent nonmetastatic primary tumors in the central nervous system are listed in Table 1[26].

Primary brain tumors are the most common solid neoplasms in children, representing up to 20% of all pediatric tumors[26]. Brain tumor incidence has increased in recent decades, probably due to improvement in imaging diagnosis methods. The estimated incidence is between 2.76 and 4.28 per 100,000 children/year. In Brazil, few available data elucidate tumor incidence in children. Argollo et al.[27] calculated an incidence of 1.85 per 100,000 children/year in a cohort from the state of Bahia comprising the age group from 1 to 15 years. Diagnosing brain tumors in a pediatric population is challenging, with several visits to a pediatrician or to emergency rooms being required before the correct diagnosis is made. This is partly due to the low symptom specificity early in the disease course. Argollo et al.[28], in a cross-sectional study, found that in up to 50% of cases the initial symptoms are only headache, nausea, and vomiting, and this may delay the diagnosis. However, advances in surgical techniques and adjuvant therapies have increased the survival in affected children, as described above.

Table 1 – Brain tumors more commonly found in children in descending order of frequency

Glial neoplasms (astrocytomas)
Ependymomas
Primitive ectodermic tumors (medulloblastomas)
Craniopharyngiomas and pituitary tumors
Choroid plexus papilloma
Gangliogliomas
Pineal tumors
Meningiomas

The most frequent tumors in children are craniopharyngiomas arising from squamous epithelium remnants of the Rathke pouch, comprising 2% to 5% of central nervous system tumors[29]. Historically, their histological characteristics make these tumors optimal for developing new surgical techniques. Morbidity resulting from radical tumor resection aiming to reduce relapse chances is explained by the close anatomical relationship of craniopharyngiomas with the neurohypophysis and particularly the hypothalamus. The hypothalamic-pituitary dysfunction (characterized by panhypopituitarism, obesity, hyperphagia, obsessive search for food, and neuropsychological disorders) dramatically affects the children's and family's quality of life[30].

Perianesthetic complications in children with brain tumors may also arise from the prone position, as the preferential location of the tumor is the posterior cranial fossa, as described above[31]. The pins used in the surgery may cause skull fractures, dural fistulae, and intracranial hematomas. Gray matter and cranial nerve injuries may also occur, as well as respiratory center injuries, possibly causing postoperative apnea.

In Brazil, an epidemiological study conducted by Monteiro et al.[32] in 2003 through DATASUS data analysis showed a 50% increase in mortality attributed to brain tumors in all age groups from 1980 to 1988, with a predominance up to the age of 10 and an increased rate from 2.24 to 3.35 per 100,000 population.

Perioperative antibiotic prophylaxis in neurosurgery

Postoperative meningitis is an important cause for morbidity and mortality after craniotomies. The most frequent infections in these procedures are surgical wound infections, followed by meningitis. Postoperative meningitis causes higher mortality and larger number of neurological sequelae compared with extradural infections. Most authors cannot accurately define the antibiotic prophylaxis efficacy for meningitis, especially because when meningitis occurs in spite of antibiotic therapy, it is usually caused by difficult to treat, resistant organisms.

Postoperative neurosurgical infections have high morbidity rates and they are among the most severe and threatening infections[33]. One of the seminal studies on local and systemic antibiotics in preventing infections used an intraoperative regimen of antibiotic prophylaxis consisting of intramuscular gentamicin or tobramycin, intravenous vancomycin, and streptomycin irrigation solution, with no postoperative antibiotics. Total protection against postoperative infections was achieved in a series of 1,732 surgical procedures[34].

In 1994, Barker et al. first collected randomized studies from the 1980's in a meta-analysis, confirming intravenous antibiotic efficacy in reducing surgical wound infections, with no differences between a short regimen and extended use protocols[35].

To date, only general recommendations for clean neurosurgeries and ventriculoperitoneal shunting were reported, and no consensus was reached regarding the optimal antibiotic class or the optimal administration period.

In 2007, Barker et al. republished a meta-analysis on antibiotic prophylaxis in preventing postcraniotomy meningitis[36]. In this analysis, six controlled studies were reviewed, with a total of 1,729 patients. Antibiotic use reduced postoperative infection rates in five out of six studies. The combined odds ratio for meningitis occurrence after using antibiotics was 0.43 (95% CI 0.2-0.92, p = 0.03). Subgroup analysis did not detect differences in antibiotic efficacy whether gram-negative cover was used or not, or for single-blind or double-blind studies. This benefit of reducing meningitis risk by almost 50% is clinically significant.

Most cases presenting with postoperative fever have no etiological or topographical diagnosis of infection and they are cause for warning and exhaustive clinical and laboratory investigation for better understanding of the subject[37].

Perioperative antiepileptic drug prophylaxis

In general, seizure incidence in patients with supratentorial brain tumors reaches 40%, except in patients with low-level astrocytomas, which may have preoperative seizures in up to 75% of cases[38].

Considering postoperative seizure prophylaxis, phenytoin is still the most used drug; however, a high incidence of side effects is found, such as cytochrome P450 enzyme induction (particularly damaging to patients requiring neoadjuvant chemotherapy with hepatic metabolism drugs). Similarly, carbamazepine and phenobarbital also significantly induce the enzyme system, whereas valproate may result in coagulation and platelet function disorders. Recent studies on oral or intravenous levetiracetam have been promising, with a high efficacy in preventing seizures and a low incidence of side effects compared to other antiepileptic drugs[39]; however, its cost and low availability in Brazil impair the drug use in the current neurosurgical setting.

The current consensus establishes that, if a neurosurgical patient has seizures before the procedure, antiepileptic drug therapy is required. However, drug selection and determination of its administration period, as well as prophylaxis selection in patients without seizures are more complex issues that lack definitive recommendation[40].

Seizures may cause severe consequences to the patient not only from neurological sequelae, but also from increased brain oxygen consumption, increased ICP, brain hypoxia, acidosis, and traumatic injuries from falls. On the other hand, postoperative seizures are rare but drug side effects are common and include cognitive dysfunction, bone marrow suppression, liver failure, and reduced action of chemotherapeutic drugs.

The concept of "mandatory" antiepileptic drugs in craniotomies comes from studies conducted almost 20 years ago. In a meta-analysis selecting four randomized and controlled studies on phenytoin use[41], a trend towards reduced seizures in three out of four trials was observed. Overall, the odds ratio for seizure occurrence was 0.42 (0.25-0.71; $p < 0.01$).

These data are in contrast with the American Academy of Neurology recommendation, which did not indicate the routine use of such prophylaxis one year before[42]. Recent meta-analysis reported by the Cochrane group concluded there was no difference between control and intervention groups in preventing a first seizure in patients with brain tumors[43]. The same analysis showed patients on antiepileptic drugs were six times more likely to have adverse effects, and these data further reduced that therapy indication. However, in an epidemiological study, over 70% of neurosurgeons were usually found to use antiepileptic drugs after brain tumor surgeries[44].

Management of the main postoperative complications in pediatric neurosurgery

Hyponatremia

Hyponatremia incidence depends on the patient population in the study. Regarding inpatients, hiponatremia may occur in up to 20% of cases, and reach up to 50% of neurosurgical patients[45].

Hyponatremia is the most common electrolyte disturbance in patients undergoing neurosurgery. Severe hyponatremia may result in brain swelling and the symptoms reflect its effects on the central nervous system; in addition, the symptom magnitude is related to hyponatremia severity and the fall rate of plasma sodium levels. Initial symptoms may include headache, nausea, and vomiting; as hyponatremia worsen, mental confusion, seizures, stupor, and coma may develop. Studies show that in adult neurosurgical patients with hyponatremia, mortality is significantly higher and directly related to the electrolyte disturbance severity[46].

In neurosurgical patients, hyponatremia is often attributed to one of the following conditions: the syndrome of inappropriate antidiuretic hormone secretion (SIADH) or the salt-losing brain syndrome[47]. The former causes hyponatremia resulting from excessive water retention, whereas the latter is characterized by hyponatremia, polyuria, and dehydration. Both are described in several neurosurgical settings. Hypothalamic-pituitary axis tumors may course with both complications, whereas tumors out of that axis most commonly course with SIADH.

The differential diagnosis between the two clinical conditions described above is fundamental, since treatment strategies are completely different in both syndromes. In SIADH, due to an excess ADH secretion, the patient should be kept in fluid restriction (including volumes administered in medications) of approximately 70 mL/100 kcal and, depending on volume status, loop diuretics (furosemide) and/or increased sodium supply may be prescribed. In the salt-losing syndrome, volume replacement with an isotonic solution and increased sodium supply are mandatory, given the severe dehydration risk. Clinical and laboratory criteria for differential diagnosis can be found in Table 2.

Diabetes insipidus

The resection of suprasellar tumors extending to the pituitary stalk can cause loss of pituitary function and consequent impairment in antidiuretic hormone secretion. Depending on tumor extension and type of surgical approach, the incidence of postoperative panhypopituitarism can reach 85% even in patients with a normal pituitary function before surgery[48].

Craniopharyngiomas are tumors whose main postoperative complication is diabetes insipidus. The absence of ADH secretion promotes hypernatremia due to intravascular solvent loss, polyuria, and dehydration. This complication onset may be seen within the first postoperative hours, with urine output higher than 150 mL/hour. The diagnosis requires suspicion raised by the type of surgical procedure, in addition to increasing hypernatremia occurrence (over 150 mEq/L), urinary sodium levels below 20 mEq/L, plasmatic hypernatremia, and dehydration. Intranasal desmopressin, an ADH synthetic analogue, should be replaced within the first postoperative hours to avoid the described metabolic complications. This medication can also be intravenously or orally used, but the intranasal route is preferred, as it makes dose titration easier, as well as the management of complications resulting from overdose, such as oliguria and dilutional hyponatremia.

Hyperglycemia

Postoperative hyperglycemia is common due to surgical stress and release of insulin counter-regulatory hormones, such as catecholamines, glucagon, and cortisol. Several studies recognize the importance of hyperglycemia in pediatric intensive therapy, increasing the patients' morbidity and mortality during hospitalization. In a neurosurgical setting, hyperglycemia is poorly studied. In a retrospective cohort study, Mekitarian Filho et al.[49] found a hyperglycemia incidence of 62.6% in 198 children undergoing several neurosurgical procedures; however, multiple analysis did not show an association between hyperglycemia and longer length of hospitalization or stay in intensive care units, or mechanical pulmonary ventilation.

Fever of unknown origin

As described above, the finding of fever, mainly within the first 48 hours of the surgical procedure, is very common and has been the subject of extended and costly investigations. The consensus is that a complete work-up, including a complete blood count, inflammatory activity assays (CRP and procalcitonin), and cultures, including urine mycological analysis and fungal culture, should be obtained after a 48-hour fever or if the patient shows worsening of clinical status with sepsis signs and/or septic shock in the presence of previous mandatory antibiotic prophylaxis.

Brain edema and transient neurological focal deficit

Surgical handling of any area of the central nervous system may cause perilesional edema in several grades, impacting the postoperative clinical symptomatology. Postoperative systemic corticosteroid use is usual in pediatric neurosurgery aiming to reduce complications; however, there is no evidence warranting a benefit from the use of these drugs. Corticosteroid adverse effects, such as hyperglycemia, infection, and slow wound healing are well known, but the role of costicosteroid use on complications is unclear.

Table 2 – Clinical and laboratory parameters for postoperative hyponatremia differential diagnosis in neurosurgery

Parameter	SIADH	Salt-wasting brain syndrome
Fluid balance	Zero or slightly positive	Negative
Urinary sodium	> 20 mEq/L	> 20 mEq/L
Serum albumin	Normal	Increased
Hematocrit	Normal	Increased
Potassium	Low or normal	High or normal
Jugular venous distention	Present	Absent

SIADH, syndrome of inappropriate antidiuretic hormone secretion.

Similarly, little is known about the incidence of neurological focal deficits in several types of neurosurgery in children; according to large case studies, the incidence ranges from 5% to 15%[7]. In certain surgeries, such as meningioma resection and spine surgical manipulation, deficits may be more common. Hamilton et al.[50] found approximately 1% of deficits related to nervous compression or cauda equina syndrome in 108,419 spine procedures in a retrospective study. In supratentorial tumors, such as gliomas and meningiomas, the findings show a new deficit development in 6.8% to 29% of cases[51,52], with a multiple analysis conducted on 57 adults with meningiomas showing that the only factor associated with increased morbidity and mortality was the aforementioned deficit.

Conclusion

Recognizing the complications in pediatric neurosurgery is fundamental for appropriate patient management during the early postoperative period. The three most common procedures in children are craniostenosis correction, hydrocephalus and ventriculoperitoneal shunting and brain tumor resection, each of them with their most common complications. Bleeding, infection, and sodium disturbances are the more frequently reported complications. Elective neurosurgeries are potentially contaminated procedures in which cephalosporins, especially second-generation cephalosporins, should be used as prophylaxis for 48 to 72 hours. Antiepileptic drugs are mandatory in early postoperative prescriptions if the patient has had seizures before the procedure.

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