Chapter 11
Neuroanesthesia

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An active 2-year-old, 12 kg boy is scheduled for a frontal craniotomy for resection of a craniopharyngioma.
VS: HR = 100/min; BP = 110/60 mmHg; RR = 24/min; T = 37 °C.
A heart murmur is detected on preoperative examination.

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Preoperative Evaluation

Questions

1. What is the possible significance of a heart murmur? How should it be evaluated?

   Are any lab tests helpful? Which ones? Should this patient have a preoperative echocardiogram? Why? Should a cardiology consult be obtained? Why? A small atrial septal defect is diagnosed. Is this of any significance?

2. What are the perioperative implications of this tumor? What is diabetes insipidus?

   How can diabetes insipidus be diagnosed preoperatively? If diabetes insipidus is present preoperatively, will this affect your preoperative fluid management? How do you assess the need for perioperative steroids? What are the possible implications of inadequate steroid replacement? What other hormones can be affected? What lab work would you require preoperatively? Explain.

Preoperative Evaluation

Answers

1. During routine random examinations, up to 30 % of children will demonstrate an innocent murmur. There are several innocent murmurs of childhood, not associated with any cardiac pathology, with which a pediatric anesthesiologist should be familiar. The innocent murmur (Still's murmur) is characterized by a high pitched, vibratory, short systolic murmur heard along the left midsternal border without radiation in children 2–7 years of age. An innocent venous hum resulting from turbulent flow in the jugular system may also be detected in the neck or upper chest. The hum can be changed or eliminated by position changes or light compression of the jugular veins in the neck. In some cases of increased cardiac output such as during febrile illnesses, murmurs of flow across normal semilunar valves are heard. The murmur of an ASD is similar to that appreciated in pulmonic stenosis. There is no murmur caused by the low velocity left to right flow across the ASD itself. Because of the increased flow across the pulmonic valve in children with right to left flow through an ASD, a murmur can be heard. The murmur is characterized as a soft ejection-type (crescendo-decrescendo) murmur of relative pulmonic stenosis which is heard at the upper left sternal border. This murmur results from the excessive flow across a normal pulmonary valve. The second heart sound is louder and also widely and persistently split as a result of this excessive flow. The most common type of ASD is the secundum type with the abnormal connection between the atria, a result of incomplete formation of the second atrial septum. PVR remains normal throughout childhood and CHF is quite infrequent. Adults with uncorrected ASDs do develop CHF and/or atrial flutter or pulmonary hypertension, so correction of the ASD is generally undertaken in early childhood. The significance of an ASD is that of the possibility of a paradoxical embolus in which air or clots in the venous system cross the ASD and lead to complications in the systemic arterial circulation.

2. Craniopharyngioma, a tumor of Rathke's pouch, may descend into the sella turcica and destroy part or all of hypothalamic and pituitary tissues as it enlarges, leading to hypopituitarism [1]. Preoperatively, the child should be evaluated for adrenal or thyroid dysfunction [2]. If ACTH secretion is impaired by the tumor, the production of glucocorticoids and androgens by the adrenal cortex will be below normal. If not evaluated preoperatively, adrenal insufficiency should be assumed and the patient treated accordingly. Diabetes insipidus is unlikely to be seen preoperatively but certainly may occur during or after the procedure. It is diagnosed by the presence of a large volume of dilute urine (Osm <300 mOsm/mL) in the face of increasing serum osmolarity and increasing serum sodium. If replacement of urinary losses with dilute IV fluid such as D2.5W or D5 0.2NS is insufficient, an infusion of aqueous vasopressin should be started. The preoperative lab tests ordered depend upon the clinical presentation but may include electrolytes, fasting glucose, thyroid function tests, and a CBC. Of course, imaging studies ordered by the neurosurgeon should be reviewed as well.

Intraoperative Course

Questions

1. Would you administer a premedication on this child? Why? Would you require an intravenous catheter before starting the induction? Why? If not, or if the initial attempts are unsuccessful, what's next? A colleague suggests intramuscular ketamine. Agree? Why? Is an inhalation induction appropriate? Explain.

2. Would you insert an arterial catheter? Why? Is a central venous catheter needed? Why? If yes, where? Potential problems? Where do you want the tip to be? How do you confirm its position? What if multiple attempts are unsuccessful? Is a urinary catheter necessary? Why? Is a precordial Doppler necessary? Explain.

3. What agent would you use for induction? Why? Explain your choice of muscle relaxant, if you are using one. Explain your choice of agents for maintenance. Suppose the surgeon asked you to give mannitol. How much is appropriate? Would hypertonic NS be a better option? Why/Why not? What is the expected effect of administering either of these agents? What are the potential problems with the administration of either of these agents?

Intraoperative Course

Answers

1. The possibility of raised ICP should be considered when planning whether or not to administer a premedication. In a child such as the one presented who does not have intracranial hypertension, an inhalation induction is appropriate, with or without a premedication, depending upon the patient's (and the family's) level of anxiety. Placement of an IV for induction is also appropriate and would allow a more rapid induction without the possibility of airway compromise that sometimes occurs during an inhalation induction and that would likely upset both the child and family. Ketamine is a potent cerebral vasodilator and also can cause sudden increases in ICP. Use of ketamine for this child is appropriate but may not be so as an induction agent in children with raised ICP. Intramuscular midazolam is another possibility for a particularly anxious, uncooperative child who refuses oral premedication. Barbiturates have some advantages in neurosurgical patients, since this class of drugs does lower both cerebral blood flow (CBF) and the cerebral metabolic rate for oxygen (CMRO2).

2. An arterial catheter is appropriate for cases such as this in which large fluid shifts or blood losses are possible and/or frequent monitoring of serum ABGs or electrolytes is planned. The radial artery is the most convenient and commonly used site, although the posterior tibial and dorsalis pedis arteries in the foot are also acceptable sites. Complications of arterial cannulation include arterial occlusion, flushing of emboli through indwelling catheters, ischemia distal to a catheter, and rarely, infection. A central venous catheter may be useful in this case as a measure of preload. For neurosurgical procedures, cannulation of the femoral vein is an attractive option. Not only is the insertion site accessible to the anesthesiologist who is at the patients side but also venous drainage from the head is not impaired. A CVP catheter is not useful in treating venous air embolism (VAE) except as a route for administration of resuscitation medications, should that become necessary. Given the possibility of DI, a urinary catheter is an important monitor. VAE is a possible complication of pediatric neurosurgical procedures. A precordial Doppler is the most sensitive monitor of VAE, detecting even minute, clinically insignificant amounts of air. The precordial Doppler is of limited use during electrocautery. Supplementing the Doppler with another monitor of VAE such as the capnograph or end-tidal nitrogen monitoring is helpful since these monitors are not affected by electrocautery [3].

3. Induction of anesthesia can be safely accomplished with either an inhalation or IV technique in this active 2-year-old without evidence of raised ICP. Muscle relaxation should be part of the maintenance since any movement of the child once positioned would be dangerous. The goals of maintenance of anesthesia should include provision of a "slack brain" for the neurosurgeon and stable

4. During the craniotomy, the blood pressure decreases to 60/40 mmHg. What are the possible causes? The end-tidal CO_2 decreases as well. Cause? How can hypovolemia be differentiated from venous air embolism? Are there different treatments for each of these? PEEP? Does the presence of the atrial septal defect influence your management? After your first intervention, the hypotension persists. What is your next move? When are vasopressors indicated? Which would you choose? Why? Would you continue/restart the nitrous oxide? Explain.

5. The urine output is 4 mL/kg/h. What is your differential diagnosis? Which lab tests might be helpful? The serum sodium is 155 mEq/L. Diagnosis? Treatment? Which intravenous fluids would you use? Why? Should they contain glucose? Why? How do you determine the rate of administration?

hemodynamics. The technique should allow for a rapid emergence at the conclusion of the procedure. Administration of opioid prior to pin placement and local anesthetic infiltration along the proposed incision will help minimize hemodynamic derangements. Mannitol administration may help reduce ICP and decrease the size of the brain, allowing better surgical exposure. Starting doses, in the range of 0.25–0.5 mg/kg IV, raise serum osmolality by approximately 10 mOsm. If given too rapidly, mannitol may cause transient hypotension. Repeated and large doses may increase serum osmolality to >320 mOsm, a dangerous level. Hypertonic (3 %) saline has been used more recently in the treatment of raised ICP in patients with traumatic and nontraumatic cerebral edema and is an option to consider in the operating room. Interest in this treatment has undergone a resurgence. Penetration of sodium across the blood-brain barrier is low. Sodium has a reflection coefficient higher than that of mannitol and shares with mannitol both the favorable rheologic effects on CBV and osmolar gradient effects. Hypertonic saline exhibits other theoretical benefits, such as restoration of cell resting membrane potential, stimulation of atrial natriuretic peptide release, inhibition of inflammation, and enhancement of cardiac performance.

4. Venous air embolism (VAE) is a distinct possibility in pediatric neurosurgical procedures. The incidence varies with the sensitivity of the detection device used, but up to 30–40 % of children undergoing intracranial procedures have VAE. Maintenance of a generous circulating blood volume and the use of positive pressure ventilation help decrease the likelihood of a VAE. Once detected or suspected (unexplained hypotension), the anesthesiologist must alert the neurosurgeon who will flood the field, while the anesthesiologist ventilates with 100 % oxygen and treats any hemodynamic instability. Vasoactive, inotropic agents may be needed to maintain the blood pressure at normal levels. Enhancing cardiac contractility may help to move any air from the right ventricle into the pulmonary circulation. The presence of an ASD in this patient is particularly troubling since air in the right atrium may cross to the left atrium and then travel to the cerebral or coronary circulation [4]. If hemodynamic instability persists, turning the patient to a left side down and head down position (Durant's maneuver) may help move the air out of the right ventricular outflow tract and improve the hemodynamics. Hypovolemia may present similarly to VAE, and if vigorous fluid administration is ongoing, the Doppler sounds may be difficult to interpret. In this situation, monitoring end-tidal nitrogen may help differentiate VAE from hypovolemia.

5. DI is a common complication of surgery for a craniopharyngioma [5–7]. It is caused by disruption of the ADH-secreting cells. Diagnosis is made when the patient produces a large volume of dilute urine in the face of hypernatremia. The diagnosis is confirmed when the serum sodium is >145 mEq/L, the serum osmolality is >300 mOsm/L, the urine output is >4 mL/kg/h, and the urine osmolality is <300 mOsm/L. Treatment, outlined above, is directed at replenishing urine output and maintaining normal serum osmolality. Since the administration of water is not an option in the anesthetized patient, dilute IV fluids can be given to

6. How much blood loss is acceptable prior to transfusion? Why? Are there alternatives? What are the risks?

7. The operation takes 10 h. Is the child a candidate for extubation in the OR? Pros/cons? How would you minimize straining at extubation? Do you anticipate hypertension at the end of the case? Is this a problem? Why? Prevention/Treatment?

Postoperative Care

Questions

1. The urine output remains high postoperatively. How long do you anticipate this polyuria will persist? What treatment is indicated? What is vasopressin? Can you use it? How? Would DDAVP be an option in the immediate post-op period? Dangers?

2. Eight hours postoperatively, the child has a seizure. What is your differential diagnosis? What treatment is indicated?

replenish the excessive water losses in the urine. If D2.5 is used, hyperglycemia may result. If the serum osmolality remains high, an infusion of vasopressin offers the greatest flexibility in the maintenance of fluid balance. An infusion of vasopressin, starting at 1 mcg/kg/h, has begun and slowly increased until the urine output decreases to <2 mL/kg/h.

6. The lowest permissible hemoglobin depends upon the patient and the situation during the procedure. Measurement of an ABG or central venous blood gas (SvO_2) may give some information about the adequacy of oxygen delivery to the patient. Elevated serum lactate or lower than normal SvO_2 could indicate an imbalance between global oxygen delivery and oxygen consumption. The potential for continued bleeding is an important factor in deciding whether or not to administer blood/blood products. The risk of transmitting an infectious agent to a person via a transfusion varies from 1:100,000 for hepatitis A to 1:1–2,000,000 for HIV. Hemolytic transfusion reactions occur as often as 1:15–20,000 transfusions. Other results of transfusion include nonhemolytic transfusion reactions, urticaria or other allergic-type reactions, and possibly immunomodulation.

7. The usual criteria apply in considering whether or not to extubate this child. However, following neurosurgical procedures, it is important to assess neurological function and much easier to do so in an extubated, nonsedated patient. If opioids were a part of maintenance and the inhaled agents decreased as closure of the wound took place, straining and coughing prior to extubation should be minimal. Deep extubation is an option for this patient, but experience with this technique is essential prior to undertaking it. Also, the anesthesiologist must be certain that the child has a very good mask airway while anesthetized prior to performing a deep extubation.

Postoperative Care

Answers

1. DI may persist for several days following surgery for craniopharyngioma and may even be permanent [5]. Management using an IV infusion of vasopressin offers greater flexibility, but once longer-term therapy is indicated, the route of administration should be switched to intermittent IV and then intranasal. Oral desmopressin is available in addition to the intranasal form. The usual starting dose is ten times the intranasal dose.

2. Other postoperative complications seen after this procedure include hyperthermia and seizures. Retraction of the frontal lobes during this lengthy procedure may be responsible for this postoperative problem. On occasion anticonvulsants are begun intraoperatively and continued postoperatively. Hyperthermia may result from damage to the hypothalamic thermoregulatory mechanisms.

Additional Topics

Questions

1. What respiratory complications can you anticipate in the life of a child born with myelomeningocele? How does this happen with each problem? At what ages would you expect these various problems to present clinically?

2. A 3-year-old showed up in the pre-op clinic scheduled for the removal of an orbital dermoid. He has four cafe au lait spots on his trunk and buttocks. He has had headaches recently, and his pediatrician noticed his blood pressure was elevated (135/105 mmHg). Any more information needed? His mom has noticed some "flushing" spells recently. What do you think may be going on? There is a family history of neurofibromatosis. Are there any associated endocrinopathies?

3. What is the Glasgow Coma Scale? What is the maximum total score you can get? How many points do you get for being brain dead?

Additional Topics

Answers

1. Myelodysplasia is an abnormality of fusion of the neural groove during the first month of gestation. The resulting saclike herniation of the meninges is called meningocele, and if neural elements are contained within the sac, then it is called myelomeningocele. There are often accompanying abnormalities such as hydrocephalus, tethered cord, and Arnold-Chiari type II malformations present in these children. At birth, fluid losses through the defect may lead to dehydration. Intraoperatively, during the initial repair, high third-space fluid losses are an important consideration. Since the majority of myelomeningoceles are in the lumbar region, as the child grows older, the resulting urinary insufficiency leads to electrolyte abnormalities [8]. In addition, as they age, various bladder augmentations and other procedures are often done on these children leading to additional difficulties with electrolytes. The paralysis at and below the level of the lesion leads to the development of thoracolumbar scoliosis. As the scoliosis worsens, pulmonary function is impaired [9–11].

2. Neurofibromatosis is differentiated into two forms, NF-1 (90 %) and NF-2 (10 %). This patient has NF-1. This disease can affect nearly every organ system. The tumor characteristics of the condition are overgrowths of Schwann cells and endoneurium. Clinically, café au lait spots, axillary or inguinal freckling, neurofibromas, bone lesions, and optic gliomas are seen. Precocious sexual development is seen as a result of invasion of the glioma into the hypothalamus. CNS tumors account for significant morbidity in these children. In addition, the incidence of pheochromocytoma, rhabdomyosarcoma, Wilms' tumor, and leukemia is higher than in the general population.

3. The Glasgow Coma Scale is used to assess cortical and brainstem function. Activity Best Response Score (changes pediatric patients)

   - Eye opening
     - Spontaneous 4
     - To verbal command 3 (young child: to shout)
     - To pain 2
     - None 1
   - Verbal
     - Oriented 5 (words, phrases, smiles/coos based on age)
     - Confused 4
     - Inappropriate words 3
     - Nonspecific sounds 2
     - None 1

4. A patient with cerebral palsy and spasticity needs to have his heel cords (Achilles tendons) lengthened. Is he likely to have swallowing problems? How will you evaluate him for the potential to reflux and aspirate? Should he receive a rapid sequence induction? Which IV agents are best? Your choice of muscle relaxant? What if the child has “no veins?”

- Motor
  - Follows commands 6 (young child: spontaneous)
  - Localizes pain 5
  - Withdraws from pain 4
  - Flexion to pain 3
  - Extension to pain 2
  - None 1

4. Cerebral palsy is a static encephalopathy that has a changing clinical presentation over time. It is a disorder of posture and movement often associated with seizures, resulting from a lesion in the developing brain. Children with CP often have surgical procedures as treatment for contractures, scoliosis, gastroesophageal reflux, and other problems [12]. If a rapid sequence induction is planned, succinylcholine may be used. Its use in children with CP has been studied, and serum potassium increases as it does in patients without CP given succinylcholine [13]. In CP patients who are bedridden, the fact of very limited mobility may make them unsuitable for succinylcholine, as with all such patients. If there is no IV access, IM administration of ketamine, glycopyrrolate, and succinylcholine is an option.

Annotated References

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Sections of this chapter review, among other topics, the clinical presentation, monitoring, and management of venous air embolism in neurosurgical patients, pathophysiology of intracranial pressure, specific issues regarding pituitary tumors, and management of patients with head injury.

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