Anaesthesia for ventriculoperitoneal shunts

Nienaber J
Chris Hani Baragwanath Hospital
Correspondence to: Dr Jan Nienaber; e-mail: nienaberjan@hotmail.com

Introduction

Hydrocephalus is usually the result of obstruction to cerebrospinal fluid flow. The aetiology may be congenital as in Arnold-Chiari malformation, or acquired as in brain tumours or intraventricular haemorrhage. The incidence of hydrocephalus is between 0.3-1.5 per 100 live births in the United States. Ventriculomegaly alone occurs in approximately 0.5-2 per 100 live births. Surgical correction involves draining fluid from the ventricular system to one of three places: peritoneum, atrium, or the pleural cavity. The most common choice is a ventriculoperitoneal shunt. As the child grows, the shunts often require replacement or revision making ventriculoperitoneal shunt placement or revision, one of the most common pediatric neurosurgical procedures.

Intracranial physiology

Anatomical differences between children and adults affect central nervous system physiology, especially intracranial pressure (ICP). Neonates have a dura mater that is covered by the calvaria, consisting of ossified plates connected by fibrous structures and open fontanelles (these close at 10-18 months, but do not ossify until the teenage years). Therefore, the infant skull is more compliant and may slowly expand in response to a gradual increase in ICP. These same structures offer a great deal of resistance to acute increase in ICP.

Infants and children may present with vague signs and symptoms such as irritability, poor feeding, lethargy, increased head circumference, expanding sutures, bulging fontanelles, "sundowning" of the eyes and lower motor deficit. By the time an infant demonstrates the classic clinical signs of elevated ICP, such as bradycardia, hypertension, papilloedema, and pupillary changes, the disease process is likely to be very advanced.

Normal ICP may be as low as 2-4 mmHg, compared to adults where ICP ranges between 8-15 mmHg. The cerebral autoregulation limit is significantly lower with a mean arterial blood pressure of 20-60 mmHg. The margin of safety is narrower because infants are less able to compensate for the changes in blood pressure. Children have a higher global cerebral blood flow (CBF) than adults, but in infants and premature babies, it is lower.

Infants are at risk for ischaemia when mean arterial pressure is low, whereas systemic hypertension may result in intraventricular haemorrhage, therefore large fluctuations in systemic blood pressure may be deleterious. The response to hyperventilation is exaggerated and ischaemia may ensue with very low PCO_2 levels (< 20 mmHg).

Anaesthetic considerations

Preoperative

Anesthetic consideration for ventriculoperitoneal shunt placement or revision requires assessment of the function of the pre-existing ventriculoperitoneal shunt (Table I) and review of the patient's co-existing diseases, medications, intravascular volume status, anaesthetic history and physical examination. Clinical assessment for evidence of ICP elevation will normally be sufficient, and invasive ICP monitoring is usually unnecessary.

Hydrocephalus and ventriculoperitoneal shunt dysfunction often allow time for appropriate full

Table I: Clinical symptoms and signs to predict shunt failure

Fluid tracking
Headache
Fever
Irritability
Bulging fontanelle
Nausea and vomiting
Loss of developmental milestones
Increased head circumference

preoperative neurologic and radiologic evaluation, but patients may occasionally present with acute ICP elevation, requiring emergent surgery.

Laboratory studies are dictated by the underlying pathology - small infants and children require at least a hemoglobin level.

Serum electrolytes should be checked if there is a possibility of disturbance of sodium homeostasis because of hormonal alterations, vomiting and intravascular volume contraction.

Patients who are on anticonvulsant therapy may have altered drug metabolism levels - only necessary if there have been recent dosing changes or if seizures worsened.

Preoperative blood gas analysis may be indicated in patients with altered mental status and those with underlying pulmonary pathology.

Preoperative sedation will alleviate anxiety, which in itself can cause a further increase in ICP. Caution is advised to prevent hypoventilation with an increase in $PaCO_2$ and ICP. (figure 1) Midazolam may be given orally. It is unlikely to cause respiratory depression in doses up to 0.7mg/kg to a maximum of 20 mg.

Ketamine, which increases both CBF and vertebral metabolic rate of O_2, increases ICP and may lower seizure threshold, and is usually avoided.

Children exhibiting signs of acute ICP elevation are likely be obtunded and do not require any sedation.

Intraoperative considerations

Induction and monitoring of anaesthesia

Standard monitoring, ECG, pulse oximeter, NIBP, CO_2, AA, FiO_2 and temperature - unless co-morbidities - require additional monitoring.

Induction of anaesthesia is guided by the patient's medical condition and age-dependant normal physiology.

Typically, young children without acute ICP issues and who have no intravenous access will undergo an inhalational induction through a face mask. All

Figure 1. Normally, cerebral blood flow (CBF) is maintained at a constant level in the face of a wide range of mean blood pressure (MBP) and PaO_2. Below the critical minimum level (approximately 50 mmHg PaO2 and 50-55 mmHg MBP, in adults), CBF increases as PaO2 decreases, and it decreases as MBP decreases. The precise minimum thresholds of MBP in infants and children are unknown.

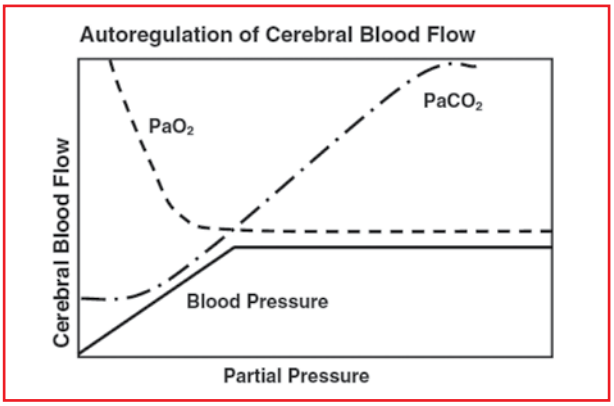

Table II: Anaesthetic drug effects on cerebral metabolism

Agent	CBF	$CMRO_2$	ICP
Volatiles	↓	↓	↓
Propofol	↓	↓	↓
Thiopental	↓	↓	↓
Ketamine	↑	↑	↑
Nitrous oxide	↑	↑	↑

CBF = cerebral blood flow;
$CMRO_2$ = cerebral metabolism of oxygen
ICP = intracranial pressure

the volatile anaesthetics cause an increase in CBF. IV induction agents have different effects. (table II).

Ventilation should be controlled as soon as possible to achieve mild hyperventilation and decrease $PaCO_2$ to offset any anaesthetic increase in CBF. During induction, laryngospasm and bronchospasm can increase $PaCO_2$ and result in elevated CBF and ICP.

If an IV catheter is available, induction can be accomplished with agents such as thiopental or propofol which reduce ICP. If the patient is at risk for aspiration, a rapid or modified rapid sequence induction is indicated.

The airway should be secured with an appropriate-sized endotracheal tube and ventilation controlled. Intubation can either be achieved with a muscle relaxant, or by means of local anaesthetic (lignocaine 1%) topically on the larynx.

Positioning

For ventriculoperitoneal shunt surgery the supine position is usually indicated, the head is turned to the contralateral side of the site of insertion of the shunt. Neck flexion may result in migration of the endotracheal tube to the main stem bronchus or may occlude the jugular vein impeding venous drainage and increasing intracranial volume and pressure. Extra care should be exercised with securing the endotracheal tube in this position. Occasionally a roll of towel can be placed under the shoulders to facilitate a straight line from the ear/neck to the abdomen for tunneling of the shunt.

The eyes should be protected from drying and injury.

Maintenance of anaesthesia

Generally, the maintenance of anesthesia is accomplished with a balanced technique of opioids, volatile anesthetics and muscle relaxants. As noted, all volatile anaesthetics can cause cerebral vasodilation and increase ICP. Isoflurane and sevoflurane appear to have minimal effects on CBF and cerebrovascular reactivity to CO_2 in concentrations of 0.5-1.5 minimum alveolar concentrations. An infusion of short-acting opioids such as fentanyl, alfentanil, sufentanil or remifentanil, can provide adequate intraoperative analgesia with predictable and rapid emergence, permitting timely postoperative neurologic assessment.

Temperature control is an important consideration in the management of paediatric neurosurgical patients. Mild to moderate hypothermia may be neuroprotective and may be therapeutic in the presence of ischemia or hypoxia. In infants, reduced body temperature may result in several undesirable scenarios. Premature and term infants who become hypothermic will have markedly increased oxygen consumption. In infants, hypothermia can result in decreased drug metabolism, increased lactate production and metabolic acidosis, peripheral vasoconstriction, and shift of the O_2-hemoglobin dissociation curve to the left. Other complications from hypothermia include prolonged emergence from anaesthesia, coagulopathy, immuno-deficiency and derangement in serum glucose metabolism. Severe hypothermia may result in cardiac arrhythmias.

Fluid management

The goal of fluid management is maintenance of cerebral perfusion, which usually translates into maintenance of isovolemia, iso-osmolarity, and iso-oncotic blood volume. Normal saline (0.9% NaCl) is the most common crystalloid used in neurologic patients. It is slightly hyperosmolar (308 mOsm) and is thought to attenuate cerebral edema. Hyperglycaemia is associated with worse brain injury after ischaemia; therefore, dextrose administration is not used routinely. Infants, particularly those who are pre-term, are at higher risk for hypoglycaemia. This group should have blood glucose measurements taken during long procedures and dextrose administered if indicated. In patients with existing intracranial hypertension, drugs may be used to reduce ICP. Furosemide, a loop diuretic, is often used to induce diuresis and decrease cerebrospinal fluid production. Hyperosmolar therapy with mannitol or hypertonic saline (3%) is often used. These agents should be given after good communication between the surgeon and anesthesiologist.

Blood and blood component therapy use is guided by the degree of blood loss, starting hematocrit level, and blood coagulation studies.

Postoperative considerations

Postoperative care for the patient for a ventriculo-peritoneal shunt is dictated by the pre-existing neurological status and the coexisting conditions. Routine ventriculoperitoneal shunt cases with no significant co-morbidities may be cared for in an in-patient unit.

The ex-premature infant with risk factors for postoperative apnoea will need monitoring for apnoea spells for at least 12 hours, and should they experience any apnoea attach, further monitoring, until the infant has an apnoea-free period of 12 hours.

References

1. Dilla Vuksanaj, Jayant K Desphande. Anaesthesia for neurosurgery in infants and children. ASA. 2008; 215-226.
2. Elod Z. Szabo, Igor Lunginbuehl et al. Impact of anaesthetic agents on cerebrovascular physiology in children. Paediatric Anaesthesia. 2009; 19: 108-118.
3. Drummond JC, Patel M. Neurosurgical anaesthesia. In Miller RD editor. Miller's Anaesthesia. Elsevier: Churchill Livingstone, 2005: 2163.
4. Clayton T, Manara A. Chapter 19: Neurosurgery. In Oxford handbook of anaesthesia. Oxford University Press, 2002; 406.
5. Morgan GE, Mikhail MS, Murray MJ. Chapter 26: Anaesthesia for neurosurgery. In Clinical Anaesthesiology. Lange Medical Books, 2006; 631-646.