ANESTHESIA FOR CEREBROSPINAL FLUID DIVERSION & ENDOSCOPIC NEUROSURGICAL PROCEDURES

Frear, D.

KEY POINTS

- Cerebrospinal fluid diversion procedures are performed in a wide variety of patients often with complex co-morbidities.
- Most procedures redirect the cerebrospinal fluid for absorption in alternate body cavities.
- Endoscopic techniques are increasingly used in the management of ventricular and periventricular pathology.

KEY WORDS

Cerebrospinal fluid, endoscopic third venticuloscopy, ventriculo-peritoneal shunt, intracranial pressure, ventriculomegaly, CSF diversion procedure

ABBREVIATIONS

CSF	Cerebrospinal fluid
ETV	Endoscopic Third Ventriculostomy
ICP	Intracranial pressure
IIH	Idiopathic intracranial hypertension
NICU	Neonatal intensive care unit
NPH	Normal pressure hydrocephalus
NSAIDS	Non-steroidal anti-inflammatory drugs
PEEP	Positive end expiratory pressure
TIVA	Total intravenous anaesthesia
VP	Ventriculo-peritoneal

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INTRODUCTION

Procedures to divert cerebrospinal fluid (CSF) are frequently used for the treatment of hydrocephalus and idiopathic intracranial hypertension (IIH). A diverse range of patients are treated by such procedures, from neonates to the elderly, either with or without multiple co-morbidities. Symptoms of raised intracranial pressure (ICP) such as headache, visual disturbance and drowsiness are usual for those patients presenting with an obstructed ventricular system. However, some patients can have an insidious onset of gait disturbance, mental decline and urinary incontinence which are features of normal pressure hydrocephalus (NPH). In this syndrome, the ventricles are dilated (ventriculomegaly) but CSF pressure is normal.

While an open diversion procedure is mostly used for the management of pathology resulting in CSF obstruction, more recently, ventricular endoscopic techniques, have seen their scope extended to manage many other conditions. The perceived advantages include reduced tissue trauma from dissection and retraction while improved access to specific areas of the brain can lead to shorter procedures and reduced length of hospital stay.

CEREBROSPINAL FLUID DYNAMICS

CSF is continually produced by the choroid plexus (60-70% of volume) as well as being exuded from vessels within the pia mater. It then circulates within the ventricles and subarachnoid space and is primarily reabsorbed from arachnoid villi which protrude into the cranial venous sinuses (Figure 18.1). In adults, the volume of the ventricular system is 100-150mls and about 500mls of CSF is produced per day. Interference with the free flow of CSF or its reabsorption results in hydrocephalus and the development of raised intracranial pressure (ICP).

Hydrocephalus is commonly classified into communicating and non-communicating types. Non-communicating hydrocephalus can be considered 'obstructive' when an internal (e.g. congenital malformation) or external (e.g. tumour) mechanism obstructs the ventricular system preventing the flow of CSF (Figure 18.2). Since production continues unabated, CSF accumulates producing a dilated ventricular system. In communicating hydrocephalus, no fixed obstruction exists, but rather flow dynamics and reabsorption are disrupted for a variety of reasons. The two theories relating to the development of hydrocephalus include; (1) the CSF bulk flow theory which suggests there is an imbalance between CSF formation and absorption and (2) the hydrodynamic theory where reduced cerebral compliance is implicated. Newer theories, however, have been proposed in which minor CSF pathways may play a significant role in the development of congenital hydrocephalus.

SURGICAL PROCEDURES

Cerebrospinal Fluid Diversion

CSF diversion by shunting is the main surgical technique for the management of hydrocephalus. The aim is to divert the CSF into a high capacity body cavity from which it can be reabsorbed. In general, the proximal end of a catheter is introduced into the ventricular system via a burr hole and connected to a valve placed beneath the galea. Access to the peritoneal cavity, the pleural space or the right atrium (via the external jugular vein in the neck) is then achieved and the distal end of the catheter is tunnelled to this point. Although contraindicated in cases of obstructive hydrocephalus, an alternative is a lumbar-peritoneal shunt, where access to the subarachnoid space is achieved in the lumbar region and a catheter tunnelled around to the abdominal incision where it is placed in the peritoneal cavity.

Shunt Assessment

Whilst shunt procedures are successful in many cases, there remains a high complication rate. The need for a shunt revision varies but can be as high as half of all shunts by two years. Identification of a malfunctioning shunt is not always easy. Intermittent malfunction, over-drainage or under-drainage may give vague clinical signs and symptoms. Diagnosis can be improved using CSF infusion studies which measure pressures and system compliance to assess shunt and valve performance. Cannulation of either the ventricular system or the shunt via its integral reservoir enables in vivo pressure measurements to be taken. In adults, this may be possible under local anaesthesia but for paediatric patients a general anaesthetic is often required.

Endoscopy

Preformed spaces such as the ventricular system, the subarachnoid space, or cystic lesions provide ideal conditions for the use of endoscopes. Endoscopic third ventriculostomy (ETV) was used initially in cases of obstructive hydrocephalus to avoid some of the complications of long term shunt insertion. The procedure involves creating a hole in the floor of the third ventricle using an endoscope inserted into the ventricular system via a burr hole. By creating a communication between the ventricular system and the subarachnoid cisterns, CSF can bypass the Aqueduct of Sylvius and the IVth ventricle. ETV has also been used with varying success in the treatment of NPH and communicating hydrocephalus.

An endoscopic approach may also be used to fenestrate intraventricular septations in cases of loculated hydrocephalus, guide shunt revision by allowing release of adhesions around the choroid plexus or obstructed catheters and aid the optimal placement of a ventricular catheter.

Intraventricular tumours may be accurately and safely biopsied using endoscopy, and where they are causing obstruction, an ETV can be performed at the same time. Complete endoscopic resection of such tumours is possible but dependent on their size relative to that of the endoscope. Endoscopic resection of colloid cysts is also possible along with the management of arachnoid cysts by fenestration of the cyst wall into the ventricular system or subarachnoid cisterns.

ANAESTHETIC CONSIDERATIONS

Preoperative Evaluation

Neonatal patients often have multiple co-morbidities including poor lung compliance, immature hepatic and renal function and the risk of post-operative apnoea. Issues associated with the transfer of these patients between theatre and the neonatal intensive care units (NICU) need to be considered along with the requirement for post-operative ventilation in pre-term infants and those with significant lung pathology.

Older children who often have had multiple shunt revisions, need to be assessed for co-existing chronic childhood diseases such as epilepsy, recurrent chest infections related to cerebral palsy and gastric reflux. Hydrocephalus may be a feature of specific paediatric syndromes and their associated organ anomalies.

A pre-operative assessment in older patients should focus on their underlying disease and co-morbidities. Specific neurosurgical issues to consider would include the presence of raised ICP, altered level of consciousness, and the risk of aspiration. Sedative pre-medication is generally best avoided.

Intraoperative Management

General anaesthesia is used for CSF diversion procedures and induction may be undertaken using either intravenous or inhalational agents. For patients with impaired consciousness or at risk of aspiration, rapid sequence induction should be considered. Intubation with reinforced endotracheal tubes is one safe technique for these cases. Neck extension and rotation to facilitate tunnelling during shunt insertion can dislodge supra-glottic airways and may cause standard endotracheal tubes to kink. Supra-glottic airways may be used when shunt infusion studies are performed as a stand-alone procedure.

Routine monitoring with electrocardiography, pulse oximetry, capnography and non-invasive blood pressure measurement is required. Invasive arterial pressure monitoring is not routinely required unless indicated by associated co-morbidities. Temperature control can be particularly challenging in children with the greatest heat loss occurring during positioning and preparation as a significant surface area is exposed and cleaned with cold surgical prep. Use of a forced air warmer and temperature monitoring is therefore essential.

Positioning

Ventriculo-peritoneal (VP), ventriculo-pleural and ventriculo-atrial shunts require supine positioning, with some degree of neck extension and rotation (greatest for VP shunts) to facilitate insertion of the tunnelling device. Lumbar-pleural shunts are performed in a lateral position and a wide area of the back and abdomen are surgically prepared and draped. Endoscopic procedures are typically performed supine, slightly head up with the neck flexed.

Maintenance

Total intravenous anaesthesia (TIVA) or an inhalational agent can be used for maintenance in the normal manner. Ventilation to normocarbia is especially relevant for shunt infusion studies where a stable end-tidal carbon dioxide level is required for interpretation of the results. Systemic antibiotics as per local guidelines should be administered at induction to reduce the risks of shunt infection.

The most stimulating event during a shunt insertion procedure is typically advancement of the tunnelling device and attention should be paid to analgesia and depth of anaesthesia during this period. Trauma to surrounding structures is uncommon but remains a potential risk. During ventriculo-pleural shunts ventilation may be halted for a short period to facilitate the distal catheter insertion. Ventilatory recruitment manoeuvres and PEEP may assist in minimizing the resulting pneumothorax.

During endoscopic procedures, a continuous flow of irrigation fluid is used to optimize the field of view but this may introduce complications including acute increases in ICP and dysrhythmias including bradycardia and even cardiac arrest. These normally respond to repositioning or removal of the endoscope, but may require pharmacological therapy. Intra-arterial blood pressure monitoring is essential during these cases. Hypothermia has also been reported in small children related to large volumes of cold irrigation fluid.

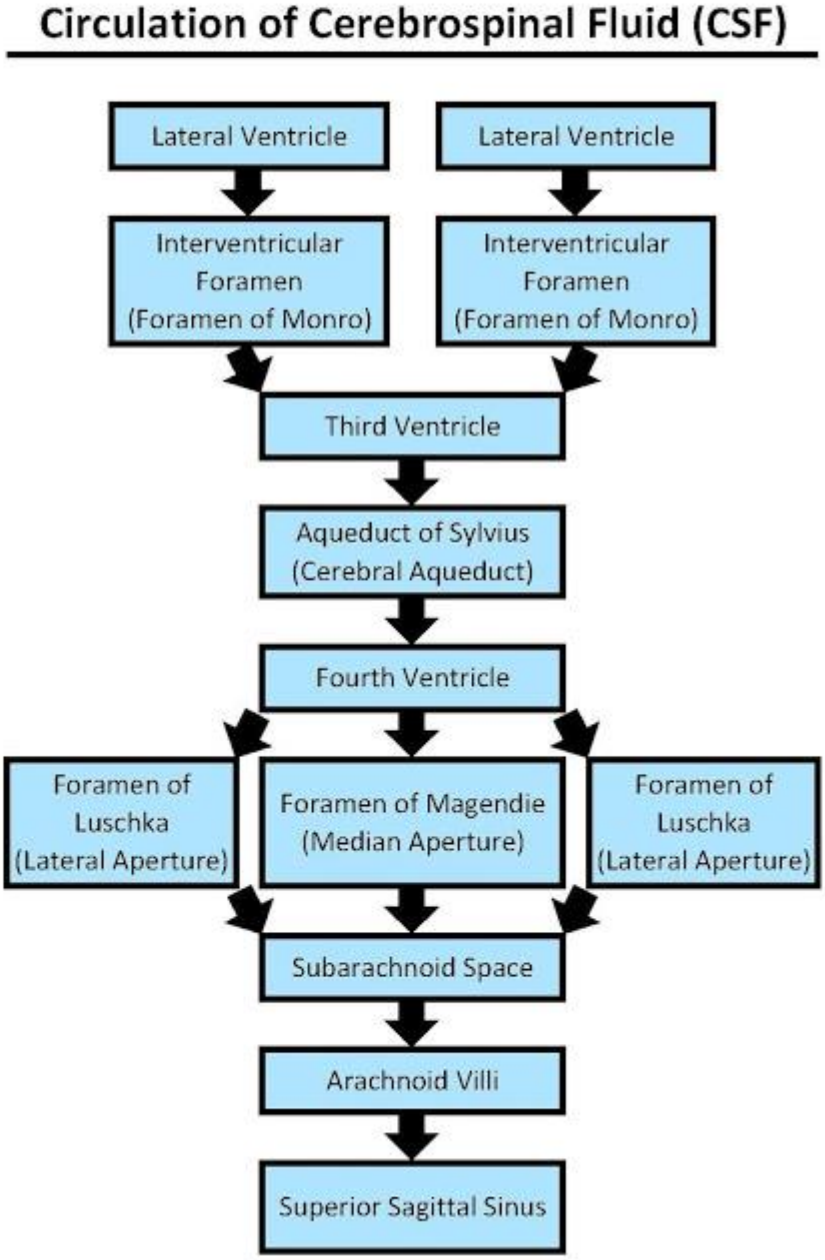
Postoperative Analgesia

Intra-operative analgesia with paracetamol and non-steroidal anti-inflammatory drugs (NSAIDS) supplemented with a short acting opiate such as fentanyl is typically sufficient. Patients quickly return to eating and drinking enabling oral analgesia to be used in the postoperative period. Chest pain following a pleural shunt may be more significant and require management with moderate to strong opiates.

FURTHER READING

1. Garton, H. 2004. Cerebrospinal Fluid Diversion Procedures. Journal of Neuro-ophthalmology, 24 (2), 146-155
2. Kestle, J et al. 2003. Lack of Benefit of endoscopic ventriculoperitoneal shunt insertion: a multicenter randomized trial. Journal of Neurosurgery, 98, 284-290
3. Rigamonti, D (Ed.). 2014. Adult Hydrocephalus. Cambridge: Cambridge University Press, ISBN 978-1-107-03177-7.
4. Schroeder, H., Gabb, M. 1999. Intracranial endoscopy. Neurosurgical Focus, 6 (4) Article 1
5. Symss, N.P., Oi, S. 2013. Theories of cerebrospinal fluid dynamics and hydrocephalus: historical trend. *J Neurosurg Pediatr.* 11(2), pp.170-177.

FIGURE 18.1


Circulation of Cerebrospinal Fluid (CSF)
Lateral Ventricle
Lateral Ventricle
Interventricular Foramen (Foramen of Monro)
Interventricular Foramen (Foramen of Monro)
Third Ventricle
Aqueduct of Sylvius (Cerebral Aqueduct)
Fourth Ventricle
Foramen of Luschka (Lateral Aperture)
Foramen of Magendie (Median Aperture)
Foramen of Luschka (Lateral Aperture)
Subarachnoid Space
Arachnoid Villi
Superior Sagittal Sinus

FIGURES 18.2

Causes of Hydrocephalus

Congenital

- Chiari malformations
- Aqueductal stenosis
- Neural tube defect
- Arachnoid cysts
- Dandy-Walker syndrome

Acquired

- Infections (Causes communicating hydrocephalus)
  - Meningitis
  - Cysticercosis
- Post-haemorraghic (Causes communicating hydrocephalus)
  - Subarachnoid haemorrhage
  - Intraventricular haemorrhage
  - Traumatic brain injury
- Secondary to space-occupying lesions (causes obstructive hydrocephalus)
  - Vascular malformations
  - Tumours & Cysts

Other

- Normal pressure hydrocephalus
- Hydrocephalus ex vacuo (due to brain atrophy)