Anaesthetic considerations for patients with neurosurgical implants

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Key points

- Survival rates for patients with neurosurgical pathology are improving, resulting in more of these patients presenting for incidental surgery. The non-specialist can safely anaesthetize neurosurgical patients by adhering to general neurophysiological principles.
- Cerebrospinal fluid diversion devices (shunts) used to treat hydrocephalus are not only ventriculo-peritoneal, the distal end may be placed into the intrapleural space or the right atrium. The proximal end can also arise from the lumbar spine.
- Neurosurgical pathology is not necessarily a contraindication to regional anaesthetic techniques, nor to laparoscopic surgery.
- The duration of dual anti-platelet therapy for patients with intracranial stents depends on the site and nature of the stent. In the emergency setting, advice from the specialist centre should be sought.
- An understanding of the indication for long-term neurosurgical or neuroradiological implants is useful when planning anaesthesia and postoperative care.

Innovations in neurosurgical technology, neurosurgical techniques, approaches to surgical access, and interventional neuroradiology have revolutionized the treatment of many neurosurgical and neurological conditions, with many pathologies now amenable to surgical intervention; aggressive tumour resection in eloquent areas and on/adjacent to the motor strip, Parkinson’s disease, epilepsy, benign intracranial hypertension, pituitary tumour, intracranial aneurysm surgery, and radiological intervention to name a few. Survival rates over 5 and 10 yr have improved and it follows that patients with residual tumour, cerebrospinal diversion devices (shunts), indwelling therapeutic implants (devices) and stents, and spinal metal work are more likely to present to their local hospital for non-neurosurgical procedures.

Broadly speaking, patients with neurosurgical pathology requiring non-neurosurgical procedures can be considered in four main groups:

- Incidental surgery in a patient with an intracranial mass lesion.
- Trauma patients requiring emergency life-saving surgery that also have acute traumatic brain or spine injury.
- Obstetric interventions in patients with intra-cranial or spinal pathology.
- Interventions in patients with neurosurgical or neuroradiological implants.

An understanding and application of basic neurophysiological principles¹ underpins successful anaesthesia in all of the mentioned groups and this has been comprehensively addressed in papers focusing on the management of patients requiring surgery with combined neurological pathology and trauma²–⁴ or obstetric problems⁵,⁶

This article will focus on anaesthetic considerations for the individual with a shunt to divert cerebrospinal fluid (CSF), those taking anti-platelet therapy for intracranial vascular stents/coils, and those with neurosurgical implants.
**General anaesthetic considerations**

**Preoperative assessment**

The baseline neurological status, with documentation of the Glasgow coma score (GCS) and pre-existing focal deficits, is important to ascertain before embarking on general anaesthesia. In addition, features suggesting elevated intracranial pressure (ICP) (Fig. 1) should be sought as they may alert the anaesthetist to a malfunctioning shunt or device.

A new or worsening headache, new neurological deficits, or increasing frequency or new onset of seizures are suggestive of raised ICP. The headache occurs as a result of traction on, or distortion of the cerebral blood vessels and dura mater. It is classically postural, worse when recumbent or upon straining and may be associated with nausea and vomiting caused by irritation of the vomiting centre.

A focused physical examination that identifies either papilloedema or decreased consciousness is also suggestive of high ICP. The predominant concern is the possibility of subsequent brain herniation with further elevations or peaks in ICP. The herniation can be transtentorial (cephalad) causing ipsilateral midriasis and contralateral hemiplegia, or tonsillar (caudal) through the foramen magnum leading to respiratory or cardiac arrest as the brainstem is compressed. The classical, although late, clinical features of brainstem compression are either Cush- ing’s triad—hypertension, bradycardia, and widened pulse pressure, or abnormal respiratory patterns caused by pressure on the respiratory centres, for example, Cheyne–Stokes or apnoeas.

In the face of new signs or symptoms, the specialist centre should be contacted for advice/review and elective procedures postponed.

A thorough drug history will enable planning of postoperative analgesic regimes, the key drugs to consider are (i) anti-platelets in those with intracranial stents, (ii) anti-epileptics, especially in patients likely to benefit from multi-modal postoperative analgesia including pregabalin or gabapentin, to prevent drug interactions or over dosage, and (iii) anti-parkinsonian drugs to prevent drug interactions.

**Intraoperative management**

For patients with raised ICP, the anaesthetic technique should maintain normal physiology, prevent further elevations in ICP, and enable rapid emergence to permit assessment of post-operative neurological function. Total i.v. anaesthesia using propofol and remifentanil target-controlled infusions has several benefits, including rapid onset and offset, maintenance of cerebral flow-metabolism coupling, and reduction in cerebral metabolic rate (CMRO<sub>2</sub>). Alternatively, volatile anaesthesia is perfectly acceptable, provided MAC is limited to ≤1 (up to 1.5 MAC sevoflurane) to avoid excessive cerebral vasodilatation. Nitrous oxide increases CMRO<sub>2</sub>, worsens the cerebral vasodilatation caused by inhalation agents, and is not recommended for use in patients with raised ICP.

For patients undergoing short procedures with normal ICP and a functioning shunt, a secured intracranial aneurysm or an implantable stimulator device, a supraglottic airway device, and spontaneous ventilation is well tolerated.

**Postoperative care**

Assuming uneventful surgery and anaesthesia, standard recovery procedures and postoperative care, with the addition of neurological observations, are sufficient until the patient is considered safe to transfer from the recovery/post-anaesthetic care unit to the ward.

High dependency or intensive care admission should be guided by the surgical insult [e.g. oesophagectomy in a patient with a deep brain stimulator (DBS)] or by any neurological deterioration or unexpected new symptoms or signs. Admission to either area due to a neurological cause warrants urgent investigation, often imaging based, and referral to the neurosurgical centre for advice that should not be delayed while waiting for a bed.

When prescribing postoperative analgesia, the anaesthetist should consider how best to reduce the need for high-dose opiates that could sedate the patient and mask neurological deterioration, or suppress ventilatory drive and cough. Regional anaesthetic techniques, including neuraxial blocks, are not necessarily contraindicated in those with neurosurgical pathology and practical guidance is available. As with any regional technique, local guidance relating to anti-platelet therapy should be followed.

Anti-neuropathic adjuvant analgesics may also be considered (while remaining aware of their sedative side-effects), including pregabalin, gabapentin, clonidine, and ketamine. Neuroanaesthetists are increasingly administering ketamine, despite the historical contraindication to its use in the neurosurgical population. Its use remains controversial, but there is emerging evidence that it may be neuroprotective and it can be used safely in adults.

**Specific anaesthetic considerations**

**Cerebrospinal fluid diversion devices (shunts) and incidental surgery**

Congenital hydrocephalus, acquired hydrocephalus, non-communicating hydrocephalus, and chronic raised ICP may be managed long term by placement of a shunt to divert CSF from

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Fig 1 Radiological features of intracranial hypertension. Axial CT shows widespread loss of grey-white matter differentiation, sulcal effacement, and effacement of the basal cisterns (arrows). The temporal horns of the lateral ventricles are dilated indicating acute hydrocephalus.

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the third ventricle via a one-way valve into the patient’s peritoneum (ventriculoperitoneal, VP, shunt), right atrium (ventriculoatrial, VA, shunt), or pleura. Occasionally, a patient may present with a lumboperitoneal shunt. When patients with shunts present for incidental surgery, concerns include the risks of:

- Laparoscopic surgery and intracranial transmission of CO₂.
- Shunt infection with potential retrograde infective meningioencephalitis or ventriculitis.
- Shunt failure with recurrent hydrocephalus.

Despite these concerns, a well-functioning shunt does not contraindicate pneumoperitoneum or dictate open surgery. It has been suggested that the intra-abdominal component of a VP shunt be clamped before carbon dioxide insufflation in laparoscopic surgery, and displaced away from the surgical field to prevent pneumocephalus and iatrogenic shunt damage, respectively. The one-way valve, however, is designed to withstand pressures below 300 mm Hg and clamping is not required. It has been reported that while pneumoperitoneum >15 mm Hg may cause a slight transient increase in ICP, the increase is of little clinical significance, whereas clamping the shunt may be more detrimental in terms of ICP increase and has the potential to cause damage to the device.

We advocate avoiding shunt manipulation unless experienced at doing so.

For elective cases, prophylactic antibiotics should be according to local hospital policy. Uncomplicated emergency cases with localized infection from appendicitis can sometimes be managed in the district general hospital after discussion with the neurosurgical centre, but the patient should be observed after operation and shunt contamination or occlusion considered early in the differential diagnosis in the face of neurological deterioration. Emergency cases with presumed widespread intra-abdominal infection should be discussed with and (most often) transferred to the neurosurgical centre to allow externalization of the shunt and treatment of the abdominal pathology. There remain, however, a number of issues the anaesthetist should be aware of listed in Table 1.

While rare, specific complications have been reported.

- The presence of a ventriculo-peritoneal shunt increased conversion from laparoscopic to open surgery due to intra-abdominal adhesions, but shunt infection rate appeared unaltered by intra-abdominal surgery.
- Positive pressure ventilation was observed to cause ventriculo-pleural shunt obstruction.
- Shunt placement affected premorbid functional status, for example, onset of pulmonary hypertension after VA shunt insertion.

### Intracranial vascular stents and anti-platelet therapy

Interventional neuroradiology is a rapidly expanding field that offers complex combined treatments to patients with neurovascular pathology. Patients who have undergone intervention

### Table 1 Preoperative considerations for the anaesthetist according to the type of shunt present

<table>
<thead>
<tr>
<th>Type of shunt</th>
<th>Considerations in preoperative assessment</th>
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| All | 1. Preoperative GCS and documentation of any focal neurological deficit, including pupil size/reactivity, to allow postoperative comparison  
  2. Careful consideration of access point for invasive lines, most shunts are tunnelled behind an ear and along the posterior border of the sternocleidomastoid muscle. Both sides of the neck should be assessed, as remnants of previous shunts may remain in situ |
| Ventriculo-peritoneal | 1. Signs of intra-abdominal infection should trigger a discussion with the neurosurgical team about the management of potential shunt infection  
  2. Multiple shunt revisions may result in intra-abdominal adhesions, and resultant prolonged/difficult surgery  
  3. Close neurological observation after operation is essential |
| Ventriculo-atrial (distal catheter tip placed in the mid to lower right atrium via the internal jugular vein) | 1. May drain high volumes of CSF, so a blocked shunt may cause a more rapid hydrocephalus than that seen with other shunts—this is less of a problem with new-generation shunts  
  2. Look for signs of pulmonary hypertension  
  3. Internal jugular and subclavian lines are inadvisable—consider alternatives, the shunt enters the right atrium |
| Ventriculo-pleural (distal catheter tip placed in the third/fourth intercostal space via a mini thoracotomy or mini thoracostomy) | 1. Look for pleural effusion on the side of the shunt that may be large—seek advice before draining the effusion, and consider transferring to the neurosurgical centre as the shunt may need to be externalized  
  2. IPPV may cause shunt blockage, a slow to rouse patient should alert the anaesthetist to this possibility  
  3. Lung atelectasis and postoperative lower respiratory tract infection should be avoided. The patient will need excellent respiratory excursion, and may benefit from postoperative physiotherapy |
| Lumbar-peritoneal | 1. Risk of lumbar meningitis  
  2. An acute increase in lumbar spinal canal pressure may compromise spinal cord perfusion pressure, hypotension must be avoided  
  3. Consider patient position to avoid excessive kinking or pressure on the tunnelled portion of the shunt. It is situated between the skin and transversus abdominus muscle, and is often palpable below the skin. Particular care should be taken when using lateral supporting bolsters to ensure they do not cause pressure on the tunnelled portion of the shunt |
without stent insertion can be anaesthetized without further concern.

For patients with intracranial stents, it is important to determine why and when it was inserted, anatomical location, and the potential consequences of stent occlusion (Table 2). Stents in vessels forming part of the circle of Willis will often have been placed to facilitate coiling of a wide-necked aneurysm (Fig. 2); the consequences of stent occlusion will depend upon overall patency of the circle of Willis.

Patients with intracranial stents will be commenced on anti-platelet therapy to prevent intra-stent thrombosis, the duration of which is variable, and should be checked with the interventional radiologist responsible. As with coronary artery bare metal stents, the risk of thrombosis decreases over time, as the lumen becomes endothelialized. Most of the ischaemic events, associated with interruption of anti-platelet therapy, occur within 6 months of the endovascular treatment.14

Typically, dual-agent therapy (aspirin+clopidogrel) is continued for 6 weeks, after which clopidogrel is stopped. Patients with jugular venous stents will continue on life-long aspirin therapy. If emergency surgery is deemed necessary, yet the patient presents in the first 6 weeks, bridging of anti-platelet therapy with perioperative infusion of the glycoprotein IIb/IIIa inhibitor, eptiabatide, is an option.15

The newer direct factor Xa inhibitors such as rivaroxiban are not currently used, and evidence is lacking on their duration of anti-coagulant effect when stopped; the general consensus is that they should be regarded as presenting a similar bleeding risk as clopidogrel, and need to be bridged if discontinued. In the event of a patient requiring emergency surgery while taking rivaroxiban for prevention of intra-cranial stent thrombosis, expert haematological advice should be sought.

Long-term dual anti-platelet therapy is unlikely to be necessary, as drug-eluting stents are not used.

**Anaesthetic considerations**

A multitude of non-cardiac implantable electrical devices (IEDs) are now available and the odds of patients with such devices presenting for surgery are increasing. Specific to the neurosurgical patient, devices include:

- Vagal nerve stimulators: inserted to control refractory epilepsy. The mechanism of action is poorly understood, but stimulation of the cervical vagus nerve is believed to modulate cerebral neuronal excitability via the limbic system, noradrenergic neurotransmitter systems, or generalized brainstem arousal systems.16 Similar to a cardiac pacemaker, the device consists of a stimulation generator placed subcutaneously below the left clavicle and connected to a left vagal nerve electrode implanted in the neck.
Deep brain stimulators: an implanted pacemaker sited to stimulate deep brain structures such as the thalamus, globus pallidus, and subthalamic nuclei. They are used to manage Parkinson’s disease and other movement disorders, depression, obsessive–compulsive disorder, chronic pain, and epilepsy. The device sits in the same position as a cardiac pacemaker (Fig. 3); there may be a second device on the right. The leads exit the chest towards the neck.

Spinal cord stimulators: indicated for failed back surgery syndrome, complex regional pain syndromes, peripheral vascular disease, and refractory angina. Electrodes are placed percutaneously or via surgical laminectomy to stimulate the spinal cord at levels appropriate for the targeted pain (C4–T1 for upper limb pain; C6–T2 for angina; T9–L1 for lower limb pain). Temporary electrodes are usually placed first and stimulated externally. Patients may, therefore, present for incidental surgery with external or internal stimulator wires. Neuraxial anaesthesia is not contraindicated, provided the site for spinal/epidural needle insertion is remote from the spinal cord stimulator. Any epidural catheter should be inserted with caution to ensure it is not within the vicinity of the stimulator electrode. An operative note or radiological confirmation of the site of the spinal cord stimulator should, therefore, be obtained before proceeding with epidural catheter placement (Fig. 4).

Intrathecal baclofen pump devices: have a box sited in the subcutaneous tissue of the abdominal wall allowing easy access for drug delivery and programming. A catheter connecting the device to the lumbar intrathecal sac is tunnelled under the skin, in much the same way as a lumbar peritoneal shunt. Sudden malfunction can result in acute baclofen withdrawal, a medical emergency.

Clear guidelines exist for the perioperative management of patients with implanted cardiac devices, whereas no such guidance is currently available for neurosurgical stimulators. Safety concerns focus on the potential interaction with or damage to the devices by electrocautery, external cardiac defibrillation, peripheral nerve stimulation, magnetic resonance imaging (MRI), and neuraxial anaesthesia. Perioperative management should be guided by an understanding of the anaesthetic implications of the underlying disease for which the electrical device has been placed. Preoperative assessment of the following will enable the anaesthetist to plan for device problems or failure:

- type and location of non-cardiac IED,
- date of implantation and last check,
- current status of IED in terms of symptom control,
- programmability of the device,
- severity of symptoms when the device is turned off,
- current medications.

The WHO preoperative checklist should include discussion regarding the nature, implications, and potential complications of the IED and how to proceed in the event of emergency cardiac defibrillation.

Diathermy and implanted electronic devices

Manufacturer’s guidelines should be followed regarding the intraoperative use of diathermy (e.g. http://professional.medtronic.com/pt/neuro/dbs-md/ind/product-advisories/WCM_PROD083579#.UJo6CrAjPdk). Electrocautery is not absolutely contraindicated, although there are risks of nerve, tissue, or device damage if used. Case reports of thermal lesioning of brain tissue and death linked to the use of diathermy have been published. Electrocautery should be avoided or limited to bipolar. If monopolar diathermy is required, the earth plate should be placed as far from the IED and the stimulator leads as possible. Wherever possible, consult with the device technician before and after surgery.
Nerve stimulators and implanted electronic devices

Nerve localization using peripheral nerve stimulators may interfere with IEDs. Insufficient case reports exist to quantify the risks, although they are likely to be low, especially if stimulation currents, pulse duration, and frequency are minimized. This complication is avoided entirely when ultrasound-guided block techniques are used.

Cardiac arrest, defibrillation, and implanted electronic devices

Literature to guide the use of external cardioversion with non-cardiac IEDs is absent. In the event of cardiorespiratory arrest or life-threatening dysrhythmia necessitating DC cardioversion, one must proceed with the expectation that the quantity of electrical energy discharged will damage the IED. The defibrillator electrodes should be positioned perpendicular to and as far away as possible from the device; use the lowest electrical energy possible (preferably delivered by a biphasic defibrillator) for the clinical scenario and subsequently reassess the patient and IED function if a shock is delivered, and there is return of spontaneous circulation.

MRI and implanted electronic devices

Theoretically, MRI may induce electrical currents and tissue heating or disrupt IED function. There have been case reports of functional impairment of deep brain stimulators after MRI and it is suggested that individual cases are discussed with the treating clinician, the MRI radiologist, and the device technician.10

Of note, electroconvulsive therapy (ECT) is considered safe, but the recommendation is to place the ECT electrodes as far away from the DBS wires as possible to reduce electrical current induction, and to turn the device off before ECT. Phaeochromocytoma is considered safe, with no interference with the device reported.10

Summary

Neurosurgical patients may be encountered outside of a specialist neurosurgical centre in a wide range of scenarios. With an absence of well-established guidelines for the management of these patients, the general anaesthetist might face uncertainty. These patients may be managed safely in the non-specialist centre by the application of basic principles combined with knowledge of neurosurgical interventions outlined in this article.

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Declaration of interest

None declared.

MCQs

The associated MCQs (to support CME/CPD activity) can be accessed at https://access.oxfordjournals.org by subscribers to BJA Education.

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