

Anaesthetic considerations for posterior fossa surgery



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Key points

The posterior fossa or the infratentorial fossa is a rigid compartment with poor compliance and houses important structures such as the brainstem and cerebellum.

Tumours are the commonest pathology affecting the posterior fossa and they account for up to two-thirds of brain tumours in children.

The sitting position offers better surgical access particularly in midline tumours but can be a significant challenge for anaesthetists.

Venous air embolism is a potentially life-threatening complication associated with surgery on the posterior fossa in the sitting position.

Anaesthetic management of paediatric posterior fossa surgery should take account of the principles of both paediatric and neuro-anaesthesia.

The posterior fossa or infratentorial fossa is a compact and rigid compartment with poor compliance. Small additional volumes (e.g. tumour, haematoma) within the space can result in significant elevation of the compartmental pressure resulting in life-threatening brainstem compression. Surgery in the posterior fossa presents the anaesthetist with significant challenges.

Anatomy

The posterior fossa is the deepest cranial fossa and is surrounded by the dorsum sellae and basilar portion of the occipital bone (clivus) anteriorly, the petrosal and mastoid components of the temporal bone laterally and the dural layer (tentorium cerebelli) superiorly and the occipital bone posteriorly and inferiorly. The foramen magnum in the occipital bone is the largest opening of the posterior fossa. The posterior fossa contains many important structures including the brainstem, cerebellum and lower cranial nerves. The sigmoid, transverse and occipital sinuses all traverse the fossa. The cerebrospinal fluid (CSF) pathway is very narrow through the cerebral aqueduct and any obstruction can cause hydrocephalus which can result in a significant increase in intracranial pressure (ICP).

Pathology

Tumours are the commonest pathology affecting the posterior fossa. They account for more than 60% of all brain tumours in children.¹ Fifteen per cent of intracranial aneurysms occur in the posterior fossa vasculature, and other vascular malformations causing compression and neuralgia of the trigeminal nerve may warrant surgical decompression. Pathologies of the posterior fossa which may require surgical intervention are listed in Table 1.²

Intraoperative positioning

Posterior fossa surgery can be carried out in supine, prone, sitting, lateral and park bench

positions. Acoustic neuroma and cerebellopontine angle tumours may be carried out in the supine position with the head turned to the opposite side, and placement of a sandbag under the ipsilateral shoulder to minimize stretching of the brachial plexus. The prone and sitting positions offer good access to structures in the midline, but care should be taken to avoid abdominal compression to minimize surgical bleeding. The lateral position facilitates gravity-assisted drainage of blood and CSF and gives good surgical access for unilateral procedures. The park bench position is a modification of the lateral position where the patient is positioned semi-prone with the head flexed and facing the floor. This facilitates greater access to midline structures and, in selected patients, avoids the need for the prone position. Meticulous care should be taken during positioning to avoid dislodgement of lines and the tracheal tube, and protection of pressure areas.

Sitting position

The sitting position improves surgical access to the posterior fossa by facilitating gravity assisted drainage of blood and CSF and decreasing ICP (Fig. 1). It improves surgical orientation, access to the midline structures and decreases the amount of surgical retraction needed to gain access to deeper structures. Patients in the sitting position must be returned to the supine position rapidly for resuscitative measures in case of an acute cardiovascular collapse.³

Complications of the sitting position

The sitting position is associated with several potential complications.

Cardiovascular instability

Venous pooling in the legs can result in significant hypotension particularly in elderly patients (Table 2). Surgical stimulation of the lower pons, upper medulla, floor of the fourth ventricle

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Table 1 Posterior fossa pathologies

1. Tumours
a. Axial tumours
Medulloblastoma (commonest)
Cerebellar astrocytoma
Brainstem glioma
Ependymoma
Choroid plexus papilloma
Dermoid tumours
Hemangioblastoma
Metastatic tumours
b. Cerebellopontine angle tumours
Schwannoma
Meningioma
Acoustic neuroma
Glomus jugulare tumour
2. Vascular malformations
Posterior cerebellar artery aneurysm
Vertebral/vertebrobasillar aneurysm
Basillar tip aneurysm
AV malformations
Cerebellar hematoma
Cerebellar infarction
3. Cysts
Epidermoid cyst
Arachnoid cyst
4. Cranial nerve lesions
Trigeminal neuralgia (cranial nerve V)
Hemifacial spasm (cranial nerve VII)
Glossopharyngeal neuralgia (cranial nerve IX)
5. Craniocervical abnormalities
a. Atlanto-occipital instability
Congenital
Acquired
b. Atlanto-axial instability
Congenital
Acquired
c. Arnold–Chiari malformation

Table 2 Contraindications for sitting position

Absolute contraindications	Relative contraindications
Ventriculo-atrial shunt	Patent foramen ovale
Right to left heart shunt	Uncontrolled hypertension
	Extremes of age
	Severe autonomic neuropathy

Venous air embolism

Venous air embolism (VAE) is a potentially life-threatening complication associated with all surgery in the steep head-up position, including posterior fossa surgery in the sitting position. The cited incidence of VAE varies from 25 to 75% during surgery in the sitting position depending on the sensitivity of the monitoring used. In one study, the incidence of VAE in children was found to be less than in adults because of the higher pressure in the venous sinuses.⁴

In the sitting position, the site of surgery is above the level of the heart and this results in a negative venous pressure at the level of surgical wound. Open veins thus entrain atmospheric air into the circulation, resulting in VAE. Air entrainment usually occurs through the diploic veins and open venous sinuses, but entrainment through head pin sites has also been reported. Dehydration exacerbates the low venous pressure and increases the risk of air entrainment, so normovolaemia must be maintained at all times. When air passes into the pulmonary circulation, it causes an increase in pulmonary vascular resistance and pulmonary hypertension. This results in elevated right heart pressure and the risk of paradoxical air embolism.

Clinical features of VAE depend on the rate and volume of air entrained.⁵ The spectrum of manifestations includes cardiovascular, respiratory and neurological changes. Elevated right atrial pressure results in decreased venous return, hypotension and shock. Tachyarrhythmia and myocardial ischaemia may ensue. A large embolus obstructing the outlet of the right ventricle can result in a sudden onset right heart failure and cardiac arrest. Pulmonary signs of VAE include wheeze, crepitations, and sudden decrease in end-tidal carbon dioxide (E'_{CO_2}). Arterial blood gas analysis may reveal hypoxia and hypercapnia. Neurological manifestations include cerebral hypoperfusion as a result of shock and stroke in the event of a paradoxical embolus.

The risk of VAE can be minimized in many ways. Use of Trendelenburg tilt and leg elevation minimize the gradient between the surgical field and the right heart and, as noted earlier, hydration status should be carefully optimized. Though Military Anti Shock Trousers can be used to elevate right atrial pressure, the potential benefits must be weighed against the risks of decreasing vital capacity and hypoperfusion to intra-abdominal organs.

When VAE is suspected, the surgical field should immediately be covered with saline soaked swabs to prevent further air entrainment, and any suspected air entry point sealed. If possible, the surgical field should be positioned below the level of heart. Though jugular venous compression reduces air entrainment, it should be used with caution as it increases ICP and decreases cerebral blood flow because of the simultaneous compression of the carotid artery.

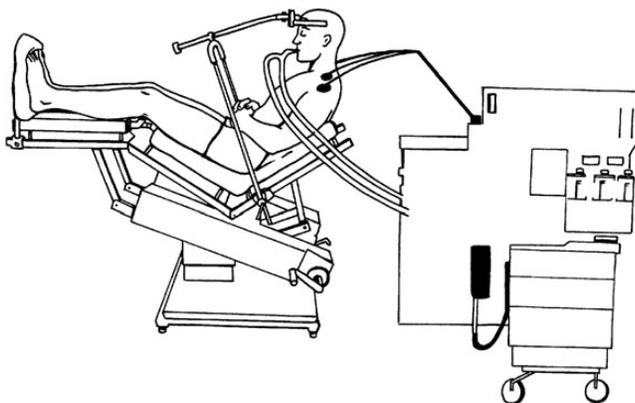


Fig 1 The sitting position for neurosurgery. Reproduced from³ with permission from the *British Journal of Anaesthesia*.

and the cranial nerve nuclei may result in a variable cardiovascular responses including hypotension, hypertension, bradycardia, tachycardia and arrhythmia. Changes in ECG and blood pressure during surgery on the posterior fossa may be signs to the surgeon of their proximity to vital structures.

Once diagnosed, the management of VAE is generally supportive. Oxygen should be administered in high concentration and nitrous oxide if used must be discontinued immediately. Cardiovascular stability should be maintained with i.v. fluid loading and a vasopressor. A carefully positioned central venous catheter can be used to aspirate air from the right atrium. It may be possible to relieve the air lock in the right ventricle by positioning the patient in partial left lateral position (Durant manoeuvre) or in the Trendelenburg position. In the event of massive VAE with cardiac standstill, immediate initiation of chest compression can result in the breaking down of a large air bubble obstructing the right ventricular outflow tract with return of spontaneous circulation.

Pneumocephalus

Pneumocephalus is a recognized complication of surgery in the sitting position. During surgery, various techniques may be used to reduce the volume of the brain which encourages air to enter the intracranial space and, when the cranial cavity is closed and the brain expands, the air is compressed causing a mass effect with elevated ICP. The condition is worsened with the use of nitrous oxide, but avoiding its use does not eliminate the problem.

Pneumocephalus can present after operation as delayed recovery, neurological deficit, headache, confusion, agitation or convulsion. CT scan enables early diagnosis. High-flow oxygen reduces pneumocephalus but, in severe cases, neurosurgical treatment by means of burr hole and aspiration of air should be considered. Untreated tension pneumocephalus can result in brain herniation and cardiac arrest.

Macroglossia

Macroglossia can occur as a result of obstruction to the venous and lymphatic drainage of the tongue because of a flexed neck during prolonged surgery in the sitting position. It may cause postoperative respiratory obstruction, particularly in children.

Quadriplegia

Quadriplegia is a rare but potentially disastrous complication that is caused by prolonged focal pressure on the spinal cord secondary to the acute flexion of the head in the sitting position. Regional spinal cord blood flow can be compromised particularly during episodes of significant hypotension resulting in ischaemic damage to the spinal cord. Meticulous attention during positioning and avoiding significant and prolonged hypotension during surgery can help avoid this complication.

Preoperative evaluation

Thorough preoperative evaluation of the neurological condition and cardiorespiratory status is very important for the safe conduct of anaesthesia for posterior fossa surgery. Routine assessment of coexisting medical conditions with a view to optimization should be performed. Other important aspects of preoperative assessment include:

- (i) Evaluation for cerebellar and cranial nerve dysfunction: presence of lower cranial nerve compression and dysfunction can result in loss of the gag reflex and aspiration pneumonitis. In some patients with bulbar dysfunction, postoperative ventilation or tracheostomy may be necessary to protect the airway. Cerebellar signs may include ataxia, dysarthria, gait disturbances and intentional tremors.
- (ii) Evaluation for the presence of elevated ICP: hydrocephalus and elevated ICP are common in patients with posterior fossa pathology. A decrease in the level of consciousness and altered respiratory pattern may indicate the presence of elevated ICP and, under such circumstances, CT or magnetic resonance imaging is mandatory. External ventricular drainage or other shunt procedures may be indicated to manage hydrocephalus before surgery or intraoperatively.
- (iii) Evaluation of hydration status and electrolyte disturbance: dehydration is common and multi-factorial. Reduced oral intake because of decreased conscious level, vomiting, administration of diuretics, presence of diabetes insipidus and the use of i.v. contrast agents to facilitate imaging contribute to dehydration and electrolyte disturbances. Preoperative administration of i.v. fluids and optimization of electrolytes should be considered on an individual basis.
- (iv) Evaluation for intraoperative positioning: patients should be carefully assessed for the suitability of surgical positioning. The prone position can be difficult in obese patients. The presence of a patent foramen ovale (PFO), which has an incidence of 10–35%,⁶ may preclude the use of the sitting position,^{3,7} though paradoxical embolism can occur even in its absence.⁸ As the complications of paradoxical air embolism can be devastating, screening for PFO with bubble contrast echocardiography and closure if present should be considered where the sitting position will have a major advantage in the outcome of surgery (see Table 2).
- (v) Evaluation of the airway: patients with atlanto-axial subluxation and lack of neck movement secondary to cranio-cervical fusion can present challenges during airway management and positioning.

Monitoring

Appropriate intraoperative monitoring is crucial during posterior fossa surgery.

Routine monitoring

Routine monitoring should include pulse oximetry, ECG, capnography and temperature. Invasive arterial monitoring will allow the measurement of beat-to-beat variability and accurate control of blood pressure, and is mandatory. The arterial transducer should be placed at the level of external auditory meatus to correlate with cerebral perfusion.

The insertion of a central venous catheter in the right internal jugular vein is a common practice in patients who undergo surgery in the sitting position as it allows assessment of volume status and the aspiration of air during VAE. Measurement of urine output with an indwelling urinary catheter is also essential.

Monitoring for venous air embolism

Various monitors can be used to detect VAE (Table 3). Precordial Doppler is the most sensitive non-invasive monitoring device used to detect air embolism, and as little as $0.015 \text{ ml kg}^{-1} \text{ min}^{-1}$ of intracardiac air can be detected.⁹ It is usually placed in the right parasternal region. Verification of the position of the probe is vital for early diagnosis of VAE and can be carried out by injecting a small bolus of saline through the central venous catheter, although a peripheral venous catheter can be used as an alternative.¹⁰ Transoesophageal echocardiography and Doppler is more sensitive than precordial Doppler but is invasive, expensive and can be associated with complications such as oesophageal injury.

VAE results in an increase in dead space ventilation and a decrease in the level of E'_{CO_2} . Setting tight alarm limits for E'_{CO_2} will issue early warning for possible VAE. Measurement of end-tidal nitrogen (E'_{N_2}) is a more sensitive and specific method for the detection of VAE and, when the nitrogen present in the air embolus is expelled by the lungs, E'_{N_2} levels suddenly increase. Though a pulmonary artery catheter can be used as a monitor to detect VAE, it is not a sensitive indicator and not routinely used for this purpose.

An oesophageal stethoscope was previously used to detect VAE but a significant volume of air has to be entrained before the classic 'mill-wheel' murmur is heard, and this is usually already associated with signs of cardiovascular collapse. With the availability of more sensitive non-invasive monitors to detect VAE, the oesophageal stethoscope is of little clinical use.

Neurological monitoring

The electroencephalogram can be used to detect cerebral hypoperfusion and cortical ischaemia, and somatosensory evoked potentials (SSEP) to monitor spinal cord ischaemia in the sitting position. Brainstem auditory-evoked potentials monitor the function of the VIII cranial nerve and continuous electromyographic monitoring of the VII cranial nerve minimize damage to the nerve during

cerebellopontine angle surgery. The use of these monitors requires modification to the anaesthetic technique to minimize interference with the monitoring. These include maintaining consistent and modest levels of inhalation or i.v. anaesthetic agents to minimize interference during SSEP monitoring, avoidance of neuromuscular blocking agents, and the use of total i.v. anaesthesia during motor-evoked potential monitoring.

Anaesthetic technique

The goals of anaesthetic management are to avoid significant increase in ICP, maintain cerebral perfusion pressure, avoid haemodynamic instability, enable intraoperative neuro-monitoring and ensure the early detection and management of complications.

Haemodynamic instability during induction and positioning should be avoided and interruptions in monitoring during positioning minimized. Remifentanyl can be used in patients with elevated ICP to reduce the stress response to intubation. Either an inhalation or an i.v. technique can be used for the maintenance of anaesthesia, but nitrous oxide should be avoided, particularly in patients with a high risk of VAE or pneumocephalus. Any unexpected haemodynamic change or instability should be notified to the surgeon immediately because it may indicate close surgical proximity to vital centres. Normothermia should be maintained throughout. Careful observation of blood loss and volume status of the patient should be ensured.

Postoperative management

Extubation depends on the preoperative condition of the patient and the intraoperative course. In a patient who is neurologically intact and who has had uneventful surgery, smooth emergence and extubation should be carried out and the patient monitored for signs of neurological changes in a high dependency area. The presence of lower cranial nerve dysfunction and potential for aspiration pneumonia may warrant postoperative ventilation. Extensive intraoperative dissection, particularly in the floor of the fourth ventricle and around the cranial nerve nuclei, may result in postoperative airway compromise after extubation. Airway oedema after prolonged prone positioning and tongue swelling after the sitting position are not uncommon. ICP monitoring should be considered if postoperative ventilation is required because hydrocephalus remains a risk. Postoperative hypertension should be carefully managed to avoid bleeding complications.

Postoperative nausea and vomiting (PONV) and pain are important considerations after posterior fossa surgery. Occipital and infratentorial approaches are associated with severe postoperative pain due to extensive muscle cutting and reflection and subsequent spasm.¹¹ All patients undergoing surgery on the posterior fossa should be considered to be at high risk of PONV because of the proximity of the vomiting centre to the surgical locality. Use of opioids to control the pain after extensive muscle cutting surgery compounds the problem.

Table 3 Monitoring of venous air embolism (VAE); VAE detection techniques in order of decreasing sensitivity. Reproduced from³ with permission from the *British Journal of Anaesthesia*

Monitor	Associated clinical signs
Transoesophageal echocardiography	Absent
Praecordial Doppler	Absent
Pulmonary artery pressure	Minor (heart rate, MAP)
End-tidal carbon dioxide	Minor (heart rate, MAP)
Right atrial pressure	Significant
Electrocardiography	Cardiovascular collapse
Oesophageal stethoscope	Cardiovascular collapse

Paediatric considerations

Brain tumours are the most common solid tumours in children.¹² Peak incidence is between 5 and 8 years of age and up to two-thirds are located in the infratentorial region. Presentation includes obstructive hydrocephalus, signs of elevated ICP and cranial nerve dysfunction. It is important to ensure the function of a shunt if already present. As in adults, preoperative screening for the presence of a PFO is very important as its presence may preclude the use of the sitting position. Though establishing the sitting position can be difficult in very young children, in one large review, the age range for the sitting position in paediatric practice was 6 weeks to 17 years, with the median age of 5.⁴

Anaesthetic management combines the principles of paediatric and neuro-anaesthesia. Premedication should be avoided in the presence of symptomatic hydrocephalus. Blood loss should be meticulously monitored and appropriately replaced. As the surface area of the head is comparatively large in children, care should be taken to prevent hypothermia. Extubation can be performed after full recovery and in the presence of intact airway reflexes. Elective admission to a high dependency area or paediatric intensive care unit will be required. Analgesia can be established by the regular administration of paracetamol and codeine, and an appropriate dose of morphine along with an antiemetic can be used effectively in the high dependency area with regular observation.

The posterior fossa syndrome can complicate the postoperative course in children. This syndrome is defined as temporary and complete loss of speech after posterior fossa surgery and risk factors include medulloblastoma and midline location of tumours. Early diagnosis is important to facilitate speech and language therapy and to promote parental understanding and coping with the syndrome.

Declaration of interest

None declared.

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Please see multiple choice questions 5–8.