Anaesthesia for major spinal surgery

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Key points
Major spinal surgery is commonly associated with massive haemorrhage.
Airway compromise has been reported to occur in up to 1.9% of patients after cervical spine surgery.
The risk of postoperative visual loss is increased in patients undergoing prone spinal surgery.
Pregabalin and gabapentin may reduce both perioperative and chronic pain after spinal surgery.

The type of surgery performed on the spine encompasses operations for trauma, deformity, and myelopathy. The complexity of procedures is continuing to increase and older patients with significant comorbidities are being offered even more major procedures for which they would have previously not been considered. Increasing numbers of decompressive procedures for metastatic spinal cord compression are being performed as a result of improved oncological therapies. Developing areas include surgery for degenerative scoliosis and an increase in operations performed on the anterior lumbar spine.

General considerations
Patients’ co-morbidities will inform the consent process. There is a significant incidence of complications in most major spinal operations and it is essential that the patient understands them and is realistic about the surgical outcome. Major blood loss, infection, and postoperative respiratory complications are all common. There is frequent need for blood transfusion even with the routine use of red cell salvage and tranexamic acid. The spectre of spinal cord damage and paralysis needs to be raised: the incidence is ~1% in corrective spinal deformity surgery.

Conduct of anaesthesia
The tracheal tube (TT) should be fixed in place securely. The technique used should be carefully considered, as intraoperative displacement of a TT is very difficult to manage. There should be a well-publicized action plan as to the appropriate management in this situation which would typically involve the use of a laryngeal mask airway.

The decision to use throat packs should be clearly justified and based on the balance of risks and benefits. If a throat pack is used, then it must be documented as part of the World Health Organization (WHO) safer surgery check list. Part of the pack must be left outside of the mouth so it is easily visible.

Large bore i.v. cannulae should be inserted in anticipation of massive blood loss. All vascular cannulae must be well secured to prevent dislodgement in the prone position. Additional access will be useful for potential multiple infusions. The decision to invasively monitor arterial pressure should be based on the planned operation, expected blood loss, patient co-morbidities, and a requirement for postoperative critical care management. The threshold for arterial cannulation and monitoring should be low as haemodynamic instability secondary to patient position and blood loss is common. It also allows sequential intraoperative blood investigations.

The use of a central venous cannula provides an additional route for i.v. infusions. Minimally invasive monitors of cardiac output (CO) using arterial waveform pulse contour analysis or transoesophageal Doppler are now widely used.

Urinary catheterization and urine output monitoring is required for all major cases and those anticipated to last > 2 h. An enlarging bladder may cause increased intraoperative blood loss as pressure is transmitted to the valveless epidural veins. All patients with a spinal cord injury should have a urinary catheter inserted.

Prone positioning
The key to safe prone positioning is appropriate selection of the many types and sizes of support that are available. Foam bolsters are commonly used, one at the level of the chest below the axillae and the other at the level of the anterior superior iliac spines. The arms should be abducted to no more than 90°, with slight internal rotation and lie in front of the plane of the body to reduce the risk of brachial plexus injury. Particular attention should be paid to the ulnar nerve at the elbow which is at risk of pressure-related injury when the arms are flexed in the prone position (Fig. 1A).

If the arms remain by the patient’s side, then the thumbs should be positioned pointing down to avoid over pronation. Care is required to avoid pressure on the abdomen as this will be transmitted to the venous system and cause increased bleeding from the valveless epidural veins. Inferior vena cava obstruction will not only make this worse but also reduce venous return causing a reduction in CO and increased risk of lower limb thrombosis.


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used specific devices are the Montreal mattress, the Jackson operating table, the Wilson frame, and the Andrews operating table (Fig. 1B–E). Additional caution is required with the latter as the TT pilot balloon may be damaged during table adjustment. The radius of curvature of the Wilson frame can be altered by means of a winding mechanism. This allows a reduction in the lumbar lordosis thus improving posterior surgical access. However, the incidence of ischaemic optic neuropathy may be increased compared with other prone-positioning devices. This is postulated to be attributable to the dependant position of the head. Failure to position correctly or match the patient’s size to the device may cause increased intra-abdominal pressure and difficulty with ventilation.

The eyes are kept closed to protect the tear film and padding should be avoided. A number of head rests are available that are designed to avoid pressure on the eyes while maintaining the neck in a neutral position. Some include a mirror to facilitate easier intraoperative checking. External pressure on the eyes may also be completely avoided by the use of devices such as the Mayfield head fixator. The head is held in a clamp by pins which are inserted into the outer table of the skull. It affords excellent control of the head and neck and is commonly used during operations on the posterior cervical spine. Its use during prolonged cases may be considered to protect the eyes; however, use in deformity surgery is complicated as fixation of the head may act as an impediment to spinal realignment.

**Anaesthetic technique**

Intraoperative spinal cord monitoring necessitates the exclusion of anaesthetic vapours (see below). Remifentanil is a commonly used agent because of its short context sensitive half life and its negligible effect on intraoperative evoked responses. Deformity surgery and

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**Fig 1** Examples of patient supports used during prone spinal surgery. (a) Bolsters—showing arm positioning (see text), (c) Montreal mattress, (c) Jackson operating table (Image: G. Bedford), (d) Wilson frame, and (e) Andrews operating table.
decompressive procedures for metastatic tumours are particularly prone to major haemorrhage. However, the use of red cell salvage and autologous transfusion is hindered in tumour surgery by concern over dissemination of malignant cells. Systems need to be in place to allow rapid transport of cross matched blood to the patient and a working dialogue should be maintained with the laboratory that allows release of coagulation factors and platelets before coagulation results are known. Near patient testing of coagulation with the thromboelastograph (TEG®) or rotational thromboelastometry (ROTEM®) devices not only provide a rapid (<5 min) indication of coagulation status but uniquely indicate which products to use.

Opiates remain the mainstay of postoperative analgesia; however, a multimodal approach to postoperative analgesia is most effective. I.V. adjuvants include paracetamol and tramadol. The use of non-steroidal anti-inflammatory agents in the immediate postoperative period is limited because of concerns over haemotoma formation causing spinal cord compression. Prolonged use is generally discouraged; however, they may have a role in selected patients after discussion with the surgeon. Ketamine 1 mg kg\(^{-1}\) bolus followed by 1–2 mg kg\(^{-1}\) 24 h\(^{-1}\) (42–84 µg kg\(^{-1}\) h\(^{-1}\)) has been found to be a useful addition to these agents.\(^3\) Thoracotomy pain may be managed with unilateral paravertebral or epidural analgesia though local anaesthetic infusions may complicate neurological assessment. Patients will need a higher level of postoperative care by appropriately trained nursing staff if these techniques are used. Intercostal blocks are a short-lasting alternative. Gabapentin and pregabalin have been shown to reduce postoperative pain and there is evidence that this effect may continue and reduce the development of chronic pain after surgery. Pregabalin has the more consistent bioavailability. Published doses of pregabalin vary from 150 to 600 mg before surgery followed by 50–300 mg for up to 14 days.\(^4\)

### Ophthalmic complications

Postoperative visual loss (POVL) occurs in 1/60 000–1/125 000 operations.\(^5\) Spinal surgery has the highest incidence of POVL. From analysis of the American Society of Anesthesiologists (ASA) Post Operative Visual Loss Registry, spinal surgery accounted for 93/131 (70%) of all cases of visual loss after non-ophthalmic surgery. Of these, 83 were attributable to ischaemic optic atrophy (ION) and 10 were caused by central retinal artery occlusion (CRAO).\(^6\) CRAO is caused by direct pressure on the globe causing raised intraocular pressure and compromising retinal perfusion. In these cases, visual loss is usually unilateral and associated with other signs of pressure (e.g. ophthalmoplegia, ptosis, or altered sensation in the territory of the supraorbital nerve). Initial careful positioning of the head and regular checks throughout the procedure in case of movement minimizes the risk. Documentation of these eye checks throughout the course of long procedures has been advised by the ASA. Though the frequency was not suggested, an interval of 30 min would seem appropriate. Horseshoe-shaped head rests should be avoided in prone patients as they have been implicated in cases of CRAO.

POVL caused by ION is associated with male gender, obesity, increasing blood loss, and operative procedures >6 h in length. The use of the Wilson frame has also been implicated.\(^2\) Although the final common pathway is thought to be hypoperfusion of the optic nerve, there is no clear association with either intraoperative systemic hypotension or with the presence of peripheral vascular disease or diabetes. The recently updated ASA practice advisory for POVL associated with spinal surgery recommends regular intraoperative testing of haemoglobin concentration. However, it was unable to suggest a transfusion threshold that would prevent POVL.\(^7\)

Other possible causes of POVL include cortical ischaemia and haemorrhage into a cerebral tumour. In high-risk cases, assessment of vision should be performed as soon as possible in the postoperative recovery unit and an early ophthalmic opinion sought if there is a suggestion of visual compromise. Initial management should include optimization of arterial pressure, oxygenation, and correction of anaemia.\(^8\) Treatment with agents such as acetazolamide has not been beneficial and there is rarely any useful improvement in vision with either injury, so attention should be focused on preventative measures. Careful positioning with the head at the same level as the heart, meticulous haemostasis, and possibly staging prolonged procedures should be considered.

Because of the devastating nature of this complication, patients should be informed of an increased incidence of visual loss after spinal operations that are expected to be of prolonged duration and associated with significant blood loss.

### Abdominal organ ischaemia

Prone positioning may also cause abdominal organ dysfunction possibly because of compromised blood flow. There have been sporadic case reports of either hepatic or pancreatic dysfunction after prone spinal surgery attributed to hypotension or hypovolaemia.\(^8\) In 2006, two cases of severe injury (one fatal) were reported to the UK National Patient Safety Agency (NPSA). In both patients, clinical features developed after 2 h of surgery and consisted of cardiovascular instability, developing metabolic acidosis, increasing lactate, and decreasing glucose concentrations. There was also an increase in the alanine transferase and a consumptive thrombocytopenia. Six other cases sharing similar features were reported as a result of a joint request for information by the Royal College of Anaesthetists (RCoA) and NPSA. Although not proved, the most likely cause was suggested to be liver ischaemia because of compression in the prone position. Faced with a lack of evidence, the RCoA reiterated advice that any prone patient support should ‘... avoid(s) focal pressure on vulnerable areas and compression of intra-abdominal organs, particularly during prolonged procedures. ...’ It is inevitable that pressure is applied in some areas and constant vigilance for this complication is required. Unexplained metabolic acidosis especially in a cardiovascularly unstable patient should lead to assessment of haematological and hepatic parameters. Intraoperative migration of the prone patient is possible especially in those with a high body mass index. Direct pressure on the abdomen should be relieved.
Treatment is supportive and an early return to the supine position should be considered with subsequent critical care management.

**Spinal cord monitoring**

Intraoperative spinal cord monitoring should be considered in any procedure where the spinal cord is at risk, for example, deformity correction. Throughout the operation, neurophysiology technicians assess two types of evoked responses consisting of somatosensory evoked potentials (SSEPs) and motor evoked potentials (MEPs). The spinal cord may be at risk if the amplitude of SSEPs are reduced to <50% of baseline values. MEPs are generally described as being present or absent.

**Somatosensory evoked potentials**

These are small-amplitude potentials measured over the sensory cortex or via epidural electrodes from stimuli applied to the posterior tibial nerves. SSEPs are transmitted via the posterior columns of the spinal cord, in the territory of the posterior spinal arteries which supply the posterior third of the cord. As they are of low amplitude, they are affected by basal muscle tremor and the signal-to-noise ratio is improved by increasing the depth of muscle relaxation. Their use is not significantly affected by therapeutic concentrations of anaesthetic vapours.

**Motor evoked potentials**

More recently intraoperative assessment of MEPs has been used. A series of short-duration constant current stimuli of 300–700 V is applied to the motor cortex and measured via needle electrodes inserted typically in the tibialis anterior, abductor hallucis, and vastus medialis muscles. Other needle electrodes are placed in selected small muscles of the hands for reference. MEPs rely on corticospinal tract integrity, which lies in the territory of the anterior spinal artery. MEPs, therefore, complement SSEPs in their assessment of spinal cord function. In contrast to SSEPs, MEPs are large-amplitude potentials and are incompatible with profound muscle relaxation. Neurromuscular blocking agents are, therefore, best given by infusion and the dose optimized in consultation with the neurophysiology technicians.

**The effect of anaesthetics on MEPs**

All anaesthetic vapours reduce MEP amplitude in a dose-dependent manner. Anaesthetic vapour concentrations more than 0.5 MAC are generally not compatible with reliable monitoring. As a result, total i.v. anaesthesia with propofol is the anaesthetic technique of choice when assessing MEPs. However, propofol also causes a dose-dependent depression of cortically evoked responses of a smaller magnitude, which affects the reliability of neurophysiological monitoring especially when baseline responses are initially small. Intraoperative Cerebral Function Analysing Monitoring allows titration of the anaesthetic to avoid burst suppression [iso-electric electroencephalogram (EEG)] and hence optimize monitoring conditions. Other devices that provide a processed form of EEG (e.g. bispectral index) should also be considered in the light of recent National Institute for Health and Care Excellence (NICE) guidance regarding depth of anaesthesia monitoring in patients receiving total i.v. anaesthesia.

Continuous monitoring of muscles innervated by individual nerve roots is being increasingly performed. This is not an evoked potential and has therefore been termed free electromyography. It enables neurophysiological monitoring in procedures that include vertebral levels below the termination of the spinal cord.

**Operative considerations**

**Lumbar surgery**

Posterior lumbar interbody fusion involves nerve roots decompression by a laminectomy performed via a posterior approach. The intervertebral disc is then removed and replaced with an implant. Fusion is obtained by means of pedicle screws and connecting rods by which abnormal movement between adjacent vertebrae is prevented. There is usually only modest blood loss; however, bleeding from epidural veins may be difficult to control. Transforaminal lumbar interbody fusion is a refinement of this technique utilizing a more lateral approach which is associated with less muscle damage.

Anterior lumbar disc replacement and anterior lumbar interbody fusion are options for treatment of degenerative intervertebral disc disease. The anterior approach to the lumbar spine is hazardous. In particular, injury to the iliac vessels is associated with potentially massive haemorrhage. Early vascular surgical assistance should be sought. In extremis aortic cross clamping has been used.

**Cervical surgery**

Anterior cervical decompression and fusion is a commonly performed operation for cervical disc prolapse causing myelopathy. Access to the spine requires retraction of the carotid sheath. As a result, some cardiovascular instability may occur and for this reason invasive arterial pressure monitoring should be considered. Blood vessels to the thyroid gland may have to be sacrificed increasing the risk of postoperative haematoma. Medial retraction of the oesophagus will commonly cause postoperative dysphagia.

The patient is positioned supine with their arms by their side. The neck is extended and a limited amount of traction is applied with tape under the chin. Alternatively, traction can also be achieved utilizing cranial pins attached to a weight. Access to the hands is restricted so either the i.v. fluid line is extended or a cannula is sited in the foot. A reinforced (armoured) TT is commonly used.

**Airway complications**

The incidence of airway compromise requiring reintubation after anterior procedures on the cervical spine has been reported as up to 1.9%. Risk factors include multiple level surgery, blood loss of more than 300 ml, duration >5 h, a combined anterior and posterior operation and previous cervical surgery. High-risk patients should...
be monitored in a critical care facility and some consideration should be made for a staged extubation utilizing an airway exchange catheter once a leak is confirmed around the TT. A smooth emergence is desirable and may be facilitated by a low-dose Remifentanil infusion to target the systolic arterial pressure between 120 and 160 mm Hg depending on preoperative arterial pressure. Ongoing hypertension can be controlled with agents such as labetalol, while excluding treatable causes.

Airway compromise may be attributable to haematoma formation or supraglottic oedema secondary to venous and lymphatic obstruction. Symptoms usually develop within 6 but up to 36 h after surgery and include neck swelling, change in voice quality, agitation, and signs of respiratory distress. Tracheal deviation may occur and compression of the carotid sinus can cause bradycardia with hypotension. An emergency airway algorithm is summarized in Figure 2. Re-opening of the wound and evacuation of haematoma has been shown to be helpful if initial attempts at tracheal intubation fail.

**Conclusion**

Successful outcomes after major spinal surgery rely on an appropriate and considered anaesthetic technique. The incidence of
complications may be reduced by close attention to detail and a good understanding of the surgical challenges.

Declaration of interest
None declared.

References

Please see multiple choice questions 1–4.