Anaesthesia for Spinal Surgery

Ian Crabb

Clinical features of spinal disorders

Intervertebral disc lesions

Prolapsed discs: lumbar backache is one of the most common causes of chronic debility in Western society. Acute lumbar disc prolapse or chronic degeneration with disc-space narrowing at L4/5 or L5/S1 are the most common pathologies. In acute prolapse, the disc may bulge beneath the posterior longitudinal ligament in the mid line (central disc) or posterolaterally with consequent distortion of the spinal canal or nerve-root compression. Local oedema may exacerbate the problem. Symptoms result from distortion of the posterior longitudinal ligament (chronic pain), pressure on the nerve-root sheath (sciatica) and compression of the nerve itself (muscle weakness, numbness and paraesthesia). Cauda equina compression may cause urinary retention, but is relatively uncommon. Management may include rest, analgesia and physiotherapy, but the prolapsed disc can be treated effectively only by bed rest, disc reduction (including epidural injection or chemonucleolysis) or surgical discectomy.

Cervical disc prolapse may be precipitated by sudden unexpected flexion or rotational movements. In most cases, there is probably a pre-existing disc abnormality. The most common levels for prolapse are C5/6 and C6/7, and symptoms are similar to those of lumbar disc prolapse. Treatment of the prolapse may be effected by rest, reduction using bed rest and traction, or surgical removal, if the symptoms are severe.

Spondylosis: lumbar disc degeneration may occur following recurrent disc prolapse or for other reasons. This results in flattening of the disc, facet-joint displacement, and a degree of instability with limited and painful movement (spondylosis). Conservative treatment for lumbar spondylosis is appropriate in less severe cases. However, if the pain cannot be controlled, spinal fusion is indicated.

Spondylosis is the most common disorder of the cervical spine. In addition to disc flattening, bony spurs may grow at the margins of the vertebral bodies, impinging on nerve roots and producing symptoms. Physiotherapy is the mainstay of treatment, but in severe or refractory cases anterior spinal fusion may be the definitive option.

Spondylolisthesis

If intervertebral facet joints become affected by osteoarthritic changes, dysplasia or fractures, one vertebral body may slip forwards on the other (spondylolisthesis). The most common levels for this to occur are L4/5 and L5/S1. Stabilization is achieved by spinal fusion and may be necessary for symptomatic relief.

Spinal stenosis

The spinal canal may be congenitally small or narrowed by the presence of a spondylolisthesis. Further narrowing consequent on disc degeneration and osteoarthrosis may produce neurological symptoms, which may be unilateral (root canal stenosis). Spinal decompression is indicated if symptoms are severe.

Rheumatoid disease

Rheumatoid arthritis affects about 1% of the world’s population. The disease causes destruction of synovial joints, tendons and bursae, and 75% of sufferers have extra-articular symptoms. The spine is commonly affected, most often the upper cervical region. Erosion of the odontoid peg or cruciate ligament may result in atlanto-axial subluxation, with the risk of cord compression. ‘Vertical subluxation’ may result from erosion of the lateral masses of the axis, causing the odontoid peg to approach or enter the foramen magnum. Of relevance to the anaesthetist is that the disease may involve the temporomandibular and artenoid joints.

Assessment of atlanto-axial subluxation may be made by measuring the distance between the anterior arch of the atlas and the odontoid peg on lateral cervical spine radiographs. However, neither this ‘anterior atlanto-dental interval’ nor the posterior equivalent correlates well with the severity of neurological symptoms. Stabilization procedures or surgical decompression may be undertaken to relieve neurological symptoms, but they are hazardous, with equivocal benefit.

Spinal curvature

Scoliosis is a lateral curvature of the spine, often with a rotational element. The deformity usually arises in late childhood and may be postural or structural. Postural scoliosis arises as a compensatory mechanism for problems outside the spine, such as a shortened leg or abnormal pelvic tilt. Structural scoliosis is a fixed deformity and is always accompanied by bony abnormalities. Adolescent idiopathic scoliosis is the most common form, presenting in the 10–15 year age group. Operative treatment for scoliosis is indicated for curvatures over 40°, the surgery being potentially complex and challenging.

Kyphosis: ‘structural kyphosis’ is a fixed, excessive dorsal curvature of the thoracic spine. It may occur in osteoporosis and ankylosing spondylitis. In Scheuermann’s disease (adolescent kyphosis), the vertebral bodies become wedge-shaped as they grow. If the curvature exceeds 60°, surgery, which carries a high risk of neurological damage, may be indicated.

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Infection
Tubercle bacilli or staphylococci may cause abscess formation within vertebral bodies. Tubercle infection may spread to adjacent vertebrae with caseation and cold abscess formation, resulting in vertebral collapse with a high risk of spinal cord damage. Antibiotic therapy is the mainstay of treatment for both infections. However, abscess drainage or spinal fusion for progressive deformity may be necessary.

Surgical procedures
Lumbar laminotomy and laminectomy: laminotomy (partial removal of vertebral lamina) or laminectomy (complete removal) are performed to decompress the spinal cord and/or nerve roots via a posterior approach with the patient lying prone. Should a discectomy also be necessary, the dura is retracted to one side and the disc removed piecemeal. During these procedures there is a risk of damage to both the dura and retroperitoneal structures (e.g. major vessels). The extent of the procedure depends on the underlying problem and may vary from simple laminotomy for single nerve-root compression to decompression over several segments for spinal canal narrowing. In such cases, a stabilization or fusion procedure (e.g. plate and screws) may also be required.

Microdiscectomy can be performed to decompress nerve roots affected by simple pathology; bone is not usually removed. The patient is placed prone or kneeling and the appropriate spinal level is identified using radiographic control. A small incision is made over the appropriate interspace and an operating microscope is used to retract the nerve-root to allow disc material to be excised.

Thoracic laminectomy and costotransversectomy: thoracic laminectomy involves midline removal of the vertebral lamina to decompress the thoracic spinal canal. Costotransversectomy (removal of transverse process and rib-head) is performed for nerve root compression. Both procedures require the patient to be prone and involve the use of an operating microscope.

Cervical laminotomy, foramenectomy and laminectomy are used to decompress the spinal cord or nerve roots in the cervical region. As with the lumbar and thoracic regions, the nature and extent of the surgery depends on the underlying pathology. The patient may be positioned prone or sitting.

Anterior cervical discectomy is a common neurosurgical procedure performed for disc herniation or degeneration with neurological symptoms. It is often augmented by vertebral fusion with a bone graft.

Other cervical procedures
Vertebrectomy is essentially an enlarged version of an anterior discectomy and is performed as an anterior decompression procedure. If access is required above the level of C3, a transoral approach may be used, which may involve a mandibular split and division of the tongue.

Cervical or craniocervical fusion is indicated for spinal instability. The fusion usually involves several adjacent vertebrae and may include fusing the occiput to the upper cervical spine. A posterior approach is used with the patient lying prone.

Spinal reconstruction procedures: significant kyphoscoliotic deformities may benefit from reconstructive surgery and, regardless of the underlying condition responsible for the deformity, the surgical approach to the anterior spine is similar. Surgery to the upper thoracic spine is achieved via a modified and extended anterior cervical exposure, often involving resection of a clavicle, part of the manubrium and first rib. Mid-thoracic spinal surgery is more easily performed via a thoracotomy with rib resection. One-lung ventilation may be required. Once the vertebrae or discs are removed, the spinal cord is at risk of damage, the degree of risk depending on the extent of the vertebral disease and the extent of reconstruction required.

A transdiaphragmatic approach involving detachment of the diaphragm is required for lower thoracic procedures. The lumbosacral spine is approached via a flank incision and retroperitoneal dissection. Often the 11th or 12th ribs are resected, risking damage to the great vessels, ureters, sympathetic chain and presacral plexus. A posterior fusion is also often undertaken with the above procedures.

Anaesthetic considerations
Thoracolumbar procedures (excluding corrective surgery)
Preoperative: surgical procedures on the lumbar spine for disc problems are common. Any preoperative neurological deficit should be recorded in the patient’s notes, especially if a regional technique is considered. Generally, these patients are otherwise healthy and no special investigations are normally required.

Intraoperative: it is possible to perform simple lumbar procedures under local or regional (spinal or epidural) anaesthesia. However, this is seldom done in practice because of medico-legal concerns that any new postoperative neurological deficit may be blamed on the anaesthetic technique. A general anaesthetic technique involving intubation and mechanical ventilation is more usual. For all posterior spinal procedures the patient is placed prone or in the knee–elbow position. It is therefore advisable to use an armoured tracheal tube to minimize the risk of kinking and to ensure that the tube is well secured before and after turning the patient. Potential problems with the prone position are summarized in Figure 1. Thoracoscopy is being increasingly used for procedures on isolated regions of the thoracic spine. This requires a double-lumen tracheal tube and for the ipsilateral lung to be deflated.

Any standard maintenance regimen is acceptable. However, blood pressure control is important, balancing the need to ensure spinal cord perfusion with the requirement to produce a bloodless surgical field. Sodium nitroprusside and esmolol infusions have been widely used for this purpose, though remifentanil is becoming popular. Blood loss is usually minimal from simple procedures, though if extensive laminectomies and fusions are performed, cross-matched blood should be available.

Standard monitoring is appropriate for simpler procedures. However, invasive blood pressure monitoring, a central venous
**ORTHOPAEDICS**

### Problems with the prone position

<table>
<thead>
<tr>
<th>Potential problem</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eyes</strong></td>
<td></td>
</tr>
<tr>
<td>• Corneal abrasion</td>
<td>Increased intraocular pressure leads to decreased perfusion pressure. Reduce risk by avoiding compression to the eyes, hypotension, low haematocrit.</td>
</tr>
<tr>
<td>• Optic neuropathy</td>
<td>Ensure eyes taped shut.</td>
</tr>
<tr>
<td>• Retinal artery occlusion</td>
<td>Avoid pressure on the eyes.</td>
</tr>
<tr>
<td><strong>Head and neck</strong></td>
<td></td>
</tr>
<tr>
<td>• Venous and lymphatic obstruction</td>
<td>Careful positioning to minimize venous obstruction.</td>
</tr>
<tr>
<td>• Skull fixation</td>
<td>Insertion of pins into skull can result in a hypertensive response that is difficult to control.</td>
</tr>
<tr>
<td><strong>Abdominal compression</strong></td>
<td></td>
</tr>
<tr>
<td>• Impaired ventilation</td>
<td>Avoid abdominal compression as far as possible.</td>
</tr>
<tr>
<td>• Decreased cardiac output</td>
<td>Bean-bag mattress or pillows are better than supportive frames or knee-chest position.</td>
</tr>
<tr>
<td><strong>Damage to major vessels</strong></td>
<td></td>
</tr>
<tr>
<td>• Aorta or inferior vena cava</td>
<td>Accidental damage following perforation of anterior longitudinal ligament. Produces major bleeding into wound, and presents with acute reduction in blood pressure and electro-mechanical dissociation arrest. High mortality.</td>
</tr>
<tr>
<td>• Iliac vessels</td>
<td>Less acute presentation. High index of suspicion to avoid delayed diagnosis.</td>
</tr>
</tbody>
</table>

Pressure line and a urinary catheter should be considered if deliberate hypotension is used or if the procedure is likely to be prolonged and involve large fluid shifts.

**Postoperative**: most spinal surgery is painful and good postoperative analgesia is important. Local anaesthetic and opioid drugs can be instilled into the epidural space before closing. More usually, however, a regimen including patient-controlled analgesia (PCA) combined with regular oral/rectal analgesics is successful. Postoperative complications include persistent hypotension, haemorrhage, urinary retention, nerve root damage and cauda equina syndrome (urinary/faecal incontinence, perineal sensory loss and lower-limb motor weakness).

**Cervical procedures**

**Preoperative**: cervical spine fractures may cause acute spinal cord trauma and result in acute ventilatory failure requiring emergency tracheal intubation. Cervical spine stabilization during intubation is essential. The acute injury may additionally produce dysfunction of the sympathetic nervous system, resulting in hypotension and bradycardia. Simple treatment with fluids and atropine usually suffices, though vasopressors (e.g. ephedrine) may be necessary.

Neurological signs and symptoms may be present. Nerve root compression produces pain in the neck and arm, often associated with weakness and sensory loss. Acute cord lesions above T1 produce paraplegia and if the lesion is above C5 the patient will be quadriplegic.

Careful airway assessment is vital in all patients requiring cervical spine surgery. Difficult intubation may be anticipated if there is reduced movement, swelling or deformity. Up to 40% of patients requiring cervical spine surgery for rheumatoid disease fall into this group. The patient may need to be prepared for an awake fibre-optic intubation and appropriate equipment and skilled staff made available. In certain circumstances (e.g. surgery involving maxillotomy or mandibulotomy), an elective tracheostomy may be necessary for postoperative airway management.

**Intraoperative**: general anaesthesia with tracheal intubation and ventilation is required; standard maintenance techniques are appropriate. For anterior cervical procedures, the patient is placed supine with the neck extended and supported. For posterior approaches, the patient is usually prone. However, the seated position is preferred by some surgeons, because surgical access may be easier and blood loss reduced. This position is associated with a high incidence of air embolism (25–45%). If a patent foramen ovale is present (20% of the population), paradoxical embolism may occur, resulting in air entering the cerebral or coronary circulations. Standard monitoring may be used for straightforward cases, but arterial and central venous pressure catheters are useful for more prolonged procedures. Additionally, spinal cord monitoring may be required (see below).

Exubation may be problematical and is best performed with the patient awake and able to support their own airway. If the risk of reintubation is high, a tracheal tube exchange catheter (e.g. Cook catheter) may be useful. The catheter can be introduced into the tracheal tube and left in situ when the patient is extubated. Should urgent reintubation be necessary, the new tracheal tube can be rapidly railroaded over the exchange catheter. However, prolonged sedation and ventilation should be avoided because this may mask postoperative neurological deterioration.

**Postoperative**: possible complications include airway obstruction post extubation, which is potentially life-threatening if the patient has had a spinal fusion and is encased in a stabilization device. Airway compromise may result from haematoma formation or neurological deficit. Pneumothorax is an occasional cause of postoperative respiratory distress.

**Spinal reconstruction and fusion**

**Preoperative**: spinal reconstruction is indicated for correction of kyphoscoliotic deformities and for stabilization following trauma, infection (e.g. tuberculosis) or metastatic carcinoma. Patients presenting for this type of major surgery require careful
Preoperative considerations for patients undergoing major reconstructive spinal surgery

<table>
<thead>
<tr>
<th>Problem</th>
<th>Comment</th>
</tr>
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<tbody>
<tr>
<td><strong>Respiratory</strong></td>
<td></td>
</tr>
<tr>
<td>• Reduction in total lung capacity and vital capacity</td>
<td>Reduction worse with increasing deformity. If vital capacity &lt; 40% predicted postoperative ventilation likely. NB A further decrease in vital capacity of up to 40% may occur postoperatively; recovery may take up to 2 months</td>
</tr>
<tr>
<td>• Increasing V/Q mismatch</td>
<td>Hypoxaemia more likely</td>
</tr>
<tr>
<td><strong>Cardiovascular</strong></td>
<td></td>
</tr>
<tr>
<td>• Increase in pulmonary vascular resistance</td>
<td>Independent of severity of scoliosis</td>
</tr>
<tr>
<td>• Increasing incidence of congenital heart disease and mitral valve regurgitation</td>
<td>High index of suspicion</td>
</tr>
<tr>
<td><strong>Neurological</strong></td>
<td></td>
</tr>
<tr>
<td>• Variable preoperative deficit</td>
<td>Careful preoperative documentation</td>
</tr>
<tr>
<td><strong>Musculoskeletal</strong></td>
<td></td>
</tr>
<tr>
<td>• Muscular dystrophy relaxants</td>
<td>Abnormal response to muscle</td>
</tr>
<tr>
<td>• Respiratory impairment</td>
<td>Postoperative ventilation may be required</td>
</tr>
<tr>
<td><strong>Nutrition</strong></td>
<td></td>
</tr>
<tr>
<td>• Malnourishment</td>
<td>Likely in patients with metastatic carcinoma</td>
</tr>
</tbody>
</table>

Preoperative assessment, because complex and chronic problems are common (Figure 2). Preoperative management should include lung function tests (e.g. forced vital capacity, peak expiratory flow rate), arterial blood gas analysis and review by a cardiologist if cardiac abnormalities are suspected.

Intraoperative: intubation with a double-lumen tube may be necessary. Standard maintenance techniques are applicable, although this may have to be modified (e.g. no muscle relaxants) depending on surgical technique and spinal cord monitoring (see below).

Major blood loss is not uncommon and suitable intravenous access should be secured. Intraoperative blood loss may be dramatically reduced by careful patient positioning, the use of controlled hypotension (mean arterial pressure 60–70 mm Hg) and mild haemodilution to a haematocrit of 25–28%.

Intraoperative monitoring should include invasive blood pressure, central venous pressure, and urine output measurement.

Evoked potentials are used to monitor spinal cord function (see below). If there is any indication of spinal cord ischaemia during surgery, normal blood pressure should be restored immediately and any traction on the cord relaxed. Strenuous efforts should be made to maintain normothermia.

Early extubation is desirable and good postoperative pain relief is essential. Epidural analgesia is considered by many to be the gold standard. An epidural catheter can be inserted before surgery or by the surgeon during the operation. Some patients require planned ICU admission for elective postoperative ventilation.

Postoperative complications include the risk of respiratory failure increased by thoracotomy, diaphragmatic injury and fat embolism. Great care should be exercised when moving and transferring patients to prevent dislodgement of spinal fixation. Careful documentation of neurological status is important because postoperative neurological deterioration is a major concern.

Spinal cord damage

Neurological damage during surgery and anaesthesia is not limited to the site of surgery. Paraplegia and quadriplegia have been reported as a result of poor patient positioning. There are reports of patients with spinal disease who have suffered neurological damage either at levels remote from the site of surgery or during surgery unconnected with their spinal disease. However, neurological damage is more likely at or near the site of surgery on the spine. Risk factors and methods for minimizing them are listed in Figure 3.

Risks of spinal cord damage

**Risk related to:**
- length and type of surgical procedure
- spinal cord perfusion pressure
- underlying spinal pathology
- pressure on neural tissue during surgery

**Risk minimized by:**
- careful positioning
- maintaining SCPP
  - SCPP = MAP – CSFP
  - CSFP can be reduced by CSF drainage
  - MAP manipulated by anaesthetist
  - keep systolic blood pressure > 90 mm Hg
- drugs
  - methylprednisolone given less than 8 hours after insult
  - NMDA antagonists (ketamine, magnesium)
- prevention of haematoma formation
  - careful haemostasis
  - stop anti-platelet medication preoperatively
  - withhold heparin immediately postoperatively

CSFP, cerebrospinal fluid pressure; MAP, mean arterial pressure; NMDA, N-methyl-D-aspartate; SCPP, spinal cord perfusion pressure
Spinal cord monitoring
The ‘wake-up test’ involves lightening anaesthesia at an appropriate point during the procedure and observing the patient’s ability to move to command. The technique requires practice and adds to the duration of surgery. In addition, it provides information at the time of the wake-up only and misses damage occurring at other times.

Neurophysiological monitoring using somatosensory evoked potentials (SEPs) provides a continuous picture and offers a more sophisticated approach. Electrical stimuli are applied to the lower limbs and appropriately placed electrodes can record cortical (SCEP) or spinal (SSEP) evoked potentials. The resulting trace can be analysed for wave amplitude and latency with respect to a reference ‘time zero’. SCEPs are affected by anaesthetic induction and inhalational agents, opioids and local anaesthetic drugs, and interpretation requires care and experience. Nevertheless, a decrease in amplitude or latency unrelated to drug administration of 35–50% is thought to be significant and indicate possible cord damage. However, even in skilled hands, interpretation can be difficult and a ‘wake-up test’ may still be required.

SSEPs can be recorded from electrodes placed into the epidural space either percutaneously or during surgery. SSEPs are affected less by inhalational agents, but are sensitive to temperature changes and local anaesthetic drugs. Their stability during anaesthesia allows them to be used with more confidence during surgery than SCEPs.

Motor evoked potentials can be obtained by stimulating the motor cortex with a transcranial electrode and eliciting a response from the distal spinal cord, peripheral nerves or muscle. They have not been used extensively for spinal cord monitoring because they are more difficult to achieve and are sensitive to inhalational anaesthetic agents.

FURTHER READING

