Anaesthesia for paediatric lower limb surgery

H Lonsdale BSc MBChB FRCA¹ and J Owen BMedSci MBChB FRCA²,*

¹Specialist Trainee in Anaesthesia, Royal Manchester Children’s Hospital, Oxford Road, Manchester M13 9WL, UK, and ²Consultant Paediatric Anaesthetist, Royal Manchester Children’s Hospital, Oxford Road, Manchester M13 9WL, UK

*To whom correspondence should be addressed. Tel: +44 161 701 1263; Fax: +44 161 701 1246; E-mail: jan.owen2@cmft.nhs.uk

Key points

- Musculoskeletal disorders can be manifestations of a systemic disease.
- There may be relative or absolute contraindications to the use of non-steroidal anti-inflammatory drugs or central neuraxial block.
- Blood loss can be substantial unless a tourniquet is used.
- Many conditions are associated with difficult airway management.
- Some co-morbidities are associated with a hypermetabolic state that can be confused with malignant hyperpyrexia.

Musculoskeletal problems in children account for about one-third of all congenital abnormalities. Many, such as clubfoot and hip dysplasia may be isolated in otherwise healthy children but a significant number of patients present for surgery with a musculoskeletal aspect of their multi-system disease. The anaesthetic care and management of the child requiring lower limb orthopaedic surgery may range from the straightforward to the very complex and this is largely dependent upon the child’s pre-existing condition for which they require the corrective surgery. This article will focus on the assessment and anaesthetic management of children requiring surgery to correct their lower limb problems.

Associated conditions

Children with some underlying medical conditions frequently require orthopaedic intervention and these include:

Spina bifida

Caused by incomplete closure of the embryonic neural tube, spina bifida has a range of clinical presentations, from spina bifida occulta to meningocele and Arnold–Chiari malformation associated with hydrocephalus. The total incidence of spina bifida is 5.8 per 10 000 total births but the incidence of elective termination in affected pregnancies is ~72%, so incidence in live births is much lower. Ten year survival now exceeds 80%.¹

Myelomeningocele is a sac containing meninges and neural elements bulging through a vertebral defect and which is closed surgically shortly after birth, but the underlying spinal cord damage remains. Abnormal lower limb growth and denervation can lead to developmental abnormalities such as hip dysplasia and talipes equinovarus (clubfoot). Neuromuscular imbalance occurs when spastic or unopposed muscles work against flaccid muscles, causing joint deformity. Surgical intervention in the form of soft tissue release and bone realignment is then required to preserve mobility.

Arthrogryposis multiplex congenita

Occurring in 1:3000 live births, arthrogryposis consists of multiple, non-progressive symmetrical rigid joint contractures, worsening distally. Children have normal intellectual function and nearly normal life expectancy. Orthopaedic intervention may be required for clubfoot, hip dysplasia, dislocated patella, and scoliosis. Surgical treatment aims to correct all lower limb deformities with soft tissue releases and osteotomies before the age of 2 yr to facilitate mobilization.

Developmental dysplasia of the hip

Developmental or congenital dysplasia of the hip (DDH) is prolonged displacement of the fetal femoral head from the acetabulum. Incidence is ~1:1000, with girls affected four times more commonly than boys.
Infants under 6 months of age generally have joint subluxation without associated bony deformity and are treated nonsurgically in a Pavlik harness for up to 8 weeks until both hips are stable. Children over 6 months of age or those with inadequate reduction after conservative treatment require open or fluoroscopically guided closed manipulation and reduction under general anaesthesia, with application of a hip spica cast to maintain the correct joint position until the hip becomes stable. After 18 months of age, open reduction is the treatment of choice. Generally no specific anaesthetic precautions are required as these tend to be otherwise healthy children.

Cerebral palsy
For a full discussion of this condition please refer to the CEACCP article ‘Cerebral palsy and anaesthesia’.2

Surgery is performed to prevent or improve defects such as the classical windswept deformity of hips or knees—an abduction and external rotation position of one joint with the opposite joint in adduction and internal rotation, caused by a combination of contractures, immobility, gravity, and time. Surgery can facilitate function or mobility, including ability to sit in a wheelchair. Common procedures include soft tissue releases, tendon transfers, tenotomies, and botox injections. These patients are frequently listed for simultaneous correction of multiple deformities.

Osteogenesis imperfecta
This autosomal dominant condition with four major variants is caused by a defect in reduction in the production of type I collagen with an incidence of 1:20 000 live births. Bones are osteoporotic, brittle, and easily fractured, joints are hypermobile and frequently dislocated. Patients with Type I osteogenesis imperfecta (OI) have characteristic blue-grey sclerae and craniofacial disproportion. Fractures may occur during nappy changes and application of a non-invasive blood pressure cuff.3 Type II is the most severe (OI congenita) and is usually lethal at birth because of multiple fractures sustained during delivery. If the neonate survives to childhood they may develop micrognathia, restrictive thoracic deformity and severe fragility of long bones. Death is frequently as a consequence of respiratory failure because of restrictive lung disease.

Children with OI present for emergency treatment of fractures and correction of deformities, including multiple site osteotomies.

Dwarfism
The most common form of dwarfism is achondroplasia, affecting 1.5 per 100 000 live births but there are over 100 osteochondrodysplasias and mucopolysaccharidoses characterized by disproportionate short stature (<157 cm in adults) and limb abnormalities. Common orthopaedic procedures include limb-lengthening techniques, joint replacement, and limb realignment.

Preoperative evaluation
Preoperative assessment concerns vary with the age and medical condition of the child. Planning is best done in conjunction with the surgeon to be aware of the location of the incision site (to plan regional techniques) the length of the procedure and any individual surgical preferences. The surgeon may also plan multiple interventions in one session and this significantly extends the duration of surgery and potentially increases analgesic requirements.

Related conditions
A thorough history of related diagnoses is essential. Important co-morbidities include scoliosis and restrictive pulmonary disease, congenital or acquired cardiac lesions, craniofacial and facial abnormalities, hydrocephalus, dental disease, and obesity. Pre-existing neurological deficits, contractures, deformities, and fractures should also be carefully documented to aid the planning of positioning and handling.

Obstructive sleep apnoea
Obstructive sleep apnoea (OSA) is especially common in dwarfism, either secondary to cervico-medullary cord compression (central OSA), or as a result of thickened pharyngeal and laryngeal structures, narrowed nasal passages, micrognathia, pharyngeal hypoplasia, and tracheal narrowing. An element of airway obstruction may be present even when awake and great care should be taken when considering sedative pre-medicants, especially in obese patients. Sleep studies are frequently performed to assess for apnoeas. Children with OSA have an increased incidence of perioperative complications such as airway obstruction, desaturation, and laryngospasm. They are also more likely to need postoperative critical care.

Children with OSA and systemic disease affecting the skeleton should also be carefully examined for upper motor neurone lesions secondary to craniofacial instability or foramen magnum stenosis and if a lesion is suspected imaging should be discussed with a paediatric radiologist.

Cardiorespiratory disease
Arthrogryposis, achondroplasia, and OI are frequently associated with congenital cardiac lesions. ECG, echocardiogram, chest radiograph, and cardiological review may guide anaesthetic technique and decision-making.

Developmental diseases of the skeleton can lead to thoracic cage deformities, scoliosis, and consequent restrictive lung disease. Pulmonary hypertension and hypoplasia can then progress to cor pulmonale and right heart failure. In children, symptoms of right heart dysfunction are non-specific and may include shortness of breath and fatigue during physical exertion or difficulty in feeding for infants.

Significant cardiorespiratory disease can lead to difficulties with extubation and postoperative self-ventilation. The risks and benefits of surgery must be carefully weighed by the multidisciplinary team and include a planned extubation strategy. There should be a low threshold for postoperative ventilation and discussion of the possibility for temporary or permanent tracheostomy with long-term ventilation. It may be necessary to decide that the procedure is contraindicated if the child has very severe cardiorespiratory disease.

Airway assessment
A thorough evaluation of the airway is imperative to highlight any increased risk for inadequate mask ventilation and difficult tracheal intubation, and to plan an airway management strategy. For example, in OI there may be craniofacial instability, brittle teeth, a cleft palate, and pre-existing facial fractures. In arthrogryposis, there may be micrognathia, gastro-oesophageal reflux, and limited neck movement because of contractures.
Laboratory tests
Abnormalities in full blood count or coagulation studies should be discussed with the surgical team and consideration given to postponing the procedure until the abnormality is corrected. If the starting haemoglobin is low (our institution would consider the lower limits of safety to be 70 g litre\(^{-1}\)) or significant blood loss is anticipated, cross-matched blood should be available before starting the procedure. In open procedures where a tourniquet is not used the potential for blood loss is significant and the requirement for preoperative blood typing or cross-matching should be discussed with the surgeon. Preoperative blood testing should also include screening for sickle cell disease where appropriate, especially if tourniquet use is planned.

Up to 30% of children with OI have bleeding diathesis in the presence of normal platelet count as collagen is involved in platelet aggregation. Platelet function tests available as part of bedside thromboelastography may be helpful but a normal result does not predict straightforward control of intra-operative bleeding. The risks and benefits of regional anaesthesia should be considered and cross-matched platelets should be available before the start of major surgery.

Communication
Some children who have systemic co-morbidities will require several procedures from a young age, with the involvement of multiple clinical teams. They may have varying experiences of hospital care (including perioperative care) and this can be challenging for the child, their whole family and the multi-disciplinary team. It is important to remember that every child has the right to have their views taken into consideration in all matters affecting their care and so the child must be placed at the centre of the decision-making process whenever possible.

It is extremely important to note that many patients with severe systemic disease, including one-third of patients with cerebral palsy (CP) are of normal intellect and may understand much more than they are able to communicate. Some children use simple signing techniques such as Makaton and may require the parent/carer to be present as interpreter for accurate assessment of pain. A preoperative anxiolytic may be necessary as these children can become very distressed.

Perioperative management
Most conventional anaesthetic techniques will be suitable for most children and procedures, including laryngeal mask airway for shorter procedures in the supine position. Some clinicians would advocate the use of total i.v. anaesthesia (TIVA) for longer cases when immediate extubation is planned but the speed of emergence with TIVA can be experience dependent so this choice is left to the individual.

Areas of particular anaesthetic concern for the related conditions described above or where technique modification may be required are discussed below.

Vascular access and monitoring
For patients with significant cardiorespiratory disease invasive pressure monitoring should be considered for all but the shortest and least invasive of procedures. In addition, for those with OI it may avoid the risk of fractures from non-invasive blood pressure cuffs.

In arthrogryposis vascular access can be difficult because of limb contractures and thin subcutaneous tissues with scanty vessels that are small and fragile. Pre-induction i.v. cannulae should be inserted at sites of sensory loss in the child with spina bifida, to minimize discomfort. Finally, the use of intraosseous needles is contraindicated in OI.

Airway management
Children with dwarfism, OI, and arthrogryposis present some of the most challenging airway management problems in paediatric anaesthesia.

In arthrogryposis mask ventilation and intubation can be difficult or impossible as the temporomandibular joint and cervical spine can be stiffened by contractures that worsen with increasing age. Micrognathia is an associated feature that may further compound the difficulties with airway management.

Complications from difficult mask ventilation and intubation are a significant cause of morbidity and mortality in children with dwarfism, who may also have cervical spine instability, thickened pharyngeal and laryngeal structures, narrowed nasal passages, pharyngeal hypoplasia, and tracheal narrowing.

In OI, the airway requires minimal manipulation during mask ventilation and intubation to prevent fractures. Care must be taken with brittle teeth, neck, atlanto-axial joint, jaw, and base of skull.

In cases where airway management is known or suspected to be difficult, strongly consider inhalation induction and a strategy involving advanced airway equipment (such as video laryngoscope and fibre-optic intubation). Airway patency can be dramatically improved by changing the head position but this must be done very cautiously as catastrophic intra-operative spinal cord ischaemia can result from a hyperextended neck. Manual cervical stabilization during laryngoscopy may be necessary. Some children will be of short stature for their age so the usual formulae for calculating tracheal tube size should be modified to take this into account. Using a smaller-diameter paediatric cuff may help to avoid the need for repeated tracheal intubation.

Although many of these children suffer gastro-oesophageal reflux, it is not usually of clinical significance at induction. Cricoid pressure should be avoided in OI.

Airway obstruction can also occur postextubation so extended pulse oximetry monitoring in a critical care setting is recommended for children at increased risk.

Neuromuscular blocking agents
Many of the diseases discussed above have a neurological or metabolic component and therefore these children have altered responses to neuromuscular blocking agents.

Succinylcholine is frequently avoided as it may cause catastrophic hyperkalaemia:

(i) In arthrogryposis with an underlying myopathy.
(ii) In achondroplasia with an upper motor neurone lesion.
(iii) In OI (in addition fasciculations and use of neuromuscular monitoring may cause fractures).

In arthrogryposis, most children have a reduced population of anterior horn cells throughout a smaller-diameter spinal cord. This can lead to an altered response to neuromuscular relaxants. Short-acting non-depolarizing agents with neuromuscular monitoring should ideally be used.

Positioning
Positioning on the operating table is of utmost importance, both for surgical access and to support fragile bones, thin skin and
reduced muscle mass. For children with contractures ensure each joint is carefully supported to prevent pressure sores and accidental dislocation. In OI padding should be carefully applied to prevent further fractures. Avoid overextension of joints during positioning as this can cause dislocation. The use of adhesive tape should be minimized where skin is thin and fragile.

Special operating tables are sometimes required such as a radiolucent table for fluoroscopy work, a fracture table, or a spica table. The surgeon may require the patient to be positioned at the extreme end of the operating table to allow access to the lower limbs from three sides of the table.

Multiple positions are used in lower limb surgery including prone positioning for clubfoot and some ankle surgery. The lateral position allows the surgeon to access the front and back of the limb without re-positioning and re-draping. Tracheal intubation is recommended to maintain a secure airway if the patient is to be repositioned from supine.

Hypermetabolic states

Arthrogryposis and OI are associated with a hypermetabolic state under anaesthesia in ~33% of cases.7 An increase in body temperature is accompanied by tachycardia, increased end-tidal carbon dioxide, and acidosis. This state is distinct from malignant hyperthermia (MH) in that the only treatment usually needed is active cooling. Dantrolene is not required. The hypermetabolic state occurs even in the absence of MH trigger agents, does not manifest with muscle rigidity, urinary myoglobin is not detectable and in vitro muscle contracture testing is negative. Intra-operative temperature should be carefully monitored and the usual paediatric perioperative warming strategies discontinued as necessary.

Tourniquets

The benefits of tourniquets in lower limb surgery are a bloodless operating field and limited intra-operative blood loss. They can potentially be used for any operative site distal to the mid-thigh and are widely used for ankle procedures. It is important to accurately size the tourniquet with a width greater than half the limb’s diameter in order to safely distribute pressure. In children the recommended inflation pressures are determined by blood pressure and limb size – for the lower limb 150 mm Hg above systolic blood pressure is sufficient.

The use of tourniquets in patients with sickle cell anaemia or trait is controversial but there is no absolute contraindication provided that the benefits outweigh risk on a per-patient basis.8 It is important to ensure adequate haemoglobin correction, patient warming, hydration, oxygenation, and maintenance of acid-base balance to prevent subsequent localized sickle crisis in the operative limb. The limb should be carefully exsanguinated and then reperfused in stages to avoid triggering a generalized sickle crisis by the release of a large load of hypoxic, acidic blood into the circulation.

Tourniquets are inadvisable in OI because of the risk of fracture as the tourniquet is inflated. Patients with thin skin, contractures, and reduced muscle mass need very careful padding under the tourniquet if it is considered necessary.

On exsanguination and inflation of the tourniquet up to 15% of circulating blood volume is redistributed. This may increase blood pressure by up to 30%, with a parallel increase in central venous pressure.

Prolonged use of bilateral tourniquets (>90 min) is associated with an increase in core temperature (1–2°C) and tachycardia so intra-operative warming may need to be discontinued. There is no evidence-based or consensus opinion to suggest a maximum safe inflation time but steps should be taken to keep this to a minimum in order to reduce the risk of irreversible cellular ischaemic damage.

Minute ventilation should be increased for 5 min after tourniquet deflation to compensate for an increase in Paco2 as venous stasis resolves.

If a tourniquet is not used either for clinical reasons or because the site is too proximal—for instance in hip surgery—substantial blood loss may occur. Cell-salvage techniques can dramatically reduce the requirement for cross-matched blood, but it is still important to have blood available. Some clinicians give additional fluids early in the procedure to lower haematocrit and reduce red cell loss.

Anaesthetic implications for common paediatric orthopaedic procedures

Spica casts

Typically used after hip surgery or to treat DDH, this procedure can take up to 90 min. The name originates from Latin ‘ear of grain’ referring to the figure-of-eight appearance of plaster bandage wrappings. Spica casts immobilize one or both lower limbs generally with knees in flexion and hips in flexion, abduction, and external rotation. A fibreglass cast is applied to envelop the mid and lower chest, the hips, the thighs, and one or both legs to the ankle (Fig. 1).

The child is positioned on a spica table by several assistants with one support under the shoulders, one under the pelvis, and a post at the perineum. Care with the airway is required during positioning on the spica table, especially if a supra-glottic airway is used.

A towel is placed under the cast during moulding to allow chest expansion and a window is cut to allow for abdominal breathing. When the surgeon applies the abdominal and chest components pay close attention to ventilation—a ventilator
Osteotomies
Osteotomies are used extensively to allow repositioning and realignment of limbs. The two cut ends of bone are rejoined and held together with metalwork, usually K-wires. They vary from simple wedge osteotomy—where a wedge-shaped section of bone is removed for correction of congenital hallux valgus, to the multi-level rotational osteotomy and intramedullary rodding performed to realign and reinforce the long bones in children with OI. These procedures are painful and if performed without tourniquet can yield significant blood loss. They can also predispose to painful postoperative muscle spasm.

Epiphysiodysis
This involves fusion of the growth plate (epiphysis) to correct limb length inequality. The epiphysis is ablated with drills and curettes under image-intensifier guidance. The small incisions give a good cosmetic result and minimize skin pain which can be controlled with local anaesthetic injection. Despite the small incision, bleeding can be extensive from exposed cancellous bone so a pro-coagulant foam may be applied to the exposed bone by the surgeon.

Tendon surgery
This is used to correct imbalance of muscle forces in joint deformity and/or improve gait. Tendon transfers detach a partial or full tendon from its point of insertion, retain its innervation and vasculature and re-attach it to another bone or tendon point. Lengthening procedures involve two tendon cuts offset from one another and tendon releases or tenotomies completely detach the tendon from the insertion point. The child may be placed in a cast after operation to encourage healing in the desired joint position. The cast also limits movement and therefore reduces analgesic requirements, which can be substantial. Common sites for tendon manipulation include the hip, groin incision, hamstrings via posterior thigh incision (prone/lateral positioning) and the ankle. Painful postoperative muscle spasm is common after tendon manipulation.

Limb lengthening
The Ilizarov method is used to preserve height in limb length inequality caused by unequal growth, trauma, or osteomyelitis. It is a lengthy and painful process of cortical osteotomy (corticotomy) distraction and fixation. Operations are prolonged (typically 10 h or more) and technically difficult as an external fixator is placed around the osteotomy to retain distraction of the bone. The fixator is periodically tightened with approximately 1 cm of new bone growth for each month of therapy.

After operation, transient nerve palsies are possible so carefully document any pre-existing conditions. These children can be at high risk of compartment syndrome, especially with tibial lengthening. The procedure is very painful but neuromuscular techniques are often avoided as there is a need to closely monitor nerve and vascular recovery and to detect compartment syndrome. High-dose opioids via patient- or nurse-controlled analgesia may then be the best option and it is worth discussing a short course of NSAIDs with the surgical team. A child with a previous experience of painful fixator may need an epidural in order to agree to undergo the procedure.

Therapeutic botulinum toxin use
An i.m. injection is used in spasticity and dystonia to improve motor function, promote longitudinal muscle growth, and decrease painful spasms. Specific indications include spastic equinus (toe walking), hip subluxation, and spastic diplegia. The site of injection can be localized by the surgeon using landmark technique, ultrasound, or electrical stimulation.

Botulinum toxin is produced by some strains of Clostridium bacteria. Seven serogroups (A–G) exist of which two (A and B) have therapeutic licences. Group A (BTA) is most commonly used in paediatric work.

The toxin creates a localized muscle paralysis by highly specific irreversible binding to pre-synaptic cholinergic peripheral nerve terminals. Neurotransmission recovers when the axon terminal sprouts new nerve endings and forms new synaptic contacts on adjacent muscle fibres. A reduction in tone can be seen in 2–3 days with maximum effect at 2 weeks. On average recovery occurs within 3 months.

Therapeutic botulinum toxin injection has an excellent safety profile. Less than 1% of children have systemic side-effects including generalized weakness and fatigue. Dystonias and anaesthesias have been reported in the literature. Procedure-related complications can also occur such as haematoma and damage to anatomical structures adjacent to the injection site.

Pain management
Minor procedures such as botox injection require only simple analgesia.

Procedures involving bone or tendons can be extremely painful so it is important to provide multi-modal analgesia including consideration of regional or local techniques, paracetamol and NSAIDs. A multi-modal approach reduces opioid use, limiting the increased side-effect profile known to occur in children. Preoperative single-dose gabapentin has insufficient evidence to support routine use in paediatric orthopaedic surgery but has been shown to significantly decrease postoperative pain and rescue analgesic requirements in adults who undergo lower limb orthopaedic surgery.

It is important to use an age and ability appropriate pain scale for postoperative assessment such as Wong-Baker Faces for children aged over 3 yr, FLACC (Face, Legs, Activity, Cry, Consolability) for children aged 2 months to 7 yr, or revised FLACC for children with developmental impairment.

Patients with communication difficulties such as in CP may find it difficult to express postoperative pain so regular (rather than as required) analgesia used in combination with careful monitoring of pain score may be preferable (Fig. 2).

Regional anaesthesia can become an increasing challenge as the child with musculoskeletal disease ages beyond infancy. A secured difficult airway may be jeopardized by repositioning for central neuraxial block. Caudal or lumbar epidurals are highly recommended for major procedures but can be contraindicated in OI-related platelet dysfunction and the abnormal spinal anatomy of spina bifida. They can be technically challenging because of patient positioning, bone condition and scoliosis. The spread of injectate can be difficult to predict in children with skeletal abnormalities. There may be fears that the block would mask compartment pain in procedures with a significant risk of postoperative compartment syndrome.
Dense sensory loss around the operative site in spina bifida may significantly reduce analgesia requirements (Table 1).

**Compartment syndrome and regional anaesthesia**

Certain procedures such as Ilizarov limb-lengthening carry a risk of postoperative compartment syndrome distal to the operative site in ~2% of patients. Some teams may therefore wish to avoid regional anaesthesia on the basis that it potentially masks the pain of compartment syndrome. Children as a group may be at increased risk of developing compartment syndrome as their physiological mean arterial pressure (MAP) is lower, giving a reduced compartmental perfusion pressure ($\Delta p = MAP - \text{compartment pressure}$). Compartment pressure can be measured using a standard invasive arterial pressure monitoring set connected to a cannula in the compartment at risk. A compartment perfusion pressure of <30 mm Hg may indicate a diagnosis of compartment syndrome and the need for fasciotomy.

A 2009 review showed no cases of patients aged <18 yr where epidural analgesia had completely masked the pain of compartment syndrome or caused delay in diagnosis and a literature search by the authors did not find any more recent reports to March 2014.

The most important aspect of early detection of compartment syndrome is clinical vigilance for disproportionate pain, swelling, paresthesia, and paralysis of the operative limb. If called to assess a child with uncontrolled postoperative pain despite good provision of analgesia, jointly review with a surgeon and examine the painful site. Consider pain distal to the site of surgery and/or increasing pain that is unresponsive to analgesia as compartment syndrome until proven otherwise. Encourage a low surgical threshold for compartment pressure monitoring.
Other strategies for limiting compartment syndrome can be surgical such as prophylactic fasciotomies at time of procedure, or anaesthetic (e.g. using low concentration local anaesthesia to avoid dense sensory, motor, and vasomotor block).

With careful postoperative observation, epidural anaesthesia can be offered appropriately to patients who are not at high risk of developing compartment syndrome. This involves good training of recovery and ward nurses in red flag signs and symptoms. It is important to remember that theoretically even patient- or nurse-controlled opioid analgesia can mask the early stages of compartment syndrome (Box 1).

**Box 1 Red flag signs of acute compartment syndrome**
- Increasing or uncontrolled pain despite good provision of analgesia
- Pain remote to site of surgery
- Paresthesia or paralysis not attributable to analgesia, and not resolving despite cessation of local anaesthetic infusion
- Reduced perfusion of areas distal to painful site
- Tight swelling
- Pain on passive movement of the site

**Postoperative muscle spasms**
Many children with co-morbidities such as CP will suffer chronic spasticity. Their anti-spasticity treatment should be continued perioperatively to prevent withdrawal and worsening of symptoms. In addition, surgical procedures such as osteotomy or tendon lengthening pre-dispose to painful postoperative muscle spasm.

Acute postoperative spasms are best managed in a critical care environment by control of pain with the techniques described above and then the addition of i.v. benzodiazepine with careful monitoring for excessive sedation and respiratory depression. Suggested regimens include diazepam 0.1 mg kg$^{-1}$, or midazolam infusion 10–30 μg kg$^{-1}$ h$^{-1}$. Baclofen or dantrolene are also sometimes used as sole agents or in conjunction with benzodiazepines.

**Postoperative care**
Many minor procedures can be performed as day cases but limited mobility, airways abnormalities, blood loss and the need for significant analgesia may require several nights of in-patient care. In addition, children with co-morbidities including upper airway abnormalities or significant cardiorespiratory disease and those having long or complex surgery with significant blood loss will require postoperative critical care.

**Declaration of interest**
None declared.

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

**References**


