Chapter

8

Congenital and Inherited Disorders Affecting Anaesthesia in Children

Nargis Ahmad

Introduction

Children with congenital anomalies or inherited metabolic disorders can present a challenge to the paediatric anaesthetist. An encyclopaedic knowledge of these conditions, however desirable, is unrealistic for most practising paediatric anaesthetists. For some of these rare disorders, the evidence base is limited to single case reports or small series describing the conduct of anaesthesia. This synopsis will outline general principles and include some of the more common conditions. For the rarer anomalies, the reader should consult a more comprehensive text or one of the web-based resources, such as UpToDate®, Orphan Anesthesia and the Online Mendelian Inheritance in Man® database accessible via the National Center for Biotechnology Information (NCBI) website.

General Points

The classification of many conditions has its basis in phenotypes with inheritance patterns observed and described. Great progress has been made in understanding the genetic basis of many congenital anomalies, and it is clear that phenotypic and genetic heterogeneity are common.

Preoperative Assessment

A systematic approach to preoperative assessment provides a useful filter to identify aspects of relevance to anaesthesia. Any involvement of the airway, the cardiovascular and respiratory system merit close scrutiny. In some conditions, there may be endocrine or metabolic issues that need to be considered, such as glucose and steroid management. Limb abnormalities or fragile skin require careful assessment for potential sites for vascular access and also for protection of skin and joints during positioning.

Many conditions are associated with dysmorphic features, abnormal growth parameters, developmental delay and learning disability. These should be identified during the preoperative assessment. The behavioural implications of any congenital or inherited disorder should always be considered preoperatively. Some conditions are associated with seizures, in which case it is important to note the nature of the seizures and how well these are controlled.

The family will often provide a wealth of useful information about their child. Families may have accessed web-based resources extensively and have joined condition-specific support groups. It is not uncommon for them to be more knowledgeable about the syndrome and its ramifications than non-specialist clinical staff. Some of these children undergo a number of surgical procedures; previous anaesthetic records should always be reviewed.

Airway

Airway assessment can help predict whether difficulty in airway management, direct laryngoscopy and intubation may be encountered. Assessment should include consideration of the nasal passages; mouth opening; oropharynx, including palate, tongue, maxilla, mandible and mandibular space; temporomandibular joint; and cervical spine.

Some disorders distort the normal anatomy of the bones and soft tissues associated with the airway. Some examples follow:

- Maxillary hypoplasia, such as Apert syndrome (a syndrome with associated craniosynostosis)
- Mandibular hypoplasia, such as Pierre Robin sequence
- Mandibular and maxillary hypoplasia, such as Treacher–Collins syndrome
- Hemifacial microsomia, for example Goldenhar syndrome

- Mucopolysaccharidoses (MPS) with thickened, stiff, abnormal soft tissues
- Macroglossia, such as Beckwith–Wiedemann syndrome and Down syndrome (Trisomy 21)

Potential challenges that may arise include the following:

- Face masks may be difficult to fit.
- The upper airway may be crowded and prone to obstruction on induction of anaesthesia.
- Mouth opening may be limited.
- Oral airways may be difficult to insert.
- Nasal passages may be too small for a nasopharyngeal airway.
- Laryngoscopy and intubation may be very difficult.
- Cleft palate may also be present, compounding any difficulty with laryngoscopy.

The impact of growth, development, medical and surgical treatment should be considered during the assessment. The natural history of some conditions is such that some airways tend to improve with age, as with Pierre Robin sequence, but may worsen in others, such as MPS.

A history of sleep disordered breathing may be suggestive of obstructive apnoea (OSA). This is usually during sleep but in rare cases may occur when awake.

Cervical Spine

The craniocervical junction (CCJ) is the site of a wide range of developmental and acquired anomalies in children. The CCJ may be compromised by:

- Deformity
- Instability
- Compression

Deformity may arise as a result of distortion of normal anatomy or anomalous vertebral segmentation. Anomalous segmentation often coexists with craniovertebral anomalies such as craniosynostosis and disorders of branchial arch development. For example, cervical hemivertebrae are a feature of Goldenhar syndrome. In Klippel–Feil syndrome, fusion of cervical vertebrae results in a short neck with very limited mobility, this can lead to difficulty with laryngoscopy and intubation.

Instability of the CCJ may occur at the occipito-atlanto and atlanto-axial joints. Anomalies of the odontoid process leading to atlanto-axial instability are well recognised in Trisomy 21, Morquio syndrome (MPS IV), Hurler syndrome (MPS I) and Klippel–Feil syndrome. Excessive movement of the neck can contribute to cervical spine injury. Airway manoeuvres and patient positioning are times of great vulnerability during general anaesthesia.

Compression of the cervicomedullary junction is a feature of some of the MPS syndromes when tissue infiltration leads to stenosis of the cervical canal. Cervical cord compression is also a common feature of achondroplasia.

Breathing

Respiratory muscle and bulbar weakness are features of myopathic conditions, and chronic aspiration and recurrent infections are common. Generalised hypotonia may be present in neuromuscular disorders, and some conditions are associated with kyphoscoliosis, which may progressively limit respiration. Limited respiratory reserve may be masked by a low level of activity in patients, such as in wheelchair-dependent children.

Cardiovascular

Many congenital syndromes have an associated cardiac lesion. In older patients, it is most likely that this will have been repaired or palliated. The implications for anaesthesia in the presence of a cardiac lesion are dealt with in Chapter 33. Particular care should be taken in patients with Williams syndrome, who may have a range of cardiovascular anomalies, including supra-aortic valvar stenosis and pulmonary stenosis, and who may also have coronary artery involvement. Other noteworthy groups are patients with cardiomyopathy, such as those with Duchenne muscular dystrophy, Pompe disease or disorders of fatty acid metabolism. A comprehensive cardiovascular workup is essential prior to anaesthesia. This should include quantitative echocardiographic assessment of cardiac function.

Endocrine, Metabolic and Renal Systems

Patients who have been on long-term steroids may need additional steroid administration to cover surgical stress. This is particularly important in adrenogenital syndrome. Careful management of glucose homeostasis is essential in children with glycogen storage disorders (e.g. von Gierke,

Pompe, Cori, Andersen, McArdle) and Beckwith–Wiedemann syndrome. It is important that fasting time is kept to a minimum, and it may be necessary to start an infusion of glucose before anaesthesia. In conditions where renal dysfunction is an associated factor, careful attention should be paid to fluid management and to the use of drugs that rely on the kidney for excretion.

Skin, Bone and Joint Disorders

Great care must be taken with positioning in patients with fixed joint deformities, or where there is abnormal joint laxity, as in Marfan syndrome. As noted earlier, some patients have a fixed or potentially unstable cervical spine which must be handled and positioned carefully. Similar considerations apply to patients with fragile bones, such as those with osteogenesis imperfecta. In Ehlers–Danlos syndrome, abnormal collagen leads not only to joint laxity but also to extremely fragile skin and other tissues. It can be difficult to site and secure intravenous access. Epidermolysis bullosa (EB) is a syndrome in which management of skin and mucosal surfaces is particularly challenging. EB is discussed in more detail in the section 'Epidermolysis Bullosa (EB)'.

Some Specific Syndromes

Trisomy 21

This is one of the most common congenital syndromes, occurring in approximately one in 600–700 live births; 95% are trisomy 21 and 2% are mosaic. The incidence increases with advancing maternal age. The characteristic phenotype includes features of low-set ears, up-slanting eyes, a small nose, large tongue, brachycephaly, short neck, clinodactyly, a single palmar crease and a varying degree of intellectual impairment.

The large tongue and a narrow nasopharynx result in a tendency to upper airway obstruction. Sleep disordered breathing and OSA are common. Laryngo-tracheo-bronchial pathology, such as subglottic stenosis and tracheomalacia, may be present. Other associated features of relevance to anaesthesia include a significant incidence of occipito-atlanto-axial instability, and hence careful manipulation of the head and neck is important during intubation and subsequent positioning. A history of recurrent chest infections should raise concern about pulmonary aspiration secondary to cervical cord compression and should prompt radiological investigation of the cervical spine.

Forty to fifty per cent have congenital heart disease, most commonly an atrial or ventricular septal defect, frequently as part of an endocardial cushion defect. Duodenal atresia may occur. Children with Trisomy 21 may be moderately hypotonic and can be hypothyroid; they also have an increased risk of leukaemia.

Epidermolysis Bullosa (EB)

This is a group of disorders characterised by mechanical fragility of the epidermis and mucous membranes which separate readily from the underlying tissues. The patient is at risk of formation of bullae and non-healing wounds with trivial trauma, particularly on exposure to shearing forces. Three major types of EB are recognised: simplex, junctional and dystrophic. In the severe forms, such as recessive dystrophic EB, recurrent skin damage and scarring of the fingers and toes lead to pseudosyndactyly and severe contractures, so-called mitten hands. Scarring of the corners of the mouth leads to progressive microstomia, and oropharyngeal mucosal scarring leads to fixation of the tongue within the mouth. There is frequently very poor dentition, and oesophageal strictures are common. Laryngeal involvement has been reported with the Herlitz subtype of junctional EB and one of the variants of simplex EB (Dowling–Meara subtype). Cardiomyopathy has also been reported, but this is rare.

These patients usually present for repair of their fused digits, oesophageal dilation and dental restoration. They are a particularly challenging group and must be treated with great care. Surgical procedures should only be undertaken in specialist units where there is ward-based nursing expertise. Patients are often colonised with methicillin resistant *Staphylococcus aureus* (MRSA).

Anaesthesia for Children with EB

Careful handling is essential for these patients. Friction and sliding during transfer must be avoided, and adhesive tapes should not be used. Pure liquid paraffin sprays (Emollin®) can be used to lubricate face masks and gloved hands. Intravenous lines should be secured with a non-adhesive dressing. Silicon-based products suitable for use are available, such as Mepiform®, Siltape®

and Mepitac®. Arterial and central lines, if required, should be sutured in. Gel should be used to cover the eyes. These patients can lose heat rapidly; a warm theatre environment is helpful.

Airway Management

Careful airway assessment is imperative to assess limitation of mouth opening and degree of neck movement. All airway equipment, including the face mask, airway and laryngoscope, should be generously lubricated with paraffin spray, jelly or vaseline gauze. Vaseline gauze should be placed under the chin where the anaesthetist places their fingers. The immobility of the tongue may keep the airway from obstructing and avoid the need for adjuncts such as oropharyngeal airways; these should be well lubricated and carefully used when needed. Laryngoscopy and intubation can be difficult because of limited mouth opening, which tends to get worse with increasing age. Although involvement of the larynx is possible, tracheal intubation does not usually appear to cause laryngeal or tracheal bullae and is generally considered safe. Nasal intubation may be preferable for extensive dental work, but whichever route is used it is essential that great care is taken to avoid sliding or shearing forces. The tube can be secured with ribbon gauze or clingfilm. A well-lubricated supraglottic airway device (SGA) may be used with caution.

Monitoring

Small ECG electrodes can be secured with non-adhesive silicon dressings, as with intravenous lines, or with clingfilm. Clip-on oximeter probes should be used.

Blood pressure cuffs can be used safely as they do not produce a shearing force, but the limb should be well padded.

Postoperative Care

Effective postoperative analgesia is essential as it will reduce the likelihood of restlessness and agitation during emergence from anaesthesia. Intravenous analgesia may be the most effective route. Regional analgesia, single dose or by continuous infusion, has been utilised successfully and will be useful in some patients. The increasing use of ultrasound to improve the success rate of regional nerve blockade may be beneficial. Many patients have difficulty with oral medications, and rectal analgesia may be helpful.

Inborn Errors of Metabolism

An overview of the more common inborn errors of metabolism is shown in Table 8.1. The signs and symptoms of inherited metabolic disease (IMD) arise as a consequence of a failure of one or more steps within a metabolic process. In essence, they result in one or more of the following:

- Accumulation of substrate
- Accumulation of metabolite
- Deficiency of normal product of metabolic pathway
- General metabolic derangement, such as acidosis

The inherited disorders of metabolism are a diverse group. They may present with acute encephalopathy, seizures or hypotonia or as a movement disorder. Hypoglycaemia or a metabolic acidosis may also be the first presentation. Myopathy is not uncommon.

Broad principles of anaesthetic management of patients with IMD include:

- Assessment of the patient and the severity of the IMD, the natural history of the condition, the nature of any treatment and the effect of that treatment.
- Assessment of any organ dysfunction.
- Avoidance of prolonged fasting and maintenance of hydration.
- Close monitoring of glucose and acid-base state.
- Maintaining metabolic homeostasis perioperatively. The aim is usually to prevent or limit metabolism via the abnormal metabolic pathway, for example avoidance of catabolism and provision of glucose during fasting.
- Consideration of strategies to correct severe acidosis, such as haemodialysis and avoidance of lactate-containing fluids.
- Prevention of the accumulation of blood in the stomach. The protein content of blood can trigger acute decompensation in many IMDs, especially those involving amino acid metabolism.
- Attention to temperature regulation. Hypothermia can trigger a metabolic crisis in some conditions.

Close collaboration with relevant IMD specialists is advised.

Table 8.1 Overview of inherited metabolic disorders

Classification	Example	Anaesthetic considerations
Disorders of amino acid metabolism	Phenylketonuria (PKU) Homocystinuria Maple syrup urine disease (MSUD)	Seizures – maintain special diet. Marfanoid, thrombosis risk high – maintain hydration, thrombosis prophylaxis. Hypotonic, hypoglycaemia, seizures.
Urea cycle disorders	Carbamyl phosphate synthase deficiency	Hyperammonaemia and encephalopathy. Avoid catabolism and dehydration during fasting. Maintain high-carbohydrate, low-protein diet. Avoid blood in the stomach (protein load). Infusion of substrate to optimise non-urea cycles for nitrogen removal is often necessary; specialist advice should be taken.
Disorders of organic acid metabolism	Methylmalonic acidaemia, propionic acidaemia	Hypoglycaemia, ketoacidosis, hyperammonaemia. Maintain normoglycaemia, hydration and acid-base status. Restrict protein.
Disorders of carbohydrate metabolism	Glycogen storage diseases, e.g. von Gierke, Pompe, Cori, Andersen, McArdle. Galactosaemia	Minimise fasting, maintain normoglycaemia and acid-base homeostasis. Avoid lactate-containing fluid. Pompe may have hypertrophic cardiomyopathy. Approximately 6% risk of arrythmias, cardiac arrest and death. Hepatic dysfunction.
Lysosomal storage disorders	MPS Lipidoses, e.g. Tay–Sachs, Fabry, Niemann–Pick	High-risk airway, cervical spine, cardiac complications. Seizures. Lysosomal accumulation of sphingolipid substrates, hepatomegaly, developmental delay.
Disorders of fatty acid oxidation	Medium chain acyl–CoA dehydrogenase deficiency	Minimise fasting, give glucose infusion, maintain acid–base homeostasis.
Mitochondrial disorders	Genetic and phenotypic heterogenous group with reduced capacity for oxidative phosphorylation	Myopathic, often with cardiomyopathy and neurodevelopmental delay. Avoid prolonged propofol infusion, avoid lactate containing fluid, maintain normoglycaemia. May have disordered control of respiration.
Peroxisomal disorders	Zellweger syndrome	Hypotonia, hepatic and renal impairment, chronic respiratory dysfunction. Associated with congenital heart disease.

Mucopolysaccharidoses

MPS are a group of inherited lysosomal storage disorders.

Abnormal sequestration of partially degraded glycosaminoglycans results in a progressive multisystem disease with organomegaly, visual, auditory and intellectual deficits, airway abnormalities, cardiovascular impairment, joint and bony deformities and characteristic coarse facial features. Patients with MPS present a very high risk for anaesthesia, although this risk can be reduced by early treatment.

Treatment options now include haematopoietic stem cell transplantation and recombinant enzyme replacement therapy. Stem cell transplantation halts progression of these diseases and reduces hepatosplenomegaly, joint stiffness, OSA, facial dysmorphism, heart disease, hydrocephalus

and hearing loss. Skeletal and ocular abnormalities are not corrected, and neurological outcomes remain poor. Enzyme replacement therapy may be of benefit in MPS I, II, IVA and VI.

Anaesthesia for Children with MPS

Behavioural problems are common, but sedative premedication should be used with extreme caution. Preoperative assessment should include thorough clinical evaluation of the cardiac and respiratory systems. Cardiomyopathy, valvular heart disease and coronary artery disease may be present. A recent echocardiogram should be reviewed. Active respiratory tract infection is a contraindication to elective surgery. Close postoperative monitoring is essential.

Airway Management

There can be multi-level airway involvement. Historically the overall incidence of airway difficulties in untreated children with MPS is 25%, with failure to intubate occurring in 8% of MPS cases (rising to 54% and 23% respectively in Hurler's syndrome). Successful early treatment with stem cell transplantation and enzyme replacement therapy and the evolution of airway technologies, such as videolaryngoscopy, has changed airway management with a reduction in the incidence of airway complications. Contributory factors include:

- Airway tissue deposition of glycosaminoglycans
- A short and sometimes unstable neck
- Poor joint mobility including the cervical spine and temporo-mandibular joints
- Macroglossia
- Micrognathia

Previous anaesthetic records should be reviewed, but as all of these factors get worse with age, a difficult airway must always be expected. Careful preparation and planning, including the full range of difficult airway adjuncts, is essential. Preoperative sleep studies may be required as OSA is often present.

Cervical spine instability most often occurs in MPS I (Hurler) and IV (Morquio). Specialist consultation and radiological studies may be indicated. In Morquio syndrome, potential cervical myelopathy secondary to canal stenosis should be evaluated with magnetic resonance (MR) imaging. Neck manipulation should be avoided. Manual inline stabilisation is recommended.

The use of an anti-sialagogue may be helpful. As a result of tissue distortion, face masks may not fit well, oral airways may worsen airway obstruction and nasopharyngeal airways may be difficult to place. An SGA can be particularly useful, and its use as a conduit for intubation is well described. Fibreoptic intubation may be necessary, in which case it is important to anticipate that the correct size tracheal tube may be smaller than that expected. Airway obstruction following tracheal extubation can lead to pulmonary oedema. Awake extubation is advised, and dexamethasone may be helpful.

Malignant Hyperthermia Susceptibility (MHS)

MHS is a progressive life-threatening hyperthermic reaction occurring during general anaesthesia. It is a genetic disorder of skeletal muscle calcium regulation in which uncontrolled skeletal muscle hypermetabolism, triggered by volatile agents alone or in conjunction with suxamethonium, leads to a life-threatening state known as malignant hyperthermia (MH). The triggering substances release calcium stores from the sarcoplasmic reticulum, causing muscle contracture, glycogenolysis, adenosine triphosphate (ATP) consumption and heat production. Oxygen demand soon outstrips supply, and ATP stores are depleted, leading to lactic acidosis and rhabdomyolysis. If treated promptly, most patients recover, although there remains a mortality rate of around 4%. Diagnostic services for suspected MH in the United Kingdom and Ireland are provided by the MH Investigation Unit in Leeds. This specialist unit provides a screening service, advice to patients and a 'hotline' for health care professionals and also conducts research.

Who Is at Risk?

The highest reported incidence of MH occurs in paediatric populations. The inheritance of mutations in three genes account for most patients with MH susceptibility. De novo mutations do arise. The majority of mutations are found within the RYR1 gene on chromosome 19 that encodes the skeletal muscle ryanodine receptor type I protein.

Inheritance is in an autosomal dominant pattern, so all closely related members of a family in which

MH has occurred must be considered susceptible. Progress in genetic analysis has greatly enhanced the understanding of MHS and has a promising role in diagnosis. Unfortunately, MHS cannot reliably be excluded by a genetic test as MH has a high level of locus heterogeneity and not all RYR1 variants have been completely evaluated. For new cases or for those with a family history, the gold standard for diagnosis is a muscle biopsy and in vitro contracture test (IVCT). The sample size required is such that muscle biopsies are not performed on children less than 10–12 years old (30 kg).

MHS patients will usually have a normal phenotype, but many myopathic disorders are associated with RYR1 pathogenic variants and have been linked with MH susceptibility. Mutations of the CACNA1S (alpha 1 subunit of the voltage-gated calcium channel gene) or STAC3 (a component of excitation-contraction coupling gene) may also confer MHS.

Myopathic Disorder Genetic Associations

RYR1

King Denborough
Central core
Multi-minicore
Congenital myopathy with cones and rods
Idiopathic hyperCKaemia (CK creatinine kinase)
Nemaline rod myopathy
Periodic paralysis
Congenital fibre type disproportion (CFTD)
Centronuclear myopathy
Heat- or exercise-induced rhabdomyolysis

CACNA1S

Periodic paralysis
CFTD
Multi-minicore

STAC3

Native American myopathy

For any patient with a known RYR1, CACNA1S or STAC3 mutation, MHS must be assumed. If a condition has a phenotype with a range of different underlying genetic aetiologies (e.g. CFTD, periodic paralysis, nemaline rod myopathy) and genetic analysis has confirmed the underlying abnormal gene is not one of the RYR1, CACNA1S or STAC3 genes, then MHS is not present. This information may not always be available, in which case MHS must be assumed.

Anaesthesia for Children with MHS

The Association of Anaesthetists Malignant Hyperthermia Guideline provides comprehensive guidance. It is important to be aware that a previous history of uneventful anaesthesia does not exclude risk. If MHS is suspected, all volatile agents and suxamethonium should be avoided. The anaesthetic machine should have vaporisers removed, and it is usual to flush the machine and circuits with oxygen for about 30 minutes prior to use to remove residual traces of volatile agent. The precise duration of circuit flushing should be available from each anaesthetic machine manufacturer. A target of 5 ppm is regarded as the maximum safe concentration of inhalation agent. Propofol, opioids, benzodiazepines, nitrous oxide, local anaesthetics and barbiturates can all be used as part of a trigger-free technique. In addition to usual minimal monitoring, it is essential to include core temperature. Dantrolene should be readily available.

Recognition and Management of MH

Recognition

At the start of an episode of MH, the patients may exhibit generalised muscle spasm, often first noticed as masseter spasm. Patients then usually develop:

- Unexplained hypercapnia
- Unexplained tachycardia
- Hyperthermia, classically rising >1°C every five minutes
- Hypoxaemia, acidosis and hyperkalaemia
- Myoglobinuria and elevated plasma creatine kinase

Management

- Immediately eliminate the agent by removal of the vaporiser and administration of 100% oxygen at maximum flow.
- Increase minute ventilation to 2–3 × normal.
- Place activated charcoal filters on the inspiratory and expiratory limbs of the circuit.
- Administer dantrolene sodium 2–3 mg kg^{-1}; this may need to be repeated in doses of 1 mg kg^{-1} to a maximum of 10 mg kg^{-1}.
- Commence active body cooling, ice packs and cold lavage.
- If surgery cannot be stopped, maintenance of anaesthesia should continue with intravenous agents.

- Treat any acidosis, hyperkalaemia, arrhythmias, myoglobinuria, disseminated intravascular coagulation (DIC) and compartment syndrome.

In due course, the family should be counselled and the patient referred for further investigation.

Anaesthesia-Induced Rhabdomyolysis (AIR)

AIR is a distinct entity from MHS, although some common features exist. AIR has occurred in children with abnormalities of the dystrophin-glycoprotein complex of the sarcolemma. Children with muscular dystrophies and some myopathies may be at risk when exposed to suxamethonium and volatile anaesthetic agents. Rhabdomyolysis and hyperkalaemia are the main features and can lead to cardiac arrest. Intravenous anaesthesia should be used, although brief exposure to volatile agents has been tolerated to facilitate placement of an intravenous cannula when awake intravenous access has failed.

Muscular Dystrophy

The muscular dystrophies (MD) are a group of X-linked genetic disorders in which there is absent or abnormal dystrophin, leading to muscle weakness and atrophy. DMD is the most common and severe form, with an incidence of 1 in 3,500 males. Diagnosis is often at the age of around three to five years. Becker MD is a milder form which does not usually present until the teenage years.

Patients with DMD experience progressive degeneration and fibrosis of all muscle types with onset from the age of about three years. It is rapidly progressive, and patients are frequently wheelchair bound by adolescence. Life expectancy has increased with advances in supportive therapies and use of steroids.

Anaesthesia for Children with MD

MD patients are especially at risk during and after general anaesthesia. The presence of the following should be sought:

- Restrictive lung disease, from respiratory muscle weakness and scoliosis
- Dilated cardiomyopathy (DCM), which is common, although the patient's history may not always reveal symptoms if they are inactive
- Rhythm disturbances, due to fibrosis of the conduction system

Multidisciplinary assessment is essential prior to elective surgery. Lung function tests, sleep studies and echocardiography are regularly undertaken as part of the management of these patients. Cardiorespiratory review should be organised prior to surgery with a current set of investigations. Full assessment may necessitate admission prior to surgery to optimise respiratory function. Non-invasive ventilation (NPPV) may need to be started prior to surgery and continue afterwards.

Perioperative steroid replacement should be used in all patients who have been on steroids in the previous six months. As described earlier, patients with muscular dystrophies are at risk of AIR and hence rhabdomyolysis and hyperkalaemia. Suxamethonium is contraindicated, and there should be minimal exposure to volatile anaesthetic agents. Total intravenous anaesthesia (TIVA) is ideal; use of a range of intravenous agents has been described. Non-depolarising muscle relaxants exhibit altered pharmacokinetics, and their use should be monitored with nerve stimulation. Gastrointestinal smooth muscle is affected in DMD, so gastric stasis may occur.

Postoperative respiratory support for patients with DMD must be available. The postoperative period is a particularly challenging phase of the care of these patients; management on a paediatric intensive care unit (PICU) will be required for all but the most minor surgery. Lung function tests have been used for predicting respiratory insufficiency postoperatively but there is no clear correlation, and the clinical assessment of an experienced anaesthetist is a better guide.

Key Points

- Many congenital disorders have an associated airway or cardiac abnormality.
- Children with mucopolysaccharidoses are high-risk cases for anaesthesia. They can present major airway difficulties and may have an unstable cervical spine.
- Children with muscular dystrophies and myotonias are not generally at risk of malignant hyperthermia but are at risk of hyperkalaemia and rhabdomyolysis if exposed to suxamethonium or volatile agents.

Further Reading

Gray RM. Anesthesia-induced rhabdomyolysis or malignant hyperthermia: is defining the crisis important? *Paediatric Anaesthesia* 2017; 27(5):490–3.

Hack HA, Walker RWM, Gardiner P. Anaesthetic implications of the changing management of patients with mucopolysaccharidosis. *Anaesthesia and Intensive Care* 2016; 44(6):660–8.

Hopkins PM, Girard T, Dalay S et al. Malignant hyperthermia 2020: Guideline from the Association of Anaesthetists. *Anaesthesia* 2021; 76(5):655–64. https://doi.org/10.1111/anae.15317.

Litman RS, Griggs SM, Dowling JJ, Riazi S. Malignant hyperthermia susceptibility and related diseases. *Anesthesiology.* 2018; 128(1):159–67.

National Center for Biolotechnology Information. OMIM. Available at: www.ncbi.nlm.nih.gov/omim.

Niezgoda J, Morgan PG. Anesthetic considerations in patients with mitochondrial defects. *Paediatric Anaesthesia* 2013; 23(9):785–93.

Orphan Anesthesia. Available at: www.orphananesthesia.eu/en/.

Walker R et al. Anaesthesia and airway management in mucopolysaccharidosis. *Journal of Inherited Metabolic Disease* 2013; 36(2):211–9.