Chapter

20 Anaesthesia for General Surgery in Children

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Introduction

Children presenting for general paediatric surgery range in both age and complexity from neonates undergoing hernia repair, to older children undergoing appendicectomy or excision of extensive neuroblastoma. Many patients presenting with congenital defects will require surgery in the neonatal period. Specific issues related to anaesthesia for neonatal surgery are discussed in Chapter 18. In this chapter, we provide an overview of general surgery for infants and children after the neonatal period.

Anaesthesia

For elective cases, breast-fed babies need only be fasted for three hours, whereas for babies receiving formula milk the usual six hours should apply. Clear fluids may be given up to one hour preoperatively. Clear fluids are defined as water, clear non-opaque fruit juice or squash/cordial, ready diluted drinks and non-fizzy sports drinks. Fluids must be non-thickened and non-carbonated. The maximum volume of clear fluids is 3 ml kg^{-1}.

Most general surgery in children is best managed by tracheal intubation and ventilation. Supraglottic airway devices can be used for shorter cases where aspiration risk is deemed low.

The minimum alveolar concentration (MAC) for all the volatile agents is slightly higher in neonates than adults, increasing with age to reach a maximum at one to six months of age before declining over the rest of life. It is common to use sevoflurane for induction and then either sevoflurane or isoflurane for maintenance. A balanced technique using fentanyl will enable a lower dose of volatile agents to be given, although high-dose opioid techniques may increase the likelihood of needing postoperative ventilation.

Some anaesthetists advocate the use of spinal anaesthesia for surgical procedures such as inguinal hernia repair to avoid any disadvantages posed by general anaesthesia; when used, surgery must be completed within one hour of the spinal. Ultrasound guided transverse abdominus plane (TAP), quadratus lumborum, rectus sheath and ilioinguinal blocks are being increasingly used as part of perioperative analgesia for general surgical procedures.

Venous capacitance is relatively low in neonates and infants, and arterial blood pressure will often fall in the face of a small drop in circulating volume. For major cases, an arterial line is indicated.

Finally, maintaining normothermia is a challenge for major general surgical cases. Forced air warmers or overhead heaters should be used during induction and siting of lines, and fluid warmers and forced-air warming mattresses should both be used intraoperatively.

Postoperative Analgesia

After major surgery, analgesia may be achieved by intravenous nurse- or patient-controlled analgesia (NCA/PCA). Morphine increases the risk of postoperative apnoea. An additional background infusion may be added if required. Ibuprofen is not licensed for use below three months of age.

Epidurals work well even in very young children and may avoid a need for postoperative ventilation. Due to lower levels of plasma-binding proteins in younger children and neonates (in particular, alpha-1 glycoprotein), higher free plasma levels of local anaesthetic are possible. Our preference is to use plain 0.125% levobupivacaine, up to 0.4 ml kg^{-1} h^{-1}.

Laparoscopic Surgery

An increasing number of procedures are carried out laparoscopically, including Nissen fundoplication, inguinal hernia repair, appendicectomy,

colectomy and pyloromyotomy, as well as primary neonatal surgical procedures.

Anaesthesia considerations for laparoscopic surgery are as follows:

Increased intra-abdominal pressure. A cuffed or snug-fitting tracheal tube should be used to facilitate ventilation in the face of possible reduced respiratory compliance.

The insufflation gas. This is almost always carbon dioxide; systemic absorption can rapidly lead to high arterial partial pressure of carbon dioxide, P_aCO_2. This should be monitored regularly, with either arterial sampling or using a transcutaneous CO_2 monitor. It may be necessary to deflate the abdomen periodically to enable CO_2 to be cleared, or sometimes to convert to an open procedure, particularly in small children with poor lung function such as those with congenital diaphragmatic hernia (CDH).

Cardiovascular consequences. Increased intra-abdominal pressure may reduce venous return and may also stimulate vagal reflexes because of peritoneal stretching. This may be relevant in neonates and children with congenital heart disease, such as those with a single ventricle circulation who are dependent on venous return for adequate pulmonary blood flow and cardiac output.

Temperature. The insufflation gas is cold. Body temperature needs to be monitored, and the child should be kept warm in the usual ways.

Gas embolism. This should be considered if there is a sudden drop in the end-tidal carbon dioxide level.

Inadvertent gastric perforation. Insertion of a nasogastric tube to deflate the stomach prior to insertion of the trocar will help reduce this risk. Nitrous oxide must not be used.

Specific Conditions

Pyloric Stenosis

Pyloric stenosis is due to hypertrophy of the pyloric sphincter and leads to gastric outlet obstruction. It occurs in approximately one in 500 live births. It classically presents with projectile vomiting in the immediate postneonatal period, but only rarely after the age of six months. These babies develop metabolic alkalosis with hypochloraemia as a result of losing hydrochloric acid from the gastric contents. Untreated, they can become severely dehydrated. Renal compensation includes excretion of bicarbonate ions along with sodium. As vomiting continues, renal compensation switches from sodium excretion to excretion of potassium and hydrogen, further worsening the initial alkalosis and causing hypokalaemia with possible hyponatraemia. This is a medical rather than surgical emergency.

- The child needs careful rehydration with 0.45% saline with 5% dextrose at 1.5 times the normal maintenance rate.
- If the baby is hyponatraemic, the deficit should be made up with 0.9% saline until the sodium is in the normal range.
- A bolus of 0.9% saline may be required if the baby is shocked.
- Additional potassium may be needed as guided by capillary or venous gas levels.
- These babies should only be considered for surgery when rehydrated and with a serum chloride level of greater than 100 mmol l^{-1} and serum bicarbonate less than 28 mmol l^{-1}. The patient is at risk of postoperative apnoea if surgery is performed before the metabolic alkalosis is resolved.

An umbilical approach is usually taken, although the classic Ramstedt procedure or laparoscopic approach may also be used. The pylorus is incised down to the mucosa. The surgeon may ask for air to be introduced via a nasogastric tube to look for a leak in the mucosal layer. Fentanyl 1–2 mcg kg^{-1} IV, local infiltration and paracetamol usually provide sufficient analgesia. Saturation and respiratory rate should be monitored postoperatively.

Inguinal Hernia Repair

Inguinal hernias are common in children, occurring in approximately 3% of the paediatric population. This incidence rises to 30% in babies born prematurely. Repair of an obstructed hernia is undertaken as an emergency, and babies should be treated as if they have a full stomach. Effective analgesia for a unilateral repair undertaken as an open procedure is provided by a caudal block or unilateral ilioinguinal/iliohypogastric nerve block. Analgesia for bilateral repair may be provided by

bilateral blocks or a caudal using 1.0 ml kg^{-1} of 0.25% levobupivacaine.

Acute Appendicitis

This is the most common indication for emergency surgery in children. The peak incidence is at 10–12 years of age with a 7% chance of developing the disease during a lifetime. A child younger than 6 years with symptoms for more than 48 hours is more likely to have perforated appendicitis. Urgent surgery is required since peritonitis and sepsis will ensue if left untreated.

- Preoperative rehydration is essential, and these children will often come to the anaesthetic room with intravenous fluid running.
- A modified or rapid sequence induction should be used.
- A nasogastric tube should be considered if one is not present on arrival to the anaesthetic room.
- The operation is commonly performed laparoscopically but can also be open.
- A reliable analgesic regimen consists of 1–2 mcg kg^{-1} of fentanyl followed by a loading dose of 50–100 mcg kg^{-1} of morphine and regular paracetamol with an NSAID.
- Postoperative NCA or PCA should be considered for open procedures.

Local analgesic infiltration or a TAP block may be used for perioperative analgesia, provided contamination of the wound is avoided.

Intussusception

This usually occurs in children aged from six months to two years but can occur in the neonatal period. Typically, the bowel 'telescopes' in on itself, and the resultant wall oedema causes obstruction. Children usually present with abdominal pain and a palpable mass. They may have rectal bleeding because of mucosal sloughing; the so-called red currant jelly stool. They may require fluid resuscitation and occasionally blood transfusion. The internal herniation can be reduced with a combination of air and saline or contrast enema in the X-ray department in up to 75% of cases, but if this fails then surgical reduction is necessary. Ninety per cent have no identifiable lead point for the apex, but a Meckel diverticulum or polyp should always be sought at laparotomy or laparoscopy.

Nissen Fundoplication

Gastro-oesophageal reflux disease (GORD) is common in children with neurodevelopmental problems, particularly cerebral palsy, congenital diaphragmatic hernia and tracheoesophageal fistula/oesophageal atresia, although reflux may also occur in healthy children. It may be associated with failure to thrive, oesophagitis, oesophageal stricture and chronic lung disease due to recurrent aspiration. Some infants may have life-threatening aspiration episodes. GORD should be confirmed, for instance by a 24-hour pH probe. If GORD is unresponsive to medical therapy, the child may require Nissen fundoplication. In this procedure, the fundus is wrapped around the lower oesophagus to reinforce the lower oesophageal sphincter. A laparoscopic approach is often preferred, although there is significant soft tissue dissection, and morphine NCA will be required postoperatively. Epidural analgesia is reserved for open cases, particularly for children with chronic lung disease.

Anorectal Anomaly

Approximately one in 3,000 babies are born with anorectal anomaly; it can be low or high. A low anorectal anomaly is where the anus is closed over, in a slightly different position or narrower than usual. There may also be a fistula to the skin. In high anorectal anomaly, the bowel has a closed end and does not connect with the anus; it may connect with another part of the body, usually the bladder, urethra or vagina, through a fistula. Most children require a series of operations. The first operation is to create a loop stoma or end colostomy usually in the days after birth. The second is a posterior sagittal anorectoplasty (PSARP) operation to join the bowel to a newly created anus. This usually happens when the child is a few months old and has gained weight. The final stage is closure of the stoma. This happens once the child's bowel and anus are working well, a few months after the second operation. The three operations are usually completed by the time the child is six to nine months old. PSARP is a major procedure; it may also require an additional abdominal incision and for the patient to be turned from prone to supine. A flexible reinforced tube should be used, and

adequate peripheral vascular access for fluid replacement and transfusion should be sited. An arterial line should be considered if the patient has additional comorbidities. If the spine is anatomically normal, an epidural provides good perioperative analgesia.

Abdominal Tumours

General surgery is an important component of the multidisciplinary care of children with solid tumours. The common tumours presenting to general surgeons are shown in Table 20.1.

Neuroblastoma

Neuroblastoma is one of the most common abdominal tumours in children. It usually presents around 2 years of age and is rare after the age of 10 years. Neuroblastoma arises from cells of the sympathetic nervous system, commonly in the adrenal gland, although paraspinal, thoracic, pelvic and cervical primaries may occur. Children usually present with non-specific symptoms of fever, weight loss, fatigue and bone pain. An abdominal primary is present in two-thirds of cases. Metastases to the liver, lymph nodes, bone and bone marrow are common at presentation. Urinary catecholamines, vanillylmandelic acid (VMA) or homovanillic acid (HVA), are raised in 90%, but unlike phaeochromocytoma, persistent hypertension is uncommon. Children with orbital secondaries may present with bilateral 'black eyes', and growth of a paraspinal tumour may present with neurological symptoms due to cord compression. There is an associated paraneoplastic syndrome associated with random eye movements and myoclonic jerks which may not resolve as the tumour is treated. Children less than 18 months may be asymptomatic and present with an incidental finding of thoracic neuroblastoma.

Prognosis depends on age at presentation, tumour biology and tumour spread. The overall survival is only around 65% at five years from presentation, although low-, intermediate- and high-risk groups can be identified. Neuroblastoma is chemosensitive, and most children undergo several cycles of chemotherapy preoperatively, using agents such as cyclophosphamide, doxorubicin, carboplatin and etoposide, followed by surgical excision of residual tumour. Children with high-risk disease may undergo radiotherapy, myeloablative chemotherapy with stem-cell rescue or immunotherapy (see Chapter 37). Infants younger than six months may present with a small primary, with metastatic spread to the skin, liver and bone marrow. This distinct condition is associated with spontaneous resolution without treatment (stage 4S disease).

Wilms Tumour

Wilms tumour (nephroblastoma) has a similar incidence to neuroblastoma but a much better prognosis. Children usually present with a large, painless abdominal mass, although they may present with pain, occasionally requiring fluid resuscitation, if there is bleeding into the tumour. Tumours may be bilateral, and there may be pulmonary metastases or, in some cases, extension of the tumour into the inferior vena cava (IVC). Five to ten per cent of children have acquired von Willebrand disease and may require treatment with desmopressin (DDAVP) or cryoprecipitate prior to surgery. There is an association between Wilms tumour and Beckwith–Wiedemann

Table 20.1 Abdominal tumours in children in England 2001–2015

	Mean number of cases per year	Total number of cases registered 2001–2015	Percentage total of all cases of malignancy registered
Neuroblastoma	85	1,268	6
Wilms tumour	81	1,208	5.6
Soft tissue tumours	91	1,369	6.4
Germ cell tumours	47	704	3.3
Hepatoblastoma	18	267	1.25

Source: Childhood Cancer Statistics, England Annual Report 2018. Public Health England Available at: www.gov.uk/phe.

syndrome. Hypertension is uncommon and is due to compression of the renal artery causing elevated renin levels. It is unusual to require specific antihypertensive agents preoperatively or intraoperatively in these children.

In contrast to neuroblastoma, 90% of children with Wilms tumour have a good prognosis, with five-year survival around 85%. In the United States, surgery may be undertaken before chemotherapy, but in Europe the preference is for treatment with several cycles of chemotherapy using agents such as vincristine, actinomycin-D and doxorubicin, followed by nephrectomy (or heminephrectomy in bilateral Wilms), and radiotherapy in high-risk cases. Children with residual tumour in the IVC after chemotherapy may require surgery on cardiopulmonary bypass. Children who relapse and receive high-dose chemotherapy and/or radiotherapy may be susceptible to late adverse effects of treatment, particularly second neoplasms and cardiomyopathy.

Anaesthesia and Surgery for Children with Abdominal Tumours

Children with abdominal tumours may present for diagnostic and staging procedures such as CT, MRI, bone marrow and trephine or in some cases tumour biopsy. Most children require long-term intravenous access insertion for chemotherapy. Neuroblastoma cells take up $I^{123/131}$-meta-iodobenzylguanidine (MIBG), which is the basis of MIBG scans to identify primary tumour and metastatic disease in neuroblastoma.

Surgery for tumour excision can be long and difficult, and there is the potential for high fluid requirements and major blood loss. Neuroblastoma commonly encases major vessels such as the aorta and IVC, and Wilms tumours may be very vascular, particularly if the child has not received prior chemotherapy. Preoperative imaging should be reviewed.

If the patient has received preoperative chemotherapy with anthracyclines such as doxorubicin, a recent echocardiogram should be reviewed.

Children usually have a tunneled central line in situ. Intravenous access suitable for rapid transfusion is necessary, and children should be cross-matched with at least two units prior to theatre. Bleeding may occur from the IVC, so vascular access in the upper body is required. Invasive monitoring should be used. Serial arterial blood gases will help guide fluid and blood replacement. Appropriate warming is required, and a urinary catheter should be inserted before laparotomy to allow for accurate measurement of urine output. If possible, an epidural should be sited for intra- and postoperative use, although this is contraindicated in children with paraspinal neuroblastoma or coagulopathy. Most children do not require postoperative ventilation and can be cared for in a high-dependency ward. Fluid balance should be closely monitored, and laboratory blood results reviewed (full blood count, electrolytes). If an epidural has not been used, an NCA/PCA will be necessary; a background infusion may also be required for the first postoperative night.

Key Points

- Congenital abnormalities requiring general surgery are often associated with cardiac and other pathologies which should be identified as part of preoperative assessment.
- All children having major surgery should have a multidisciplinary team meeting as part of their preoperative care planning.
- Multimodal analgesia should always be provided, and regional anaesthesia should be used where possible as part of the perioperative analgesia plan.

Additional Reading

Greaney D, Everett T. Paediatric regional anaesthesia: updates in central neuraxial techniques and thoracic and abdominal blocks. *BJA Education* 2019; 19(4):126–34.

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Whyte SD, Ansermino JM. Anesthetic considerations in the management of Wilms tumor. *Pediatric Anaesthesia* 2006; 16:504–13.