Principles of anaesthesia for term neonates: an updated practical guide

Andrew Pittaway

Abstract

Term neonates may present for various different surgical procedures. Most of these cases are urgent and are probably best cared for in specialized paediatric centres, where expertise is concentrated. Pathophysiological derangements caused by the underlying condition, associated congenital anomalies and immaturity of key physiological and metabolic processes all contribute to make anaesthesia especially challenging. For these reasons, surgery-associated morbidity and mortality are greater in this group than in older infants and children. Meticulous attention to all aspects of perioperative care is vital to ensure the best possible outcome. The principles of safe practice of anaesthesia for term neonates are outlined in this article which excludes neonatal cardiac surgery and the details of neonatal pain management. Finally, the potentially deleterious effects of general anaesthetics on the developing brain are discussed.

Keywords Anaesthesia; infant; neonate; paediatric; term

Learning objectives

After reading this article, you should be able to:

- list typical procedures for which neonates present for surgery
- describe those aspects of neonatal physiology which render them vulnerable to the effects of general anaesthetics
- outline the necessary steps and equipment required to safely and efficiently anaesthetize a term neonate for surgery

Definition

By definition, a term infant is born between 37 and 42 weeks' gestation. The gestational age is calculated as the interval between the first day of the mother's last menstrual period and birth; this method's reliability is superseded by ultrasonographic measurement of in utero fetal crown-rump length during the first trimester.[1] The neonatal period is defined as the first 28 days of life whatever the gestational age.

Inpatient or day surgery?

Common neonatal surgical conditions are detailed in Table 1. Most neonatal surgery is undertaken on an urgent basis. Neonates usually present to the operating theatre from the neonatal intensive care unit (NICU) and thus there is no question of going home. However, finite resources have driven a trend towards increasing outpatient surgery and stimulated interest in the suitability of this approach for neonates. There is surprisingly little available evidence for the suitability of healthy term neonates for day surgery.[2] Although not directly applicable, such data might be inferred from a study of pyloromyotomy surgery in term babies, which quantified the risk of postoperative apnoea as 16%.[3]

The type, duration and complexity of the surgical procedure, as well as the associated physiological derangement and need for postoperative analgesia, influence the need for admission. Current evidence suggests that healthy term neonates who undergo uneventful surgery not requiring opioid analgesia may be allowed to go home after an unspecified period of postoperative monitoring. In the ongoing absence of available evidence, individual centres develop their own guidelines (e.g. minimum gestational age in term infants of 44 weeks plus 4 hours of uneventful postoperative observation).

Location

Neonatal surgery should proceed only in units with the trained personnel, infrastructure and processes in place to ensure safe practice. Increasing prenatal diagnosis (e.g. gastroschisis) has resulted in increased referral for planned delivery at specialist centres where early corrective surgery can proceed without delay.

Common neonatal surgical conditions

Surgical speciality	Procedures/conditions
General surgery	• Tracheo-oesophageal fistula • Congenital diaphragmatic hernia • Gastroschisis/exomphalos • Pyloromyotomy • Laparotomy (e.g. atresia/malrotation/ Hirschsprung) • Central venous access • Inguinal hernia repair • Imperforate anus
Neurosurgery	• Myelomeningocoele • Encephalocoele • Ventriculoperitoneal shunt
Plastic surgery	• Cleft lip/palate
Eye surgery	• Examination under anaesthesia • Laser treatment • Congenital cataract
Radiology	• Diagnostic cardiac catheter • Interventional cardiac catheter (e.g. atrial septostomy) • Other radiological interventions (i.e. magnetic resonance imaging)
Urological surgery	• Posterior urethral valve excision • Cystoscopy

Table 1

Andrew Pittaway *FRCA is Consultant Paediatric Anaesthetist at Seattle Children's Hospital, USA. He trained in anaesthesia in the north and south-west of England and in Australia. Conflicts of interests: none.*

Preoperative evaluation

Antenatal and birth history

It is important to record gestational age, intrauterine problems and mode of delivery. If delivery was complicated it is prudent to record Apgar scores and the need for or duration of any cardiorespiratory support. Thorough enquiry should elicit other early problems, if they have been treated and resolved or are ongoing and likely to require intervention (e.g. hyperbilirubinaemia, hypoglycaemia, seizures and sepsis). Congenital anomalies must be excluded before embarking on anaesthesia (e.g. cardiac lesions in exomphalos). One congenital anomaly raises the possibility of another. The anaesthetic implications of an unfamiliar syndrome should be determined before discussion with parents/carers.

A baseline haemoglobin measurement should be obtained and blood samples from both neonate and mother tested for ABO/rhesus D incompatibility. This assumes significance if for instance a blood group A child of a group O mother receives a transfusion of group A packed red blood cells. Transfusion thresholds are typically higher (12 g/dl) in neonates than in older infants. Ensure that vitamin K was given at delivery.

Current status

A systematic approach to assessment at the preoperative visit reduces the chances of missing significant problems (Table 2). Appropriate fasting times are as follows: 6 hours for formula milk, 4 hours for breast milk and 2 hours for clear fluids. Prolonged fasting risks dehydration and hypoglycaemia, so dextrose-containing intravenous maintenance should be started simultaneously with the fast whenever possible.

Assessment at the preoperative visit

Factor	Check
Airway	Oro/nasopharyngeal airway, endotracheal tube size, length, cuff. Intubation details/difficulties. Suctioning requirements
Breathing	Recent arterial blood gas/chest radiograph, inspired oxygen/nitric oxide, ventilator settings (mode, inspiratory/positive end-expiratory pressures, rate), chest drains
Circulation	Intravascular access, pulse rate, blood pressure, central venous pressure (plus trends). Capillary refill time, urine output, inotrope requirements
Disability	Wakefulness, sedation, paralysis. Neurological deficits
Exposure	Core temperature, core–peripheral difference
Fluids/infusions	Maintenance fluids/requirements. Blood/clotting products available (capillary samples overestimate haemoglobin). Stoma/nasogastric tube output
Glucose	Recent blood glucose. Total parenteral nutrition/10% dextrose/insulin infusion rates
Weight	Drug dose calculations

Table 2

The anaesthetic plan should be explained to the parents and consent obtained for any regional techniques, blood transfusion and/or rectal suppositories. Information on postoperative intravascular lines, plans for analgesia and need for elective postoperative ventilation can be discussed at this time.

Preparation of the operating theatre

Temperature: neonates lose heat rapidly to their surroundings due to a combination of increased: surface area to volume ratio, skin conductance (little subcutaneous fat) and evaporative heat loss (reduced skin keratin content) resulting in a higher thermoneutral temperature of 32 °C. Simultaneously, they are unable to shiver and rely upon brown fat metabolism for thermogenesis. The operating room must be warmed to 30 °C in advance of the neonate's arrival because cooling occurs rapidly. It is common to use a forced-air warming convector, a radiant heater, warmed gamgee blankets and/or clear plastic drapes.

Fluids: a fluid warmer should be used whenever fluid requirements are likely to exceed maintenance, and is mandatory if blood products are administered. The author's practice is to attach a burette to the fluid warmer and a distal three-way tap to allow warmed fluid boluses to be dispensed accurately. Maintenance fluids are simply continued from the ICU or given via an infusion pump.

Positioning: requires meticulous, ongoing attention. Safe, reliable support of both baby and attached devices is accomplished by the combination of tape, soft foam padding and rolls. A metal bar attached firmly to the operating table and stationed above the head once positioned for surgery allows better access to the draped baby, provides protection from errant elbows and prevents kinking or occlusion of the breathing circuit.

Equipment

Airway: a selection of appropriately-sized masks, endotracheal tubes (ETTs), oropharyngeal airways, straight and curved laryngoscope blades, stylets and suction catheters should be immediately available (*Anaesthesia and intensive care medicine* 2009; **10**(10): 480–488). For selected infants undergoing certain procedures, an appropriately-sized laryngeal mask airway (LMA) may be considered. Many paediatric anaesthetists consider the smaller-sized LMAs to provide unreliable airway control.[4]

Ventilation: an infant-compatible ventilator capable of delivering small tidal volumes (usually in pressure-controlled mode) and positive end-expiratory pressure (PEEP) is essential. The Jackson–Rees modification of Ayre's T-piece is the most frequently used breathing attachment in the UK. Spontaneous respiration is seldom indicated for intubated neonates; ventilation can be achieved by attaching the T-piece to e.g. a Nuffield Penlon™ ventilator via a Newton™ valve. Ventilatory parameters can then be titrated according to positioning, observed chest/abdominal excursion and measured airway pressures/capnography.

Other: core temperature is best monitored with a probe placed in the distal third of the oesophagus. Oesophageal stethoscopes incorporating a distal temperature probe facilitate accurate positioning where the heart sounds are loudest. Precordial

stethoscopes provide continuous breath/heart sound monitoring. Finally, anaesthesia should not proceed without the presence of a suitably trained assistant.

Premedication

Sedatives and atropine are not generally required; neither is parental presence in the induction room.

Anaesthesia

Induction

The neonate should be placed on a forced-air warming mattress and the overhead radiant heater positioned, ensuring that it is maintained at a safe distance to prevent accidental overheating.

An electrocardiograph, pulse oximeter and non-invasive blood pressure cuff should be attached to the baby. If there is concern about the possibility of right-to-left shunting through a patent ductus arteriosus, one saturation probe can be applied to the right hand (preductal) and another to a postductal site. Invasive arterial pressure should be monitored depending on the degree of surgical intervention/likely need for intraoperative blood sampling. If a nasogastric tube is present, it should be gently aspirated and left open to continuously vent the stomach. In the UK it is common to have two anaesthetists present at induction. This is particularly helpful if dealing with an unstable neonate or if intravenous access is to be secured after gaseous induction.

After preoxygenation, induction can be either inhalational or intravenous. Awake placement of intravenous cannulae can be facilitated by the use of topical local anaesthetics — calculate and beware toxic doses of these agents. Inhalational induction has the advantage of maintenance of spontaneous ventilation (useful if dealing with a potentially difficult airway) and should proceed with sevoflurane in 100% oxygen. Nitrous oxide should be avoided — even healthy preoxygenated neonates start to desaturate after 7 seconds of apnoea, so gentle mask ventilation may need to be continued[5] until the airway is secure. Intravenous induction, either using propofol (2–4 mg/kg) or ketamine (0.5–3.0 mg/kg), has the advantage of speed, but usually results in apnoea. Intubation will usually be necessary and can be achieved under deep inhalational or intravenous anaesthesia supplemented with short-acting opioids or muscle relaxants. Cricoid pressure is of unproven benefit and may actually hinder attempts at laryngoscopy.

Straight-bladed laryngoscopes are popular for intubation. A styletted ETT is often helpful. Typically a 3.0 or 3.5 uncuffed ETT is placed and should be tested for an audible leak at an inflation pressure of 20 cm H_2O. Modern cuffed tubes are as safe as uncuffed if they are managed carefully, and may possess certain advantages.[6] The neonatal trachea is only 5 cm long and left endobronchial intubation is as likely as right. Flexion of the neck causes more downward displacement of the ETT than upward displacement by neck extension.[7]

Intraoperative management

Balanced general anaesthesia may be maintained by intravenous or inhalational anaesthesia supplemented with intravenous opioids, regional techniques and/or muscle relaxation.

Transitional circulation

Hypoxia, hypercapnoea, hypothermia, acidosis and light anaesthesia can cause pulmonary hypertension, with right-to-left shunting of blood through the foramen ovale and ductus arteriosus, leading to worsening hypoxaemia and return of the so-called transitional circulation. Therapeutic manoeuvres include deepening anaesthesia, volume expansion, hyperventilation and/or increased inspired oxygen. Pulmonary vasodilators may be necessary in refractory cases.

Fluids

Fluids reduced hepatic glycogen stores in the neonate necessitate infusion of perioperative glucose. Maintenance doses of 10% glucose should be continued. Blood glucose should be monitored frequently and infusion rates and concentrations adjusted accordingly. Hypotonic dextrose-containing fluids are the commonest cause of potentially lethal postoperative hyponatraemia, and should be avoided.[8]

Fluid requirements depend on calculated fluid deficits, the nature of the surgery and extent of blood loss. A basal maintenance rate of 4 ml/kg/hour is supplemented to account for insensible and third-space losses. These losses may be dramatic (considerably >10 ml/kg/hour), particularly in abdominal surgery. Healthy neonates up to 3 days old require less maintenance. Fluid administration should be guided by empirical formulae and trends in haemodynamic variables and urine output (target >2 ml/kg/hour). A useful approximation is to maintain mean arterial pressure approximately equal to gestational age in weeks.

Neonates physiologically drop their haemoglobin concentration from around 17 to 11 g/dl during the first few months of life. Blood volume is estimated at 90 ml/kg. Blood loss should be closely monitored and replaced to maintain haemoglobin around 12 g/dl. Blood is typically irradiated and may need to be washed before transfusion to reduce potassium load.

Analgesia

For a review of analgesia please see *Anaesthesia and intensive care medicine* 2008; **9**(4): 147–151 (an updated version of this will appear in the April 2011 issue).

Postoperative management

The decision to extubate at the end of surgery is multifactorial and influenced by both patient and surgical factors. Neonates are often slow to wake even from light, brief general anaesthesia and elective postoperative ventilation is an attractive choice, particularly if ongoing opioid requirements are likely to be significant (e.g. following thoracotomy). It is safe to leave the child intubated and ventilated for the transfer back to the NICU. Certain procedures demand a period of elective postoperative ventilation (e.g. tracheo-oesophageal fistula repair when the suture line is thought to be under tension).

Extubation has the same incidence of complications as intubation and requires the same vigilance. The operating room should be warmed and the radiant heater retrieved. Residual neuromuscular block should be reversed and ventilation with 100% oxygen performed before waiting until the baby nearly self-extubates before removing the ETT. Bradycardia, breath-

holding and hypoxaemia are common. Re-intubation equipment and drugs should be available. Postoperative intravenous fluid requirements will be determined by the nature of surgery and the timing of resumption of enteral feeds. Electrolyte requirements should be estimated frequently as a guide to their replacement.

Monitoring

Monitoring of cardiorespiratory and other physiological parameters is customary in the NICU. When considering discharge to home the unknown risk of postoperative apnoea is the main concern. The meta-analysis by Cote addressed this risk in the *ex-premature* infant, concluding that they should be admitted overnight for monitoring until 54 weeks postmenstrual age. Apnoea monitoring is achieved either by the use of a specialized mattress or by transthoracic impedance measurement via the ECG leads. In term neonates aged 44—46 weeks, discharge appears safe after 4 hours of uneventful postoperative monitoring.

General anaesthesia and the developing brain

There is accumulating animal experimental evidence that early exposure to a wide variety of anaesthetic agents during a 'vulnerable' period of brain development causes neuro-apoptosis with measurable subsequent learning disability. There are currently no studies demonstrating similar histological changes in human infants exposed to anaesthesia, nor are there ever likely to be. Of the four recent retrospective studies performed, three suggest an association between early exposure to anaesthesia and various measures of learning and behavioural disturbance whereas the fourth refutes this premise.[9] ◆

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