Principles of anaesthesia for term neonates

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Abstract

Anaesthesia for term neonates is associated with increased perioperative morbidity and mortality and as a result should be reserved for specialized paediatric centres. Neonatal systems are immature and are undergoing rapid growth and development. Neonates are uniquely different in how they respond to surgery, drugs and fluids and this response varies across the neonatal period. Many of the physiological differences in neonates are a reflection of their high metabolic rate, increase in oxygen demand and maturing organ systems. Due to the difficulties in studying this age group, a lot is still unknown about neonatal physiology and pharmacology.

Keywords Anaesthesia; neonate; paediatric

Royal College of Anaesthetists CPD Matrix: 1A01, 1C02, 2A03, 2A05, 2D02, 2D04, 3D00

Learning objectives

After reading this article, you should be able to:

- describe key differences in the neonatal airway compared to an adult
- summarize the changes that happen between the fetal and neonatal circulation and explain how that might impact on anaesthesia
- discuss the important neonatal physiology that influences your choice of fluid management perioperatively
- list important measures you would need to take to ensure safe anaesthesia of a neonate

Introduction

The neonatal period is defined as the first 28 days after birth. A term neonate is born between 37 and 42 weeks' gestation. The neonate undergoes major anatomical and physiological changes during this time. Most of these changes are a result of the adaptation required to convert from an intrauterine to extrauterine life. The newborn is a different entity to the neonate at 28 days. Understanding the changes and their anaesthetic implications is vital to providing appropriate perioperative care.

Neonates have increased rates of perioperative complications compared to older infants and children. To reduce complication rates, their care should be undertaken in specialist centres.

Ventilation and oxygenation in neonates – the airway, lungs and ventilation

The airway

Perioperative airway problems are a common cause of morbidity and mortality in neonates. There are three clear anatomical/physiological distinctions. The normal airway, the normal impaired (underlying anatomically normal but acutely altered), the known abnormal (congenital abnormalities and syndromes).[1]

There are a number of key anatomical differences influencing management of the neonatal airway. These differences can be exacerbated by either acute alterations or congenital abnormalities. Techniques used to ventilate and intubate older children and adults are often less effective in this age group. It is important to remember that the primary goal of airway management is oxygenation.

The head is relatively large with a prominent occiput. Neonates have small facial structures with small nasal passages and a small oral cavity. The neonatal tongue appears large due to its limited lateral mobility in the small mouth.[1]

Neonate's small nasal passages contribute significantly to their total airway resistance. Any narrowing dramatically increases their work of breathing. Infants up to 6 months of age tend to be obligate nose breathers. It is important that close attention is paid to any cause of potential nasal obstruction. Orogastric tubes may be a better option than nasogastric tubes. Respiratory illnesses causing partial nasal obstruction can significantly increase airway resistance causing respiratory distress.[2]

When anaesthetizing a neonate, their head should be placed in a neutral or slightly flexed position. This may require a shoulder roll due to their relatively large head. Hyperextension creates an acute angle between the larynx and trachea and should be avoided. During bag mask ventilation, avoid pressure on soft tissues as it causes external airway compression. Movements of the head and neck to open the airway should be gentle and subtle. Gastric insufflation is common during mask ventilation. Gastric distension can significantly compromise respiration. A gastric tube should be placed to aspirate any air in the stomach.[2]

The glottis sits more cephalad at the C2/C3 spine level and is tilted anteriorly. The epiglottis is long, narrow and omega shaped making it more prone to obscuring the view of the glottis during laryngoscopy. The glottis appears different due to more prominent arytenoids and shorter vocal cords. The vocal cords cover about half of the anterior glottis compared to two-thirds later in life.[1]

Cadaveric studies suggested the larynx was a conical shape, different from the cylindrical shape of older children and adults.[1] Recent MRI studies in spontaneously breathing children challenge this view. They suggest the shape does not change significantly with age and that the narrowest part in neonates is also at the vocal cords.[1]

The cricoid ring is functionally the most vulnerable area of the airway. It is a full cartilaginous ring with little distensibility covered by a delicate mucosa. More recently the cricoid is thought to be an ellipsoid rather than circular shape.[3] A fitting uncuffed endotracheal tube (ETT) is likely to exert pressure on the lateral mucosa. Choosing a smaller sized cuffed ETT is

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thought to adhere better to the ellipsoid shape, exerting less pressure on the mucosa.[3] Damage to the cricoid mucosa can result in subglottic stenosis. Care when selecting and placing an endotracheal tube is vital in preventing long-term damage.[1]

The trachea in a term neonate is approximately 5 cm long. Ideally the tip of an ETT should lie mid-trachea.[2] This corresponds to an oral length of approximately 9 cm and nasal length of 10 cm. A size 3.0–3.5 ID uncuffed ETT or a size 3.0 high-volume low-pressured cuffed ETT should be selected for a term neonate. It is important to remember that neck flexion moves the ETT down the trachea whereas neck extension withdraws the ETT.[1]

If choosing a cuffed tube, ensure a pressure manometer is used when placing air in the cuff. This should be regularly checked and monitored.[1] The cuff pressure should be kept as low as possible to prevent significant airway leak and should not exceed 20 cm H_2O.[3] Studies suggest pressures of 10–12 cm H_2O are adequate in high-volume low-pressure ETTs.[3] A cuffed tube should always have a small amount of air in the cuff to prevent mucosal damage caused by the deflated cuff.

A size 1 laryngeal mask airway (LMA) is very useful as a rescue airway device or as an adjunct for intubation in this age group. They can be particularly beneficial in the neonate with congenital airway difficulties.[1] Due to the vulnerability of the neonatal respiratory system, the complexity of surgery and their easy displacement, LMAs are not commonly used as the airway of choice in this age group.

Airway resistance is a product of turbulent flow and the diameter of the airways through which air is flowing. Airway resistance is 7–10 times higher in neonates than adults. Any narrowing of the airways or obstruction significantly increases airway resistance. Damage to the laryngeal and tracheal mucosa can cause swelling and oedema. Consider the possibility of airway swelling when planning to extubate a neonate.

The lungs and ventilation

The basal metabolic rate in neonates is approximately twice that of an adult. The increase in oxygen demand is met by an increase in alveolar ventilation. This is primarily achieved by increasing the respiratory rate rather than the tidal volume.[2] The neonate has a restricted ability to increase its tidal volume due to its lung mechanics. The liver limits an increase in downward movement of the diaphragm.[2] The high oxygen demand reduces the respiratory reserve. With a proportionally similar functional residual capacity (FRC) compared to adults, the high oxygen consumption causes a rapid depletion of oxygen reserves and desaturation.[2]

The respiratory system is not fully developed in the full-term neonate. A term newborn has approximately one-sixth of its total alveoli.[2] These alveoli are larger than their mature counterparts. Their development is mostly completed by 2 years of age.[2] Having fewer alveoli reduces the elastic recoil in the lungs and increases airway collapse.[4]

The epithelial cells in alveoli produce surfactant. Surfactant helps reduce the surface tension of the alveoli and prevents airways collapse.[2] Lack of surfactant generally results from preterm birth. In term newborns it takes a few hours for the amniotic fluid to completely clear and a few days for the pulmonary surfactant to be well distributed. During this time the alveoli will have reduced distensibility (reduced specific and static lung compliance), making them prone to collapse. Surfactant levels can also be reduced by meconium aspiration and production delayed by gestational diabetes or perinatal asphyxia.[4]

The FRC is a balance between the outward recoil pressure of the chest wall and the inward collapsing pressure of the lungs.[4] The cartilaginous rib cage in neonates has less outward recoil pressure than the adult bony rib cage. The reduced pulmonary elasticity increases the collapsing pressure of the lungs creating an imbalance. This results in a closing volume greater than FRC causing terminal airway closure during normal respiration.[4]

Neonates have a number of mechanisms to prevent their lungs from collapsing. They close their vocal cords before the end of expiration (functional positive end expiratory pressure, PEEP), their high respiratory frequency and short expiratory times means they initiate inspiration before the end of passive expiration causing dynamic hyperinflation (auto-PEEP) and post-inspiratory activity of intercostal and diaphragmatic muscles (self-recruitment maneuver).[4] General anaesthesia interrupts these mechanisms resulting in a drop in the FRC, airway closure, atelectasis and ventilation-perfusion mismatch.[2]

The chest wall compliance in neonates is very high, creating very little resistance to over distension of the lungs. Neonates are very susceptible to barotrauma.

The pharynx, larynx, trachea and bronchial tree are more compliant. Neonates are prone to laryngomalacia and tracheobronchomalacia. These create functional airway narrowing and increase the work of breathing in effected neonates. PEEP is an important measure to help reduce airway collapse and stent airways open.[4]

Respiratory control

Cardiorespiratory control matures over the course of the neonatal period in babies born at term.[4] The immaturity of the respiratory control system causes irregular and periodic breathing and can result in life-threatening apnoeas.[4] The ventilator response to hypoxia and hypercapnia is impaired. Anaesthetic agents can further exacerbate this lack of response.[4] All term neonates should be admitted overnight for postoperative apnoea monitoring. Well infants born at term and over 1 month old can be considered for day surgery.

Haemodynamics in term neonates – the myocardium and hypoperfusion

Transition from fetus to neonate

The fetal circulation has a high pulmonary vascular resistance (PVR) and low systemic vascular resistance (SVR) with left to right shunting through the foramen ovale and ductus arteriosus. At birth, the clamping of the umbilical cord increases SVR. The initiation of respiration, expansion of the lungs and oxygenation of the alveoli, drops the PVR. Functional closure of the foramen ovale and ductus arteriosus removes the right to left shunt, increasing pulmonary blood flow.

Anatomical closure of the foramen ovale can occur as early as 3 months, but persists in up to 50% of children and approximately 30% of adults.[2] An increase in right atrial pressure in excess of left atrial pressure can reopen the foramen ovale allowing a right to left shunt.

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