Paediatric Anaesthesia- Key Topics

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Aim:
To cover topics of relevance to trainees working in paediatric anaesthesia and preparing for the FRCA exam.

Age Definitions

Preterm infant	born < 37 weeks gestation
Neonate	within 44 weeks from date of conception
Infant	up to 1 year
Child	1 – 12 years
Adolescent	13 – 15 years
Adult	from 16 years

Applied Sciences

Airway

- Large head
- Short neck
- Prominent occiput
- Large tongue
- High anterior larynx (C3-4) (C6 in adults)
- Long-u-shaped epiglottis
- Obligate nasal breathers
- Airway narrowest at cricoid cartilage (at C4)(vocal cords in adults)
- Epithelium only loosely bound to underlying tissue so trauma causes oedema easily
- Funnel-shaped trachea

Exam question;

a) List the normal anatomical features of young children (<3 years old), which may adversely affect airway, manage (25%)
b) What airway problems may occur due to these anatomical features? (30%)
c) Describe how these problems are overcome in clinical practice (35%)

Respiratory

- Limited respiratory reserve
- Increased basal metabolic rate and o2 consumption (5-6ml/kg/min) → rapid desaturation
- Horizontal ribs so no bucket-handle movement (so unable to increase tidal volume by much)
- Minute volume is rate dependent
- Higher resting RR (<1y: 30-40, 1-2y: 25–35, 2-5y:25-30, 5-12y: 20-25, >12: 15-20)
- Ventilation mainly diaphragmatic
- Chest wall much more compliant (cartilaginous rib cage and poorly developed muscles) so FRC low (especially during GA when there is decreased intercostal tone)
- Closing volume>FRC until 6-8y so airways close at end expiration (PEEP is beneficial)
- Work of respiration can consume approx. 15% oxygen
- Fewer Type I fibres (i.e. slow contracting highly oxidative fibres for sustained contractions) in diaphragm and intercostal muscles during 1st year so fatigue easily
- Thick walled alveoli
- 10% of total number of alveoli cf. adults
- Apnoeas common in neonates post-operatively, particularly if premature
- Surfactant produced by type II pneumocytes in lungs from 23w
- Surfactant in tracheal fluid from 28w
- Most surfactant produced after 30-32w gestation
- Surfactant production is associated with increased lecithin in amniotic fluid
- Response to $PaCo_2$ is more sensitive in neonates (i.e. increase ventilation with lower CO_2 cf. adults)

Cardiovascular

- Stroke volume limited because myocardium less contractile
- Ventricles less compliant so can't generate as much tension during contraction
- Cardiac output rate dependent
- Vagal tone dominant, so prone to bradycardias (→ decrease CO)
- Sinus arrhythmia common
- PDA contracts in first few days and fibroses in 2-4 weeks
- Closure of foramen ovale is pressure dependent, happens on day 1 (but can reopen if increased PVR)
- SNS not fully developed at birth

- CO 300-400ml/kg/min at birth
  200ml/kg/min after a few months

- Resting O_2 Consumption

Neonate	6-8ml/kg/min
Infants	5-6ml/kg/min
Adults	3-4ml/kg/min

- Blood volume

Premature	100ml/kg
Newborn	85-90ml/kg
6w – 2y	95ml/kg
2-15y	80ml/kg

Renal

- GRF and renal blood flow relatively low until approx. 2y due to high vascular resistance
- Tubular function immature until 8m, so less able to excrete large Na^+ load
- Premature infants have increased insensible losses (large surface area relative to weight)
- Neonatal kidneys can't concentrate urine >600mosm/l during 1st week
- Higher ECF (40% body weight cf. 20% in adults)
- Urine output approx. 1-2ml/kg/h

- "4,2,1 Rule" for fluid maintenance:
  4ml/kg/h for 1st 10kg
  2ml/kg/h for next 10kg
  Add 1ml/kg/h for every further kg

Hepatic

- Immature initially, especially carbohydrate metabolism and detox
- Decreased function of hepatic enzymes (e.g. barbiturates and opioids have longer duration of action due to slower metabolism)
- Low activity of hepatic uridine diphosphoglucuronyl transferase means can't conjugate bilirubin and drugs with glucuronide
- Liver enzyme system reach adult levels at approx. 3m

Glucose Metabolism

- Hypoglycaemia common in stressed neonate
- Glycogen stores are in liver and myocardium
- Hyperglycaemia usually iatrogenic
- Premature babies don't have a glycogen store (fat and glycogen stores are made in the 3rd trimester) so get hypoglycaemic easily
- Glucose crosses from mother by facilitated diffusion: in it's the main metabolic substrate of foetus in utero. Foetal [Glu] is approx.. 70% mothers [Glu]

Haematology

- At birth 70-90% of Hb is HbF
- HbF: 2α, 2γ
- γ is different from β by 37 AAs
- At 3m, 5% of Hb is HbF (mainly HbA)
- HbF combines more readily with O_2 but released less readily (since less 2,3-DPG), P_{50} = 2.5kPa
- HbF is protective against RBC sickling
- As levels of HbA and 2,3-DPG rise, ODC moves to right
- Factors II, VII, IX and X (vitamin K dependent) and platelet function are deficient in 1st few months (which is why vitamin K is given vs. haemorrhagic disease of the newborn)
- Newborn [Hb] = 18-20g/dL (Hct 0.6)
  3-6m [Hb] = 9-12g/dL

Thermoregulation

- Lose heat easily because:
  - Large SA:weight ratio (3x that of adult), so more radiant heat loss
  - Minimal subcut fat
  - Poorly developed shivering
  - Poorly developed sweating (despite having 6x more sweat glands)
  - Poorly developed vasoconstriction
  - Can't alter their behaviour in reaction to temperature change

- Non-shivering thermogenesis in brown fat needs more O_2 for metabolism of these stores (can increase BMR by 3). Inhibited by volatiles.

- Brown fat has
  - Lots of mitochondria
  - Rich symp innervation
  - Activated by stim^n of ventromedial nucleus of hypothalamus
  - 11% of total body fat
  - Found interscapular/mediastinum/perinephric/axillae/near major vessels in neck/adrenals
  - Deficient in premature

- Consequences of hypothermia
  - Respiratory depression
  - Acidosis
  - Decreased CO
  - Increased duration drug action
  - Decreased platelet function
  - Increased risk infection
  - Hypoglycaemia due to increased metabolism

- Avoid hypothermia by increasing theatre temp (28C), warm mattress, keep patient covered, hat, humidified gasses

- Thermoneutral temperature is the rage of environmental T within which the body will maintain its T with minimal O_2 consumption. Narrow for the naked newborn. Body T in this range is only controlled by skin blood flow.

- Critical temperature is the T at which extra heat must be generated to prevent a fall in body T

Central Nervous System

- BBB poorly formed (barbiturates, opioids, antibiotics, bilirubin crosses)
- Thin fragile cerebral vessels in premature, so prone to intraventricular haemorrhage
- Cerebral autoregulation present and functional from birth
- SC ends at L4 at birth
- Myelination not complete until 6m
- High proportion of fat in brain: volatiles reach high concentration rapidly
- SNS incomplete (tolerate neuroaxial blockade well cardiovascularly)

Prematurity

Definitions

- Premature birth — Gestational age <37w (irrespective of birth weight)
- Moderate prematurity — 31-36w
- Severe prematurity — 24-30w

- ELBW (extremely low birth weight) — 500-1000g
- VLBW (very low birth weight) — 1000-1500g
- LBW (low birth weight) — 1500-2500g

Clinical consequences

- Increased morbidity
- Respiratory distress syndrome (RDS)
  - Presents within 4h birth (↑RR, recession, grunting, ↓SpO_2, ↓breath sounds)
  - The deficiency in surfactant in immature alveoli causes inflammation, oedema and an exudate which forms hyaline membrane in alveolar sacs.
  - May require ventilator support. If prolonged, risk LRTI, barotrauma, hyaline membrane disease, bronchopulmonary dysplasia (BPD).
  - BPD (chronic lung disease): areas of emphysema, collapse, fibrosis, pulmonary arteriole thickening

- Apnoea of prematurity
  - Occur in >80% of those <30w
  - Different from periodic breathing (common in preterm)
  - Increased post-op
  - May herald another disease (e.g. sepsis)

- Intraventricular haemorrhage
  - Increased risk with hypoxia/hypercarbia/hypernatraenia/low Hct/changes in BP & CBF

- Necrotising enterocolitis
  - Presentation: abdo distension, vomiting, bloody stools
  - Gut ischaemia causes damage to the mucosa, perforation, peritonitis, sepsis, shock
  - Management: stop enteral feeding, NG drainage, IV antibiotics +/- TPN +/- laparotomy

- Retinopathy of prematurity
  - Occurs in response to high FiO_2 (so avoid, aim for SpO_2 in low 90s)
  - Initial retinal vasoconstriction, followed by release of vascular endothelial growth factors and retinal neovascularisation, which can lead to retinal detachment and visual loss.
  - May require laser treatment under GA

Pyloric Stenosis

- 1/350
- 80% male
- Thickened pylorus smooth muscle obstructs gastric outflow
- Infant present with hypovolaemia & hypochloraemic hypokalaemic alkalosis

- Projectile (non-bilious) vomiting
  → loss of H^+ & Cl^- & hypovolaemia
  → ↑aldosterone due to hypovolaemia
  → body tries to retains Na^+ and excretes K^+ (in exchange for H^+ in kidneys to try to maintain normal pH)
  → hypokalaemia & alkaline urine
  → as patient more Na+ deplete, kidneys try to retain Na (and so excrete K^+ & H^+ in exchange)
  → acidic urine

- Electrolyte imbalance should be corrected prior to surgery (pyloromyotomy via L upper quadrant incision/laparoscopically)

- Pre-op,
  - Rehydrated
  - Cl^->100mmol/L
  - pH <7.5
  - BE <6mmol/L
  - HCO_3 <30mmol/L pre-op

- Increased risk of aspiration, NG inserted

- Aspirate NG in all 4 quadrants prior to induction

Exam question:
What is the anaesthetic management of pyloric stenosis in a 6 week old child?

Down's Syndrome

- Trisomy 21
- 1/700 births (increases with maternal age)

- Of relevance to airway management:
  - Small head
  - Short thick neck
  - Macroglossia
  - Small mouth
  - Micrognathia
  - Atlanto-axial instability (so avoid excessive neck mvmt. e.g. avoid shoulder roll during tonsillectomy if possible and keep head in neutral position during intubation if possible)
  - OSA (50%)
  - Subglottic stenosis (in approx. 5%) (so have smaller ETT ready)
  - LRTI common
  - GORD

- 40-60% have congenital heart disease (esp. AV canal, VSD. Also ASD, PDA, Tet Of Fallot)
  - If L to R shunt, pulmonary hypertension more severe (and earlier)

- Other features
  - Brachycephaly
  - Epicanthic folds
  - Brushfield's spots
  - Hypotonic neonates
  - Mean population IQ 50
  - Epilepsy (10%)
  - Cataracts
  - ↑ risk leukaemia
  - Hypothyroidism
  - Difficult IV access

Exam question:
A nine year-old with Down's syndrome is scheduled for an adenotonsillectomy.
a) List the airway/respiratory (30%), cardiovascular (10%) and neurological (10%) features of the syndrome relevant to the anaesthetist.
b) What are the general principles involved in the preoperative (15%), intraoperative (25%) and postoperative (10%) management of this patient with Down's syndrome?

Caudal anaesthesia

Anatomy

- Injecting through the sacral hiatus (covered by skin and the sacrococcygeal membrane) allows us to access the inferior epidural space. This is easier to feel than in adults, who have a sacral fat pad overlying the area.
- Sacral canal contains cauda equina, filum terminale, spinal meninges, coccygeal/sacral nerves, epidural fat and veins.
- Epidural fat is loose, less fibrous connective tissue in epidural space so greater LA spread
- Dura ends at S4 at birth, S2 by 2y.

Technique

- Insert 22G needle at sacral hiatus advance at 45degree angle
- LOR as penetrate membrane
- Good correlation between spread of given dose and age (poor correlation with weight/height)
- Regimen of Armitage can be used to calculate dose of 0.25% levobupivacaine for infants/school children (lasts 4-6h)
    - Lumbosacral block to L1 0.5ml/kg
    - Block to T10 1ml/kg
    - Block to T6 1.25ml/kg

- Can add clonidine, diamorphine, morphine to injection. Ketamine addition now controversial due to neurodevelopmental implications.

- **Complications**
    - Failure
    - IV injection
    - Intraosseous injection
    - Dural/subdural puncture
    - Bowel perforation
    - Cardiovascular instability may occur with older children, but not in the under 6y due to delay in ANS maturity

Exam question:
Regarding caudal anaesthesia in children:

a) What anatomical features are important to consider when performing the block (caudal) safely? (30%)
b) What are the contraindications? (20%)
c) What are the problems and complications? (20%)
d) What constraints limit the effectiveness of the block and how can they be overcome? (20%)

Safeguarding Guidelines

Child Protection and the Anaesthetist: Safeguarding Children in the Operating Theatre, Intercollegiate Document (March 2007)

- We may encounter abused children in different situations:
  - Resuscitation
  - Intensive care
  - Anaesthetising for routine/emergency surgery
  - Anaesthetising for forensic examination

- Anaesthetists must undertake Level 2 child protection training

- Concerning clinical features
  - Bruising (unusual/excessive), esp. if the patient can not yet walk
  - Cigarette burns
  - Bite marks
  - Injuries in inaccessible places (e.g. ear, hands, feet, buttocks, neck)
  - Intra-oral trauma
  - Intra-oral frenulum damage
  - Trauma with inadequate history

- Actions to take if suspect non-accidental injury
  - Act in the best interests of the child
  - Consult your senior/child protection expert in hospital (often on call paediatrician). Ensure that action has been taken if necessary.
  - Do not undertake any additional/intimate/invasive examination (this requires additional consent)
  - Respect confidentiality: only discuss the case with others if it is necessary to help the child

Exam question:
All health care professionals have a responsibility to act if they suspect that a child has been subjected to physical abuse.
a) In what situations may the anaesthetist encounter possible child abuse? (20%)
b) List the clinical features that would arouse suspicion that physical child abuse has occurred (40%)
c) What should the anaesthetist do if they suspect child abuse has taken place? (30%)

Further Reading

For a list of past FRCA paediatric exam questions, go to the Trainee Section of the website of the Association of Paediatric Anaesthetists of Great Britain and Ireland (www.apagbi.org.uk)

Disclaimer: The information contained in this hand-out represents the views of the author, not the APAGBI or the Royal College of Anaesthetists exam board.