

## Paediatric Anaesthesia- Key Topics

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This hand-out accompanies the lecture delivered at the Group of Anaesthetists in Training Annual Scientific Meeting in Oxford, 5<sup>th</sup> April 2013.

### **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

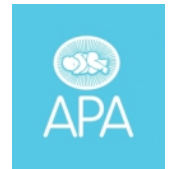
## Applied Sciences

### **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

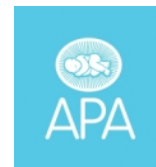
- Limited respiratory reserve
- Increased basal metabolic rate and  $O_2$  consumption (5-6ml/kg/min) → rapid desaturation
- Horizontal ribs so no bucket-handle movement (so unable to increase tidal volume by much)
- Minute volume is rate dependent
- Higher resting RR (<1y: 30-40, 1-2y: 25-35, 2-5y:25-30, 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 1<sup>st</sup> 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<sub>2</sub> is more sensitive in neonates (i.e. increase ventilation with lower CO<sub>2</sub> 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<sub>2</sub> 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<sup>+</sup> load
- Premature infants have increased insensible losses (large surface area relative to weight)
- Neonatal kidneys can't concentrate urine >600mosm/l during 1<sup>st</sup> 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 1<sup>st</sup> 10kg  
2ml/kg/h for next 10kg  
Add 1ml/kg/h for every further kg

## Hepatic

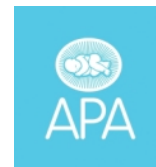
- Immature initially, especially carbohydrate metabolism and detox
- Decreased function of hepatic enzymes (e.g. barbiturates and opioids have longer duration of action due to slower metabolism)
- Low activity of hepatic uridine diphosphoglucuronyl transferase means can't conjugate bilirubin and drugs 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 3<sup>rd</sup> 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: 2 $\alpha$ , 2 $\gamma$
- $\gamma$  is different from  $\beta$  by 37 AAs
- At 3m, 5% of Hb is HbF (mainly HbA)
- HbF combines more readily with O<sub>2</sub> but released less readily (since less 2,3-DPG), P<sub>50</sub> = 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 1<sup>st</sup> 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

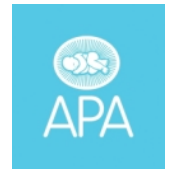


## Thermoregulation

- 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<sub>2</sub> 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<sup>n</sup> 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 range of environmental T within which the body will maintain its T with minimal O<sub>2</sub> 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

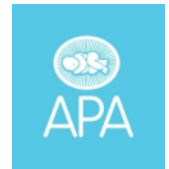
- Increased morbidity
- Respiratory distress syndrome (RDS)
  - Presents within 4h birth (↑RR, recession, grunting, ↓SpO<sub>2</sub>, ↓breath sounds)
  - The deficiency in surfactant in immature alveoli causes inflammation, oedema and an exudate which forms hyaline membrane in alveolar sacs.
  - May 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/hypernatraemia/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<sub>2</sub> (so avoid, aim for SpO<sub>2</sub> 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 & hypochloaemic hypokalaemic alkalosis
  
- Projectile (non-bilious) vomiting
  - loss of  $H^+$  &  $Cl^-$  & hypovolaemia
  - $\uparrow$  aldosterone due to hypovolaemia
  - body tries to retain  $Na^+$  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
  - $Cl^- > 100 \text{ mmol/L}$
  - $pH < 7.5$
  - $BE < 6 \text{ mmol/L}$
  - $HCO_3^- < 30 \text{ mmol/L}$  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?*



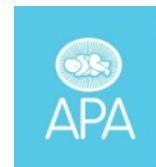
## Down's Syndrome

- 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

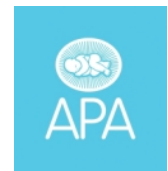
- Insert 22G needle at sacral hiatus advance at 45degree angle
- LOR as penetrate membrane
- Good correlation between spread of given dose and age (poor correlation with weight/height)
- Regimen of Armitage can be used to calculate dose of 0.25% levobupivacaine for infants/school children (lasts 4-6h)
  - 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](http://www.apagbi.org.uk))

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