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# Neonatal & Infant Physiology

## Definitions
- **Neonate** - first 44 wks of post-conceptual age (first 4 weeks of life)
- **Premature infant** - < or = 37 weeks gestational age
- **Infant** - 1-12 months of age
- **Low birth weight** - < or = 2.5kg

## Table 34.1 Respiratory parameters in the neonate and adult

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Neonate</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume (spontaneous) (mL/kg)</td>
<td>7</td>
<td>7-10</td>
</tr>
<tr>
<td>Tidal volume (IPPV) (mL/kg)</td>
<td>7-10</td>
<td>10</td>
</tr>
<tr>
<td>Dead space (mL/kg)</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>VD:VT ratio</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>30-40</td>
<td>15</td>
</tr>
<tr>
<td>Compliance (mL/cmH₂O)</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>Resistance (cmH₂O/L/s)</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>Time constant (s)</td>
<td>0.5</td>
<td>1.1</td>
</tr>
<tr>
<td>O₂ consumption (mL/kg/min)</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>

Parameters for children over 2yr approximate to adult values. Estimate respiratory rate from the formula $= 24 - \text{age/2}$.

FRC = 30ml/kg

## Table 34.2 Cardiovascular parameters in children

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Heart rate (bpm)</th>
<th>Mean systolic BP (mmHg)</th>
<th>Mean diastolic BP (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonate</td>
<td>80–200</td>
<td>50–90</td>
<td>25–60</td>
</tr>
<tr>
<td>1</td>
<td>80–160</td>
<td>85–105</td>
<td>50–65</td>
</tr>
<tr>
<td>2</td>
<td>80–130</td>
<td>95–105</td>
<td>50–65</td>
</tr>
<tr>
<td>4</td>
<td>80–120</td>
<td>95–110</td>
<td>55–70</td>
</tr>
<tr>
<td>6</td>
<td>75–115</td>
<td>95–110</td>
<td>55–70</td>
</tr>
<tr>
<td>8</td>
<td>70–110</td>
<td>95–110</td>
<td>55–70</td>
</tr>
<tr>
<td>10</td>
<td>70–110</td>
<td>100–120</td>
<td>60–75</td>
</tr>
<tr>
<td>12</td>
<td>60–110</td>
<td>110–130</td>
<td>65–80</td>
</tr>
</tbody>
</table>

Mean systolic BP over 1yr = 80 + (age in yr $\times$ 2).

## Table 34.3 Estimating paediatric circulating blood volume

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonate</td>
<td>90mL/kg</td>
</tr>
<tr>
<td>Infant</td>
<td>85mL/kg</td>
</tr>
<tr>
<td>Child</td>
<td>80mL/kg</td>
</tr>
<tr>
<td>Premature</td>
<td>100mL/kg</td>
</tr>
</tbody>
</table>
Applied Anatomy

Airway
- smaller
- nasal breathers - until 3-6/12
- tongue large
- larynx
  › high C3/4
  › funnelled shaped with anterior angulation
- epiglottis long, U shaped and angled at 45deg
- vocal cords angled
- narrowest portion = cricoid cartilage
- obligate nose breathers (nearly all convert to mouth by 5 months)
- small diameter of airways -> higher resistance to air flow.
- highly compliant -> kink
- trachea short (5cm) & in line with right bronchus
- large occiput

RESPIRATORY
- at birth each terminal bronchiole opens to a single thick walled alveolus
- 10% of adult alveoli
- full alveolar clustering develops until 8 years old
- cartilaginous ribs are horizontal - no bucket handle
- intercostals muscles are poorly developed
- diaphragm is more horizontal reducing mechanical advantage
- diaphragm contains lower % fatigue resistant type I muscle fibres
- \( \therefore \) tidal volume is fixed
- THUS, ventilation is essentially diaphragmatic and rate dependent
- closing volume within TV -> increased shunt
- nasal resistance contributes to 50% of total airway resistance
- NGT can occlude one nasal passage
- apnoea common (more so in premature (20-30%) — significant if:
  ‣ >15secs
  ‣ cyanosis
  ‣ bradycardia
- sensitive to volatiles -
  › quicker induction: higher metabolic rate & alveolar minute volume
- TV 7mL/kg
- Dead space 2.2mL/kg
- RR 30-40/min
- O2 consumption 7mL/kg/min (adult 3.5)

CARDIOVASCULAR
- PVR falls @ birth c/o first breath in response to \( \uparrow \)PO2 and \( \downarrow \)PCO2 -> closure of foramen ovale & ductus
  \( \Rightarrow \) if see hypoxia & acidosis may see opening of FO & DA \( \Rightarrow \) transitional circulation (R to L shunt)
- small ventricles and poor ventricular compliance
- RV wall thickness > LV at birth (equilibrates at 3-6months)
- CO high and is rate dependent (200ml/kg/min) (fixed stroke volume)
- low SVR
- if bradycardic think O2 (not atropine)
- HR <60 -> needs CPR
- higher parasympathetic tone @ birth \( \therefore \) why risk of stimulus induced \( \downarrow \)HR
- HR 80-200/min
- normal SBP 70-90mmHg
- normal MAP <6/12 = >35mmHg
- systolic pressure 50-90mmHg = 80 + (age x 2)

GASTROINTESTINAL
- liver immature
  - by 12 weeks enzyme systems have matured but drugs still metab’ed differently & slowly
    > barbituates & opioids prorlonged & enhanced effect
  - bilirubin metabolism poorly developed (susceptible to jaundice):
    > avoid drugs which displace bilirubin from plasma proteins ⇒ kernicterus
      > eg sulphonamides, diazepam, vit K
- carbohydrate reserves low (vunerable to hypoglycaemia)
- vitamin K dependent factors low -> at risk of haemorrhagic disease of newborn

RENAL
- nephrons formed but renal function is immature
- RBF reduced due to high renal vascular resistance
- GFR @ comparable /kg adult values by 2yrs old
- tubular function @ adult values by 6 months
- neonates cant excrete large solvent or sodium loads

HAEMATOLOGICAL
- circulating blood volume = 85mL/kg
- post delivery Hb = 13-20g/dL -> then develops physiological anaemia of infancy (10-12 g/dL)
  > plasma growth exceeds bone marrow activity
- 90% HbF @ birth -> 10% by 6 months
  > HbF has ↑ed affinity for O2 by having ↓ed2,3 DGP levels
- Hb <10 should be investigated

CENTRAL NERVOUS SYSTEM
- neurons are complete but total no of brain cells is reduced
- dendritic proliferation, myelination and synaptic connections develop from 3rd trimester -> 2 years
- BBB more permeable in neonates
- normal autoregulation
- ↑ed fat in brain ⇒ ↑ed volatile concentrations more rapidly
- increased sensitivity to pain - see development of descending inhibitory pathways later
- MAC:
  > neonatal = adult
  > premature = less than adult
  > growing neonate sees ↑MAC which peaks at 1yr (50% greater than adult)
  > then decline to adult level at onset puberty

WEIGHT
- neonate – 3-3.5kg
- 3-12 months = (age in months + 9)/2
- over 1 year = (age + 4) x 2

THERMOREGULATION
- high surface to volume ratio
- minimal SC fat
- poor insulation
- limited ability to vasoconstrict
- can’t shiver
- Non-shivering thermogenesis:
  > brown fat in back, shoulders, legs, thoracic vessels
  > may worsen pre-existing hypoxia
  > is deficient in premature
- heat lost by:
  - conduction
  - convection
  - evaporation
  - radiation = highest loss
- thermoneutral environment = 34 C for premature, 32 C neonate, 28C adult
  \( \leftrightarrow \) = temps where least metabolic requirement to maintain core temp
- GA ➔
  - ↓ thermoregulatory response
  - redistribution of heat to periphery
  - acidosis & ↓ perfusion
  - ↓ platelet function <32dec
  - longer action of opioids & NMBs
- Strategies:
  - heat theatre to 21-26 C
  - no draughts
  - cover head
  - insulate with gamgee
  - warming blanket or radiant heater
  - warm and humidify anaesthetic gases (use circle system)
  - warm fluids
- measure temperature in all neonates & anything longer than short paediatric surgeries

**FLUID REQUIREMENTS**
- neonate TBW = 80% of weight
- 2yr old reaches adult 60%
- Td ECW in children (%of TBW):
  - preterm >50%
  - term 45%
  - adult 35%
- plasma volume constant at 5% of weight
- water loss is double adults (thin, vascularised skin):
  - 40% ECW is lost daily
  - \( \therefore \) small ↑loss or ↓intake ➔ rapid dehydration

**Neonatal Maintenance Fluids**
- neonatal (mL/kg/day) – day 1–5: 50, 90, 120, 150, 150
- use dextrose 10%
- if ↓BSL given 2ml/kg of 10% glucose
- add 30mL/kg/day for those under radiant heat or undergoing phototherapy
- add Na+, K+ and Ca2+

**Paeds Maintenence Fluids**
- preop:
  - infants 4, 2, 1mL/kg/hr
  - use 5% dextrose and isotonic crystalloid (P1/4 or NSL)
  - hypotonic fluid ➔ NNT 5 causing hyponatraemia
  - dextrose used to prevent ketosis & not to provide adequate calories
- intra op losses:
  - blood loss: may replace with crystalloid 3:1
  - insensible losses:
    - open abdo = 6-10ml/kg/hr
    - intrathoracic = 4-7ml/kg/hr
    - superficial = 1-2ml/kg/hr
    - historical figures, likely much smaller than this
- post op:
  - use \( \frac{2}{3} \) maintenance fluid
  - electrolyte deficits can be calculated using:
    - deficit (mmol) = weight \( \times \) (desired plasma conc - measured plasma conc) \( \times \) 0.3

**Resuscitation**
- dehydration & hypovolaemia are different:
dehydration = intracellular loss of fluid
Hypovolaemia = intravascular loss
\[ \text{represent different chronicity's of fluid loss} \]
Dehydration can be Ax’ed via table below
- elective surgery child deficit = hourly fluid requirement x hours of starvation
  - replace 50% of this in 1st hr of surgery, then 50% over 2 hours
  - or if urgent can give 10-20ml/kg bolus
- Emergency surgery:
  - Ax of dehydration/hypovolaemia is made on clinical grounds:
    - CRT > 2seconds
- use isotonic crystalloid:
  - give 20ml/kg
  - if no improvement rpt 20ml/kg bolus
  - if no improvement after total 40ml/kg then give blood (10ml/kg) for replacement of losses
- transfuse if >15% of blood volume lost
  - calculate blood volume prior to surgery (N=90, I=85, C=80 ml/kg)
  - aim for Hb of 80 (if cyanotic HD or neonates aim higher >100-120)
    - 4ml/kg of blood \[ \Rightarrow \] Hb conc by 10
    - blood should be fresh, warm, filtered, CMV -ve
      - esp if neonate to ↓K load (consider co-dosing CaCl to protect myocardium)
  - platelets (target 100-120):
    - <15kg: 10-20ml/kg
    - >15kg = 1 apheresis unit
  - FFP: 10-20ml/kg
  - cryoprecipitate (target fibrinogen >1)= 5ml/kg
  - TXA 50mg/kg (max 2g). Can run as infusion 5mg/kg/hr
  - If using TEG then use normal adult targets
  - can transfuse rapidly with a syringe and 3 way tap

---

**Table 34.6 Clinical assessment of dehydration in pediatrics**

<table>
<thead>
<tr>
<th>Sign</th>
<th>5% dehydration</th>
<th>10% dehydration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin</td>
<td>Loss of turgor</td>
<td>Mottled, poor capillary return</td>
</tr>
<tr>
<td>Fontanelle Up to 1yr</td>
<td>Depressed</td>
<td>Deeply depressed</td>
</tr>
<tr>
<td>Eyes</td>
<td>Sunken</td>
<td>Deeply sunken</td>
</tr>
<tr>
<td>Peripheral pulses</td>
<td>Normal</td>
<td>Tachycardia, weak pulse</td>
</tr>
<tr>
<td>Mental state</td>
<td>Lethargic</td>
<td>Unresponsive</td>
</tr>
</tbody>
</table>

Replacement volume (mL) = Weight (kg) x % loss, e.g. a 10% loss in a 5kg infant requires a replacement volume of 500ml
50kg = 5000g x 0.1 = 500ml

<table>
<thead>
<tr>
<th>Sign</th>
<th>Compensated</th>
<th>Uncompensated</th>
<th>Irreversible</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Systolic BP</td>
<td>Normal ↑</td>
<td>Normal ↓</td>
<td>↑</td>
</tr>
<tr>
<td>Pulse volume</td>
<td>Normal ↑</td>
<td>Normal ↓</td>
<td>↑</td>
</tr>
<tr>
<td>Capillary refill</td>
<td>Normal ↑</td>
<td>Normal ↓</td>
<td>↑</td>
</tr>
<tr>
<td>Skin colour</td>
<td>Pale</td>
<td>Mottled</td>
<td>White/grey</td>
</tr>
<tr>
<td>Skin temp</td>
<td>Cool</td>
<td>Cold</td>
<td>Cold</td>
</tr>
<tr>
<td>Mental status</td>
<td>Agitated</td>
<td>Lethargic</td>
<td>Unresponsive</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>Normal ↑</td>
<td>↑</td>
<td>Sighing</td>
</tr>
<tr>
<td>Fluid loss</td>
<td>&lt;25%</td>
<td>25-40%</td>
<td>&gt;40%</td>
</tr>
</tbody>
</table>

---

**Post op Hyponatraemia**
- Na <135 = uncommon
- most likely from administration of hypotonic fluids
- symptoms: N&V, vomit, headache, seizure, resp arrest
- Rx:
  ‣ seizures respond poorly to anti-convulsants
  ‣ infusion of 3% NaCl to get Na >125mmol/L
    \( \rightarrow \) (1ml/kg of 3% NaCl \( \Rightarrow \) ↑Na by 1mmol/L)
- asymptomatic ↓Na then give 0.9% saline
- if ↑Na then fluid restrict to 50% maintenance
### Anaesthetic Equipment

#### Airways

**Oropharyngeal Airways**
- 000 -> 4 (4-10cm in length)
- not useful in neonates (nose breathers)
- measure: incisors to angle of jaw
- don’t invert when inserting (damage to palate)

**Nasopharyngeal Airways**
- rarely used but ↑ed tolerance at lighter levels of anaesthesia
- may be useful with some congenital airway problems or OSA
- measure; tip of nose -> tragus of ear
- possible to use an ETT as modified NPA = size = age/4+3.5

#### Facemasks
- round for neonates/infants
- tear drop for rest
- size appropriately - bridge of nose to cleft of chin

#### SADs

**Table 34.8 Estimating the size of LMA in paediatrics**

<table>
<thead>
<tr>
<th>Size of LMA</th>
<th>Weight (kg)</th>
<th>Cuff volume (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0–5</td>
<td>2–5</td>
</tr>
<tr>
<td>1.5</td>
<td>5–10</td>
<td>5–7</td>
</tr>
<tr>
<td>2</td>
<td>10–20</td>
<td>7–10</td>
</tr>
<tr>
<td>2.5</td>
<td>20–30</td>
<td>12–14</td>
</tr>
<tr>
<td>3</td>
<td>&gt;30</td>
<td>15–20</td>
</tr>
</tbody>
</table>

- air in cuff = (size – 1) x 10mL

**Laryngoscopes**
- lengths 0-3
- curved Mac
- straight blade Magill for infants - esp <6months with high ant larynx

**Tracheal Tubes**
- aim for leak @ 20cmH2O
- if ETT to big ⇒ occlusion at cricoid ring (narrowest part of conical airway) ⇒ risk of scarring ⇒ sub glottic stenosis
- correct size is one which gives small leak at 20cmH2O

**Table 34.9 Paediatric endotracheal tube sizes**

<table>
<thead>
<tr>
<th>Weight or age</th>
<th>Tube size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;2kg</td>
<td>2.5</td>
</tr>
<tr>
<td>2–4kg</td>
<td>3.0</td>
</tr>
<tr>
<td>Term neonate</td>
<td>3.5</td>
</tr>
<tr>
<td>3 months–1yr</td>
<td>4.0</td>
</tr>
<tr>
<td>Over 2yr</td>
<td>Tube size = Age/4 + 4</td>
</tr>
</tbody>
</table>
- microcuff tubes available in sizes 3-5:
  ➤ advs:
    - ↓ tube exchange rate
    - no ↑ in post extubation stridor (remains present in uncuffed tubes)
    - ↓ cost of volatile as less leak
    - good if ↓ compliance & high aspiration risk
  ➤ disadv:
    - must monitor cuff pressures (must be <20cmH2O) esp if using N2O
    - trauma from deflated cuffs
    - ↑ cost of tubes
- tube length: (1,2,3,4kg = 7,8,9,10cm)
  ➤ oral = tube size × 3
  ➤ nasal = age/2 + 15
- confirm clinically or using black line at end of tube

**Double Lumen Tubes**
- options depend on age:
  ➤ >8yrs od = DLT
  ➤ 6-8 yrs = bronchial blocker, endobronchial intubation, univent tube
  ➤ <6yrs = bb or endobronchial intubation
- paeds scope can get down size 3 tube
- use bronchial blocker outside of ETT ≤ 4.5 tube ie have to make seperate pass through vocal cords
- smallest DLT = 26Fr

**Bronchoscopes**
- 2 main types:
  ➤ flexible
  ➤ rigid:
    - ventilating
    - venturi type

**Storz Ventilating Bronchoscope**
- rigid use for diagnostics & therapeutics
- ventilation occurs between lumen of bronchoscope & outer surface of telescope
- attachments at distal end
  ➤ breathing system - usually Jackson Rees T piece
  ➤ suction channel
  ➤ light prism
- size so that can hear audible leak at 20cmH2O pressure

**Venturi Scope**
- = open ended metal tubes
- gas exchange via jet insufflation of lungs with entrained air
- must use TIVA
- EtCO2 cannot be monitored
- risk of barotrauma → should only be done on >40kg pts

**Fibreoptic Scopes**
- smallest in use = ED 1.8mm & 2.2mm
- angle 160 deg up & 90deg down

**Anaesthetic Breathing Systems**

**AYRE’S T-PIECE WITH JACKSON REES MODIFICATION**
- = a Mapleson F
- =open ended 500ml reservoir bag modification
- = most commonly used circuit in anaesthetic practise
- =suitable up to 20 kg
- =expiratory limb must exceed Vt in order to prevent entrainment of RA during SV

**Advantages:**
- low resistance,
- valveless,
- light weight,
- can assess TV,
- can apply PEEP,
- potential for assisted or controlled ventilation,
- qualitative appreciation of compliance,
- reduction in dead space during SV,
- partial re-breathing allow conservation of heat and humidification
- fast wash in

**Disadvantages:**
- scavenging limited
  → are newer versions with closed bag, expiratory valve & scavenging attachment
- FGF must be higher for SV than CV,
- ETCO2 may be underestimated in children below 10 kg from dilution of expiratory gases
- difficult to assemble if not familiar
- learning curve with manual dexterity to control hole in bag

**FGF settings:**
- spont breathing: x2-3higher than alveolar MV
- IPPV: 1L + 200ml/kg
  → for both situations if have a ↑ed MV then ⇒ must ↑FGF
- in practise most need a minimum FGF 3L then titrate to normocapnia
  → partial re-breathing allows conservation of heat & humidity
**BAIN SYSTEM**
- can only use above 20kg due to resistance of expiratory valve
- co-axial
- = Mapelson D system

**HUMPHREY ADE SYSTEM**
= hybrid system
E mode behaves similarly to the T piece & that A mode is efficient in children >10kg

D & E modes are suitable for IPPV
expiratory valves are of low resistance

**CIRCLE ABSORPTION SYSTEM**
- most cost-efficient with low flows
- simple construction
- reduces atmospheric pollution
- light weight disposable systems
- conserves warmth and moisture - reaction with soda lime is exothermic $\Rightarrow$ heat & water
- able to monitor inspiratory and expiratory gas concentrations
- 15mm circuit can be used in children 5 kg
- during IPPV may need to increase FGF to compensate for leak

**Mechanical Ventilation**
- use childrens ventilator in kids <20kg
- pressure controlled ventilation reduces risk of barotrauma
  ‣ adv: compensates for leak around ETT
  ‣ disadv: does not compensate for changes in compliance, tube obstruction, bronchospasm
- volume controlled ventilation
Neonate Ventilators

- important characteristics required:
  - a high frequency of breaths (normal neonatal respiratory rate 30-40/min)
  - low TV breaths (normal neonatal TV = 7-10mL/kg)
  - deliver PEEP (important for ventilation of disorders such as transient tachypnoea of neonate and premature babies that have a lack of surfactant)
  - humidification
  - a high FiO2 (neonates can have incredibly high FiO2 requirements from multiple pathologies within lung parenchyma)
  - it must be portable (transportation to theatre and for interhospital transfers)
  - low compliance as this can dramatically effect volumes and pressures generated
  - pneumotachograph to accurate measure delivered TV
  - capacity for high frequency oscillatory ventilation
  - pressure control ventilation to decrease risk of baro/volutrauma (but ability to compensate for leak around tube required)
  - disconnection alarm mandatory because of high O2 consumption with rapid desaturation and bradycardia with hypoxaemia

Drugs

Dexmed
2mcg/kg intranasal;
0.5-1mcg/kg load over 20mins
elim ½ life 2hrs

Intraop Hypotension

- exclude potential causes then trial Rx:
  - ↓ volatile
  - Crystalloid
  - albumin
  - unresponsive then:
    - Metaraminol 10mcg/kg
    - CaCl 0.1ml/kg
    - HCT >0.25 = rbc transfusion
    - dopamine 5mcg/kg/min
    - adrenaline/norad
General Principles

Anaesthesia Use in Developing Nervous System

- Animal research shows alarming damage caused by anaesthesia on developing brain
- Methods of damage via neuronal apoptosis & hypoxic ischaemic injury caused by:
  - Suppression of neurotrophic synaptic signalling
  - Pro-inflammatory effects
  - Induced seizure activity
- Agents implicated include most anaesthetic agents except LAs, clonidine & dexmedetomidine, opioids & xenon
- Interspecies variations in dosage exposure required for apoptosis

Studies

- Animal studies:
  - Rats - showed cognitive & memory impairments
  - Primates - isoflurane & ketamine at clinical concentrations → degeneration of myelinating oligodendrocytes
- Epidemiological studies:
  - Cohort studies linked multiple exposures to anaesthetic & surgery to ↑ learning & behavioural problems
  - BUT evidence poor
  - Twin study retrospective = single anaesthetic (hernia repair) did not alter educational achievements
- Prospective studies:
  - GAS study (ongoing) = awake regional vs sevoflurane GA + regional in neonates for hernia repair. GA showed ↑ early apnoea & need for active interventions (no ↑ late apnoeas >5hrs). BUT no cognitive impairment at 2yrs. 5yr = endpoint

Clinician Impact

- Not enough evidence to warrant change practice
- Suggested altered techniques:
  - Delay surgery until later life. ↓ed general complications of surgery for children (non neuro) >1yr old
  - Use high dose remi as volatile agent sparing
  - Avoid nitrous & ketamine in neonates
  - Use of dexmedetomidine with neuroprotective properties
  - Awake regional anaesthesia in neonates:
    - Awake spinal & caudal are feasible
    - Keep baby warm, minimise light, noise & oral sucrose has good effects
    - Good haemodynamic stability seen as SNS is immature. Vasodilation is not prominent

<table>
<thead>
<tr>
<th>Table 1: Comparison of awake spinal with awake caudal anaesthesia in neonates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spinal</strong></td>
</tr>
<tr>
<td>Instant onset</td>
</tr>
<tr>
<td>Short duration</td>
</tr>
<tr>
<td>Haemodynamic stability</td>
</tr>
<tr>
<td>Dose 0.5–1 mg kg⁻¹ solution</td>
</tr>
<tr>
<td>Levobupivacaine (5 mg ml⁻¹)</td>
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<tr>
<td>Failure rate 5–26%</td>
</tr>
</tbody>
</table>

= 0.1ml/kg of 0.5% = 1ml/kg 0.25%
Anaesthesia Conduct

Preoperative

- rapport with child and parents

  - **URTI;**
    ‣ preschool child has 6-8 URTIs/yr & 25% have chronic runny nose
    ‣ concurrent URTI has ↑ ed risk: increased risk of excess secretions, airway obstruction, laryngospasm, and bronchospasm
    ‣ if post viral, apyrexial, clear chest & constitutionally well ⇒ continue & try to avoid intubation
    ‣ if unwell delay 2 weeks (hyper-reactivity may last up to 4 weeks)
    ‣ Evidence is unclear whether LMA increases or decreases risk in management

  - **LRTI;**
    ‣ symptoms incl productive cough, purulent chest or nasal secretions, fever, constitutional illness incl D&V
    ‣ delay 4 weeks

- **Risk of adverse resp event intraop** - RFs:
  ‣ Anaesthetic:
    ‣ airway instrumentation ie ETT>LMA
    ‣ agents: Des>sevo>propofol
    ‣ experience of anaesthetist
  ‣ Surgery:
    ‣ airway surgery, ENT, eye
    ‣ upper abdo, cardiac surgery
  ‣ Patient:
    ‣ age <6yrs (esp <1yr), premature
    ‣ Resp comorbidities ie asthma, CF, any chronic lung disease
    ‣ Infection:
      ‣ URTI - purulent cough, coryza, otitis media
      ‣ Any systemic infection ⇒ fever, malaise
    ‣ parental smoking
    ‣ Parental concern
  ‣ only proven prophylactic management is pre-op salbutamol for bronchospasm

- **bronchiolitis**; delay 6 weeks
- **recent vaccinations** - some consider delaying 1 week for inactive vaccine & 3 week for active vaccine in order to ↓ risk of confusion with post op complication

- **murmur;**
  ‣ most pathological murmurs are diagnosed perinatally
  ‣ common to hear murmurs at 2-4yrs - most functional (<1% pathological if otherwise F&W)
  ‣ assume innocent if systolic murmur AND
    ‣ Hx: good ex tolerance, growing & feeding well, no obvious syndromes, no FH of sudden death
  ‣ innocent murmurs do not need prophylactic antibiotics
    ‣ Exam: palp periph pulses, normal vitals, no thrills, norm abdo exam
    ‣ Ix: ECG:
      ‣ RVH = V1 lead [R wave = <5yr: >1.75mV]; [5-12yrs: >1.25mV] or upright T wave
      ‣ LVH = V5 or V6 R wave >4mV
  ‣ **premature babies;** asphyxia, hyaline membrane disease, bronchopulmonary dysplasia, PDA, IVH, retinopathy of prematurity, hypoglycaemia, anaemia, haemorrhagic disease of newborn, immunosuppression, impaired thermoregulation, difficult IV access, post-operative apnoea

- **consent;**
  ‣ >16yrs competent to consent
  ‣ <16yrs : Gillick competency = competent child can consent to Rx against parental wishes but cannot refuse it
  ‣ if parental dissagreement:
    ‣ only need one parental consent but illadvised to continue
    ‣ should try to gain consensus
    ‣ if unable & urgent then can act unilaterally in best interests of child; if non urgent ⇒ courts

- **fasting** - abide by local policies
  ‣ <6months=
    ‣ 4 hrs formula
- 3 hrs breast milk
- 2 hrs clear fluid (includes ice block and clear fruit juice)

>6months:
- 6hr food/milk
- 2hrs clear fluid

- fasting 1s gastric volume but does not guarantee empty
- prolonged fasting in infants ⇒ dehydration & hypoglycaemia
- ↑risk in infants of aspiration: ↓lower oesophageal sphincter tone & ↑insufflation of stomach at BMV
- pneumonitis post aspiration in children: adults is much lower

- airway:
  - MP not useful but worthwhile attempting to assess inside mouth
  - look at
    - standard adult Ax eg MO, AROM, teeth
    - AP & lat aspects of head & neck
    - anomalies of palate & mandibular floor
    - TM distance
  - consider associated comorbidities eg OSA, MH, cardiac disease, ↑ICP

- topical anaesthesia;
  - EMLA (eutetic mixture 2.5% lidocaine & 2.5% prilocaine 1:1,
    - 45mins but can produce vasocostriction
    - duration acti on = 30-60min
    - risk of metHb if <1yr
    - avoid in <37wks
  - Ametop = 4% tetracaine
    - onset time = 30min venesection; 45min cannulation
    - duration action = 4hrs
    - has vasodilating properties
    - ↑risk allergy
    - apply gel for no longer than 90min & remove if rash
  - ethyl chloride = cryoanalgesic
    - useful when other topicals forgotten or contraindicated
    - apply for 3-10secs & provide analgesia for <60secs

- premedication;
  - not routine, give if required. preschool child most at risk (separation anxiety with no ability to reason)
  - midazolam 0.5mg/kg PO - onset 15-30mis, waning at 45mins. dilute into pamol as bitter
  - midazolam 0.2mg/kg intranasally - onset 5-15mins. burns nasal mucosa
  - ketamine 5mg/kg PO alone or in combo with 0.25mg/kg midazolam. Onset within 15mins, peak 25min. May ↑salivation
  - ketamine 2-5mg/kg IM - uncooperative child. onset 5mins, offset 45min
  - fentanyl
    - Intranasal = 2mcg/kg
    - transmucosal lollipop - bioavailability 33%: 15-20mcg/kg.onset 20min, peak 30-45min
  - clonidine 4mcg/kg - good conditions for induction BUT assoc with hypotension & prolonged recovery
  - antisialogues reserved for excessive secretions eg Downs, CP, difficult airway, ketamine use:
    - atropine 40mcg/kg PO but variable absorption; alt = 10mcg/kg IV at induction
    - glycopyrulate 5mcg/kg IM or IV at induction
  - not routine. give if required. preschool child most at risk (separation anxiety with no ability to reason)

Investigations
- FBC if:
  - neonates & ex prems <1yr
  - risk of sickle cell disease
  - intraop transfusion may be required
  - systemic disease
  - metabolic/endocrine/renal disease
  - child on IVF
- Hb <100 s abnormal & needs investigating (although may proceed if systemically well)

Intraoperative
- parents in OT; only shown to be of benefit in those 4 yrs and over with one calm parent
- have emergency drugs drawn up

- **Endocarditis prophylaxis:**
  - give prophylaxis if high risk=
    - prosthetic heart valve
    - prev IE
    - un repaired R to L shunts or conduits
    - prev cyanotic CHD with unrepaired deficits
  - not required in any normal surgery incl dental for otherwise well pts where Abx not routinely given

- **induction of anaesthesia;** at least have SpO2, more if possible

- **inhalational induction;** sevo;O2, sevo:N2O:O2, position child on parents lap
  - Sevo disadv: rapid awakening, ↑ post op anxiety
  - use cupped hand approach if mask not tolerated

- **IV induction;**
  - propofol 3-5mg/kg and lignocaine 1% 1ml/10mls propofol
    - diluting propofol 50:50 with saline also ↓s injection pain
  - other options: thiopentone 4-6mg/kg, ketamine 2mg/kg, fentanyl 1mcg/kg
    - sux dosing:
      - child = 2mg/kg
      - neonate = 3mg/kg
      - IM paeds = 4mg/kg

- **IV vs inhalational:**
  - IV
    - adv: simple & safer
    - disadv: ↑hypoxia - less preoxygenation
  - inhalational:
    - adv: no cannula needed
    - disadv: more coughing & laryngospasm, may be more traumatic for child

- **airway management;** head tilt, chin lift and jaw thrust, use CPAP

- **laryngospasm;**
  - RFS: inhalational induction, asthma, URTI, chronic lung disease
  - Rx: FiO2 1.0, CPAP, gentle ventilation, propofol 1-2mg/kg, suxamethonium 1-2mg/kg + atropine 10mcg/kg, larsons point, gentle chest compression

- **intubation;**
  - neonate differences:
    - large head , short neck, large tongue, small mandible
    - larynx ant & superior - C3/4 vs C5/6 in adults
    - large epiglottis which is floppy, V shaped
    - obliquely angled cords
  - < 6 months use a straight blade, > 6 months use a curved,
  - intubation increases WOB ⇒ size 3.5 tube generally = ↑ resistance by x16 . use controlled ventilation,
  - fix tube to maxilla with two-trouser leg tapes - one across upper lip, other around tube
  - OPA can splint tube

- **difficult airway;**
  - predict eg syndromes = Pierre-Robin (↓ed submandibular space), Treacher-Collins and Goldenhar
    - dysmorphia
    - ↓neck extension
    - limited mouth opening
    - ↓TMJ movement
    - macroglossia
  - premed with IM antisyndromes eg atropine 20mcg/kg or glyco 5mcg/kg 30mins prior
  - deep gas induction
    - if becomes obstructed should try lateral or semi prone positions
    - do not assist ventilation if apnoeic
    - use NPA > OPA
  - blind nasal possible but experience based method & risk of trauma
  - other options = LMA, VL, asleep fiberoptic
    - bronroscope (with suction) = fit min ETT 4-4.5
    - ultra-slim bronroscope (no suction) = fit min ETT 2.5mm
  - emergency trachy is not an option
  - emergency cricothyroidotomy cannula should be possible with 18G & 16G:
- use rapi-O2 (set flow at child's age & hold for 1 sec. then ↑ flow in increments of 1 litre)
- **RSI**: standard procedure but:
  - pre-O2 = 4 VC breaths or ETO2 >90% but difficult in child
  - 0.25mcg/fent IV may provide slightly sedated more compliant child
  - always give atropine with sux
  - sux good: rapid, fasciulations, profound blockade, myalgias less of problem
  - if NG tube in situ - don't remove if infant (older children +/-)
- **maintenance**: 3 way taps allow administration of drugs and fluid when necessary, no bubbles, check glucose, hypothermia cares, theatre temp 21deg
- **extubation**: deep or light

**Postoperative**
- **PONV**;
  - uncommon under 2 years,
  - high risk procedures = ENT, squint surgery, travel sickness and previous PONV, morphine (↑ risk by 30%)
  - N2O does not ↑ PONV
  - use dexamethasone 0.1mg/kg, ondansetron 0.15mg/kg, cyclizine 0.5-1mg/kg

**Analgesia**
- underdosage of pain relief is common
- techniques:
  - assessment - adjusted pain scales eg FLACC, CRIES
  - explanation, reassurance, distraction
  - simple analgesics:
    - Paracetamol ORAL:
      - term - 3 months:
        - Load 20mg/kg
        - Main 10-15mg/kg 6-8hrly
        - Max 60mg/kg/day
      - >3months:
        - load 20mg/kg
        - Main 15mg/kg 4-6hrly
        - Max 90mg/kg/day
    - Paracetamol IV (no loading doses):
      - <5kg = 7.5mg/kg 6hrly max 30mg/kg/d
      - 5-10 = 10mg/kg 4-6hrly max 40mg/kg/d
      - 10-50 = 15mg/kg 4-6hrly max 60mg/kg/d
      - >50kg = as adult
    - ibuprofen 10mg/kg tds (max 30mg/kg/d), (5mg/kg qds if 1-3 months)
  - mid strength opioids:
    - codeine - not longer used <12 yrs old
    - tramadol 0.5-1mg/kg PO or IV qds
  - opioids PO PRN:
    - morphine 0.2mg/kg 4hrly
  - morphine IV titration:
    - 0.2mg/kg then made up to 10ml syringe. Give 1-2ml increments as in adults
    - or 0.05mg/kg boluses 3-4hrly
  - opioids PCA:
    - morphine PCA = 0.5mg/kg in 50mL of saline = 10mcg/kg/mL, bolus 1-2mL, lockout 5min, infusion 1mL/hr
    - NCA for small children & neonates (↑ lockout time to 20mins)
    - parents must not press buttons
    - use low background infusion
  - caudal analgesia & PNBs useful in day cases
- **regional**: done mostly asleep, use low concentrations as dont need motor block eg 0.25% bupiv
Anaesthesia for Child with URTI

Preventative Strategies to Reduce Risk
- Pretreatment with salbutamol:
  ‣ can ↓ risk by 35%
  ‣ multidose inhalers: <5yr = 6 puff via spacer (2.5mg neb); >5yr 12puffs (5mg neb)
- Lignocaine: no evidence to support spraying cords or IV boluses
- Desflurane: x5↑ in risk compared to sevo
- propofol TIVA: ↓ incidence of laryngospasm compared to sevo (although more coughing)
- Airway: risk of adverse event : ET>LMA>FM.
- Experience of anaesthetist

Anaesthesia for Premature
= (<37weeks)

Physiology

Respiratory
- alveoli @ 17-28wks, pulmon capillaries at 28-36weeks
- <32 weeks surfactant production is inadequate
- preterms & those who had >28days of O2 ⇒ bronchopulmonary dysplasia (BPD)
- BPD = ↑ O2 need, ↓ compliance, reversible airway obstruction
- apnoea:
  ‣ normal response to hypoxia = hypervent ⇒ hypovent or apnoea
  ‣ in preterms = apnoea only
  ‣ diff types:
    ‣ central - caused by:
      • ↓ hypercapnic response
      • hypoxic vent depression
      • active inhibitory reflexes
    ‣ obstructive:
      • nasal occlusion & pharyngeal soft tissue
    ‣ mixed
  ‣ pathological when apnoeic
    ‣ >20s alone
    ‣ <20s with
      • bradycardia (30beats from resting HR)
      • cyanosis or pallor
      • ↓ tone
  ‣ post op:
    ‣ Apnoea monitoring must occur if:
      • term infant and <44weeks PCA
      • Premature infant and <60wk PCA
    ‣ early apnoea = <12hrs
    ‣ late apnoea = 12-72hrs
  ‣ risks:
    ‣ younger than 44-60weeks
    ‣ apnoea at home
    ‣ neurological disease
    ‣ chronic lung disease
  ‣ strategies to minimise risk:
    ‣ apnoea v uncommon in fit preterm infants >2hrs post surgery
    ‣ ex prem infants not day cases until reach 60weeks PCA
    ‣ IV caffeine 10mg/kg - use with caution esp in premerates

CVS
- often see PDA ⇒ L to R shunt ⇒ ↑ pulmon flow ⇒ heart failure
- HPV is potent ⇒ can ↑ R to L shunt ⇒ worsening hypoxia
- prolonged ↑PVR ⇒ R heart failure ⇒ death

**Haem**
- term Hb = 180-200
- preterm = 130-150 with 70-80% HbF
- HbF = ↓O2 releasing ability which is normally compensated at term by ↑ed number of Hb

**Renal**
- ↓renal tubule ability to reabsorb HCO3 ⇒ normal acidosis of newborns
- evaporative water loss ↑ x15
- TBW ~75-85%

**Temp**
- ↑ed s.a., ↓brown fat stores, non-keratinised skin ⇒ ↑↑ heat loss
- hypothermia induced stress ⇒
  - ↓BSL
  - apnoea
  - met acidosis

**Glucose**
- ↓ed glycogen stores
- Rx BSL <2.5
- avoid ↑ BSL ⇒ hyperosmolar state ⇒ IVH, osmotic diuresis & dehydration

**GI**
- NEC ⇒ sepsis
- reflux ⇒ laryngospasm, laryngitis, tracheitis, apnoea, cough

**Nervous System**
- cutaneous nociceptors complete @ 20wks
- flexion spinal cord reflex to pain @ 26wks
- inadequate descending inhibitory pathways
- IVH inversely related to gestational age

**Preop**
- all will have ECHOs
- routine bloods
- Xmatch blood if expected blood loss >10% of volume
- consider atropine

**IntraOp**
- temp controls - aim for ambient temp of theatre 27deg
  - once draped temp can be dropped
- SpO2 on
  - R hand (in case PDA) (preductal)
  - LL (post-ductal)
- induction:
  - RSI not recommended. Should continue ventilation throughout
- ETT:
  - length: 1,2,3,4 kg baby = 7,8,9,10 cm mark at gum margin
- fluid:
  - estimated maintenance fluid = 100ml/kg/24hr
  - replacement of insensible losses = as previous noted
  - aim haematocrit 35-40%
  - aim UO 0.5-2ml/kg/hr

**Post Premature Babies**
- considerations:
  - apnoeas
  - intubation - for all <60weeks
  - spinal vs GA

**Anaesthesia for Infants**
- (<6months)
- specialist Anaesthetists recommended
Preop
- Manage parental anxiety
- ?Hx of prematurity
- Apnoea (as above)?
- Any murmur or low SpO2 must be assessed by cardiologist
- premeds not used
- drying agents not used

IntraOp
- prefer IV induction in emergent situations:
  ‣ neonates need small dose compared to infants who require big dose ie double neonates
- IPPV & PEEP preferred to SV with small tidal volumes & atelectasis

Pharmacology For Infants
Pharmacokinetics
Absorption
- ↓gastric emptying rate ⇒ ↓absorption
- IM drugs = ↑ed rapid uptake due to ↑ed CO & mm blood flow
- erratic PR blood flow
- inhalational agents taken up & eliminated more rapidly

Distribution
- ↓ed PPB 2nd to ↓albumin & αAGP
- Blood volume:
  ‣ ↑TBW, ↑ECF & ↑blood volume
  ‣ ↑ed CO ⇒ rapid delivery to target tissues
- solubility
- tissue blood flow - ↓flow to mm & fat

Metabolism
- hepatic enzymes mature at different times:
  ‣ ↓phase I reactions
    • normalise within days
    • effects synthetic opioids
  ‣ ↓phase II reactions
    • normalised at 6months
    • effects natural opioid eg morphine

Excretion
- ↓renal function:
  ‣ GFR = adult @ 1month
  ‣ clearance @ 3month
  ‣ PCT secretion @ 5months
- must ↓dosing of really excreted drugs eg penicillins & aminoglycosides

General
- ↑ed risk of toxicity:
  ‣ ↑ed uptake & distribution of drugs
  ‣ ↓ed elimination
- ↑↑VD of drugs:
  ‣ ↑ECF: effects ionised drugs eg NMBs
  ‣ ↓protein binding: effects protein bound drugs eg thio
- ↓elimination:

Drug Classes
- Volatiles
  ‣ ↑ed rate of wash in:
    ‣ ↑alveolar ventilation in relation to FRC
    ‣ ↑CO distributed to vessel rich group
    ‣ ↓tissue/blood solubility
    ‣ ↓blood/gas solubility
  ‣ sevo:
    ‣ do not see ↑in MAC in first few months of life (unlike other volatiles)
- 1.3MAC = intubate; 1MAC = LMA
- ↑ed incidence of agitation on emergence

- IV agents:
  - neonate = ↑sensitivity to barbituates & opioids due to ↑permeable bbb
  - propofol:
    - ~50% ↑induction & ↑maintenance doses
    - faster recovery than thio
    - ↓SVR by 15-20%; CI ↓13%

- MM relaxants:
  - NDNMBs:
    - NMJ in neonates = x3 more sensitive but ↑ed VD
      - ↔ see balance ↔ give normal adult dosing
    - longer elim half life due to ↓renal function ⇒ dose less often
  - DNMBs eg sux
    - ↑VD ↔ dose x2 adults;
    - (elimination may be slower in prems)

- LA's"
  - neonate =
    - ↑ed toxicity risk:
      - ↑ed elimination half lifes (x2 adults)
      - permeable bbb
      - ↓PPBs
        (but against = see ↑VD)
    - ↓all bolus doses by 50%
    - limit epidurals to 36hrs
    - ↓infusion rates by ⅓ after 24hrs

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### Anaesthesia in Uncooperative Children

- preop anxiety caused by:
  - fear of separation from parents
  - fear of strange environment
  - fear of painful procedures
  - fear of operation itself

#### Developmental Differences

- <12months (infants):
  - will accept parental surrogates
  - soothing voices, gentle rocking & being held
- 1-3yr:
  - separation anxiety a problem - allow parent in
  - unlikely to understand what is happening around them
  - distraction therapy
- 3-6yrs:
  - concern about body mutilation
  - simple explanations of operation & procedures
  - play therapy
- 7-12yrs:
  - more explanation & participation
  - need to feel in control
  - benefit from chosing facemask or holding it at induction

#### Psych Strategies

- pre-hospital visits -
  - must be done 5-7days prior
  - if done 1 day prior may make anxiety worse
- play therapy
- parental presence - may be Rx for parental satisfaction rather than child outcome
- hypnosis, music, lighting
- screens
Physical Strategies
- premed drugs
- restraint
- elective - delay, return to ward and discuss eg premed & wait or defer until another day with premed on arrival

Emergence Delirium (ED)
- = severe subset of emergency agitation
- = ‘dissociated state of consciousness in which child is irritable, uncompromising, uncooperative, incoherent & inconsolably crying, moaning, kicking or thrashing’
- Differentiate from pain:
  ‣ Immediate walking
  ‣ lasts ~15min
  ‣ Doesn't recur
- assoc factors causing ↑ED:
  ‣ short acting volatiles ie sevo
  ‣ surgery with ↑ ed post op pain
  ‣ ENT & eye surgery, MRI
  ‣ <6yrs olds
  ‣ preop anxiety of child or adult
- can define using scales: PAEDS & WATCHA

Causes
- proposed:
  ‣ rapid emergence - BUT propofol & sevo similar emergence times & less problems with propofol
  ‣ pain - but also see ED post painless MRI
  ‣ volatiles - interfere in balance between brain synaptic inhibition & excitation

Prevention
- coadministration of:
  ‣ propofol - diff options:
    - 1mg/kg over 1min
    - 3mg/3min at end of procedure
    - low continuous infusion during
    - run TIVA anaesthetic
  ‣ midaz - premed not effective
  ‣ fentanyl - 1mcg/kg given 10mins prior to end of procedure
  ‣ ketamine - 0.25mg/kg IV at end of procedure
  ‣ clonidine - 2-3mcg/kg - .: better premed in high risk children than midaz
  ↓ all strategies will ↑sedation & effect PACU stay .: must consider advs/disadv
- an episode of ED will ↑ incidence of post-op maladaptive behaviour changes eg night time crying, enuresis, sep anxiety, tantrums

Treatment
- pharmacological:
  ‣ fentanyl
  ‣ Morphine 0.05mg/kg
  ‣ propofol 0.5mg/kg
  ‣ midaz
  ‣ Clonidine 1-2mcg/kg (dexmed better)
- Not effective = reuniting with parents

Paeds Day Cases
Selection Of Patients
- standard exclusions eg concurrent illness and also....

Discharge Criteria
- dogma ie not required anymore prior to d/c:
  ‣ drink
  ‣ ability to pass urine (except on surgical grounds eg penile surgery)
- most common reason for unplanned admission is intractable vomiting & pain

**Unexpected Admissions**

- RFs:
  - ASA >3
  - OSA
  - longer surgery
  - ortho, ENT ⇒ pain!

**High Risk tonsil**

- Should not be day cases:
  - Criteria as above
  - <3yrs
  - Abnormal overnight saturations ie ?OSA

**Regional Blocks**

- infants show ↑ed risk of amide LA toxicity $\leftarrow$ ↑ed if R to L cardiac shunts as bypass lung clearance
- MOA = ↑CBF, ↓ed bbb integrity, ↓PPB, ↓hep clearance
- early warning signs not exhibited ⇒ 1st sign generalised seizure
- if emergency must Rx with benzos, intralipid & if needed V-A ECMO
- dosing should be calculated on IBW
  - $= (BMI \text{ at 50th percentile for age}) \times (\text{height (m)}^2)$

**Caudal Epidural Block**

- Indication = all surgery below umbilicus
• easier than with adults with success rate ~95%
• will achieve higher dermatomal block than adults
  ↪ epidural fat less dense & less packed

Technique
- L lat with flexed hips
- palp sacral hiatus = apex of triangle formed by line joining PSIS's
- sacral hiatus covered by sacrococcygeal membrane
- make small nick in skin
- use 20G or 22G cannula & insert 60º pointing cephalad
- small give = penetrated sacrococcygeal membrane
- flatten cannula, withdraw needle behind cannula & advance
- if easy to advance cannula then in successful position
- gentle test aspiration
- commonest failure reason is cannula too caudal

Dosing
- 1 ml/kg of bupiv 0.25% ⇒ 4-8hr block, but onset ~15-20mins
- can be extended with:
  ‣ clonidine 1mcg/kg - ↑sedation
  ‣ morphine 50mcg/kg - catheter required
- avoid adrenaline - risk of spinal ischaemia

Benefits
- adv = simple, safe, successful
- disadv: motor block, parasthesia, ↓bp, urinary retention, dural puncture, IV injection
  but rare with single shot

Continuous Caudal Epidural Analgesia
- Can thread catheter via caudal route up to required epidural space - estimate tip height
- single curve of back facilitates this
  ‣ >2yrs = Lx/Sx curve ⇒ ↑failure rate
- only leave max 36hrs - close to perineal faecal soiling

Epidural
- technically harder:
  ‣ lig flavum less developed
  ‣ narrower intervertebral spaces
  ‣ infant: epidural space depth ~1cm
  ‣ intercristal line is at L5/S1
  ‣ spinal cord terminates L3
- NAP3 = paeds epidurals = less complications than adults
- should not use air
  ‣ bolus = 0.75ml/kg 0.25% bupiv
  ‣ infusion = 0.1-0.4ml/kg/hr (standard light mix)

Subarachnoid Block
- rare in children because of low spinal cord
- indications eg herniotomy in high risk neonate eg O2 dependant prem, or ex prem with chronic lung disease
- technique:
  ‣ firmly gripped infant
  ‣ needle pas right anlge to skin below L3 - L5/S1 safest
  ‣ judicious use of skin LA helpful
- rapid onset, lasts <40mins
- 5cm 21G
- 0.1ml/kg 0.5% heavy plus 0.06ml for needle dead space

**Periph Nerve Blocks**

**Ilioinguinal & iliohypogastric**
- useful alt to caudal esp if children >20kg
- block easy under direct vision by surgeon
- LM technique:
  ‣ 1cm medial to ASIS
  ‣ regional block needle right angle to skin
  ‣ hit resistance at aponeurosis of ext oblique
  ‣ bounce needle through
  ‣ 0.75ml/kg of 0.25% bupiv  1-2ml for s/c fan
- US technique:
  ‣ probe 1 end close to ASIS & other end pointing towards umbilicus
  ‣ nerves see as oval hyperechoic structures between IO & TA (TAP plane)

- adv: easy, good success rate
- disadv:
  ‣ does not block visceral pain from traction of spermatic cord or peritoneum
  ‣ not good for high undescended testes
  ‣ 10% incidence of FNB

**Dorsal nerve block of penis**
- for distal penis surgery

---

*Fig 5 (1) Iliohypogastric and ilioinguinal nerve block with position of the probe and needle entry point; (2) the iliocostal and iliobasal nerves seen in between the internal oblique muscle and transversus abdominis muscle; (3) needle pointing towards the nerves; and (4) LA spread.*

- inplane approach from medial to lateral

---
Technique:
- 2 s/c swells of LA either side of midline 5mm from pubis symphysis at base of penis
- 4-10ml 0.25% bupiv
- Adv: safe, predictable, don't need to inject into Buck's fascia
- Disadv: may not block ventral surface

**TAP Block**
- Good for lower abdo surgery
- Use US:
  - Anatomy:
    - Lower 6 thoracic nerves & upper 2 lumbar nerves innervate ant abdo wall
    - They fan out on ant abdo wall as ant branches of intercostal nerves
    - Run in plane between IO & TA
    - Extensive branching & interconnection
  - US:
    - Transverse plane, slide laterally from umbilicus
    - Should see 3 distinct layers at nipple line
    - Move more laterally & aim to insert needle tip at mid axillary line
  - Blind technique:
    - Mid axillary line half way between costal margin & iliac crest
    - Blunt needle perp to skin
    - Double pop
- 1ml/kg 0.25% bupiv
- Adv: simple,
- Disadv: intraperitoneal injection, bowel perf, LA toxicity

**Rectus Sheath**
- Midline hernias
- Use US
- Gives a bilat block
- Technique:
  - Midpoint of rectus sheath
  - Small nick ⇒ regional needle until pop elicited
- 1ml/kg 0.25% bupiv
Infraorbital Nerve Block
- for cleft lip repair.
- inject half way between pupil & angle of mouth
- 1ml 0.25% bupiv

Vascular Access
- caution using chlorhex <2months of age - isopropyl alcohol wipes recommended

Sizing:
- French = ↑ing number = ↑ing size
- Gauge = ↓ing number = ↑ing size

Sites
- long saphenous vein usually palpable ant to medial malleolus

Central Lines
- PICCs:
  - single - triple lumen
  - >3 Fr if need to aspirate blood
  - dwell time not over 6 months
  - basilic vein above elbow or long saphenous preferred
  - cephalic makes an acute angle at subclavian vein junction & is prone to vasospasm
  - tip should be sited distal ⅓ of SVC or SVC/atrial junction
- CVLs:
  - dwell time <7days
  - sizing:
    - 4-5Fr = <6month
    - 5Fr 6month - 5yr
    - 7Fr >5yr
  - length:
    - <15kg = 5cm line
    - 16-40kg = 8cm line
    - >40kg = 13cm line

Midline
- tip lies in larger portion of vein
- dwell time 6-10days

Tunneled
- entered into central vein
- exit site tunneled to a more distant point
- dacron cuff mounted within tunnel where subcutaneous tissue grows over weeks
  - stabilises line & serves as a barrier to organisms
- removal requires GA

Ports
- tunneled CVI connected to a titanium or plastic reservoir which sits in a subcutaneous pocket
- entire system is internal
- reservoir covered by a thick silicon self sealing membrane
- advs:
  - allows less care of line
  - swimming
  - less body image problems
- disadv:
  - accessing line needs special equip
  - painful
  - remove requires GA

IO lines
- recommend use in critically ill if other vasc access can not be obtained within 90secs
- all lines are 15G
- different colours reflect diff lengths
- risks:
  - fracture
  - growth plate injury
compartment syndrome
OM
- must not reinsert an IO line into prev access site within 24hrs
- must infuse drugs under pressure with constant monitoring of site

PeriOp Use of Long Term Devices
- strict aseptic technique
- use syringes >10ml (smaller syringes = possible to generate high pressures)
Complex Airway Surgery

Laryngomalacia
- most common congenital upper airway obstruction
- present within 2 weeks of birth with inspiratory stridor → worse feeding & lying supine
- cause = collapse of supralaryngeal structures during inspiration
- diagnosed by nasoendoscopy
- often no Rx required: slowly worsens for 6-9 months then improves
- if severe should have GA & examination for second lesion which is seen in 20-30%
- 5-10% require surgery using cold steel or laser

Subglottic Cysts
- all children have had tracheal intubation at birth
- months later can see biphasic stridor

Respiratory Papillomatosis
- HPV 6 & 11 viral disease which can spread through the lungs but in juvenile form prefers true vocal cords & ant commissure
- see hoarseness or slow TSAB
- no cure
- symptom control by debulking lesions with microdebrider or CO2 laser

Subglottic Haemangioma
- stridor at 2-6 months with symptoms worsening for up to yr then decreasing over 2-5 yrs
- Rx includes
  - surgery: laser, tracheostomy (if lesion >50% airway) awaiting natural regression, excision
  - drugs: steroids & propanolol

Tracheomalacia
- soft cartilage → collapse of airway
- primary or secondary (external compression)
- Rx = CPAP or stenting

Subglottic Stenosis
- congenital or acquired (intubation trauma)
- Rx: tracheostomy then laryngotracheal reconstruction
- tracheostomy can be in for 3-6 months

Laryngeal Clefts
- failure of development of
  - posterior cricoid lamina or
  - septum between trachea & oesophagus
- present with feeding problems, choking +/- stridor, infections, cyanotic spells
- 4 grades: 2-4 = surgery

General Approach
- spontaneous respiration through technique recommended:
  - good V/Q matching
  - allows surgeon to perform bronchoscopy
  - maintains mm tone

Perioperative
- 3 techniques:
  - volatile induction & maintenance:
    - prolonged induction - 25-30 min
    - CPAP to splint airway
    - spray cords with lignocaine 3-5 mg/kg - risk of laryngospasm/coughing
    - place NP airway
    - adv:
      - pt controls own depth of anaesthesia
    - disadv:
- CO2 monitoring difficult
- environmental pollution

TIVA & spont resp:
- slow propofol induction to maintain spont vent
  - eg 200mcg/kg/min note keo 2.5min
- titrate remi & propofol to RR
- similar to volatile technique but
- adv:
  - deep anaesthesia which is not airway dependant
  - no environmental pollution
  - excellent surgical access
- disadv:
  - ↑ed chance of movement

High frequency jet ventilation:
- subglottic cannulation & jet carries high risk of barotrauma & air trapping
- supraglottic technique is possible

Interventional & Diagnostic Cardiological Procedures

Interventional Techniques

Valvuloplasty
- pulmonary valvuloplasty:
  ‣ common
  ‣ Rx of choice for isolated pulmon stenosis with gradient >50mmHg
- aortic valvuloplasty:
  ‣ critical stenosis carries high risk of sudden CVS collapse
  ‣ high risk of instability & arrhythmias during procedure

Septal Defect Closure
- TOE & XR use to guide placement
- much more common atrial closure (ventricle norm closed surgically)
- dislodged or embolised device is a risk

Atrial Septoplasty
- allows mixing of blood to ↑O2 in cardiac lesions eg transposition or single ventricles
- usually be getting a PGE1 infusion to maintain a PDA
- balloon drag through FO to enlarge hole & repeated

Angioplasty

Percutaneous Valve Placement
- = pulmonary valve replacement for severe PR or mixed PV disease

Closure of Systemic to Pulmonary Shunts

Complications
- overall complication rate = 7.3%
- mostly related to femoral access point - include:
  ‣ Haem:
    - haemorrhage - local, retroperitoneal, pseudoaneurysm
    - AV fistula
    - neuropathy
    - thrombosis in LL
    - stroke
  ‣ CVS:
    - arrhythmias
    - stroke - given heparin ACT >200
    - ↓MAP
    - ischaemia on ECG
Anaesthesia

Preoperative
- Signs of poor CO:
  ‣ poor feeding
  ‣ poor growth
  ‣ sweating - in infants; ↓ed exercise tolerance - older child
- recent imaging incl MRI, ECHO

Perioperative
• Induction - standard
• Maintenance
  ‣ positioning - arms above head
  ‣ difficult to access child so secure everything
  ‣ avoiding high FiO2 >30% impt : can ⇒ ↓PVR ⇒ ↑L to R shunts
  ‣ Sevo & air is preferred maintenance
  ‣ non stimulating procedure
  ‣ contrast is nephrotoxic:
    - sometimes give in high doses and volumes should be accounted for in fluid plan
    - RFs for renal problems: pre existing problems, DM, heart failure
• Extubation

Electrophysiological Studies
- non painful procedure
- avoid deep anaesthesia as it may effect results
- TIVA preferred by some

Pacemakers & Defibs
- Generator normaly fixed below L sternum
- wires via subclavian vein
- may require GA due to size of equipment compared to patient

Cardiac MRI
- high quality info on anatomy, function & tissue character
- may avoid GA in up to 7yr old & small babies (feed & wrap)

Diaphragmatic Hernia
= repair of defect in diaphragm either by suturing to abdominal wall or with a synthetic graft

Perinatal Care
- no benefit in delivering these babies by Caesarian
- avoid aggressive BMV
- intubate, NG tube, avoid PIP >25, Preductal SaO2 >85%, permissive hypercapnia
- PICU care:
  ‣ HFOV an option
  ‣ ECHO to Ax severity of pHTN:
    - ECHO findings: flat ventricular septum, TR, R to L shunt through duct arteriosus
    - inhaled nitric oxide trial
  ‣ ECMO - rescue & stabilisation prior to surgery

Preoperative
- mostly effecting left side
- associated with other anomalies - cardiac = 20%
- presents with respiratory distress, cyanosis and a scaphoid abdomen
- diagnosed on CXR
- overall mortality 50% with associated lung hypoplasia, abnormal pulmonary vasculature, pulmonary hypertension & cardiac defects
- affected lung is very abnormal: ↓develop airway, abnormal pneumocytes, ↓ed artery numbers
- never performed in emergency: optimise gas exchange first to FiO2 < 0.5 (high frequency oscillation or NO)
- N/G insertion essential pre-op

**Intraoperative**
- supine
- GA + IPPV
- art line (right radial = preductal)
- cautious face mask oxygenation (prevent distension)
- avoid NO
- 2 IV's
- temperature cares
- ventilation:
  ‣ high rate
  ‣ pressures <25cmH2O - pulmon hypoplasia & risk of PTX
- high dose fentanyl 25mcg/kg -> reduces pulmonary vasoconstriction

**Postoperative**
- NICU & vent for 24hrs then attempt to wean
- can deteriorate within 12 hours c/o pulmonary hypertensive crisis
  ‣ pulmon vasculature is abnormal & less prevalent
  ‣ smooth mm dominates
  ‣ ⇨ ↑↑ pulmon vasoC ⇨ hypoxia & acidosis
  ‣ Rx: hyperventilate, 100% O2, fluid, prostacyclin, NO, ECMO
- caudal epidural may help

**Gastrochisis/Exomphalos**
= replacement of abdominal contents into the abdominal cavity

**Preoperative**
- gastroschisis = herniation of contents with no sac. repair = urgent
- exomphalos = failure of gut to return to abdominal cavity (covered)
- increased risk of cardiac defects
- large evaporative losses -> should be in bag or covered with cling film

**Intraoperative**
- GA + IPPV
- supine
- N/G
- hypothermia cares
- access:
  ‣ 2 IV's lines in arms - abdo distension may prevent VR from LLs
  ‣ percutaneous long line or CVL - used for post op feeding. ↑ ed swelling may occur post op
- ability to hand ventilate allow assessment of how much can be replaced into abdomen (if all can’t then silo created)
- fentanyl 5-10mcg/kg +/- epidural

**Postoperative**
- ventilation
- head up
- close fluid management
- monitor for infection
Emergency Neonatal Laparotomy

- neonate = up to 28 days of life & preterm <37 weekers
- common cause of neonatal death = necrotising enterocolitis (NEC)

Table 1 Indications for neonatal emergency laparotomy

<table>
<thead>
<tr>
<th>Urgency in taking case to theatre</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency (i.e. as soon as possible allowing for resuscitation)</td>
<td>Perforated NEC</td>
</tr>
<tr>
<td></td>
<td>NEC failing to respond to medical management</td>
</tr>
<tr>
<td>Semi-urgent (i.e. normally next available daytime slot but may become an emergency depending on clinical condition)</td>
<td>Intestinal perforation from any cause</td>
</tr>
<tr>
<td></td>
<td>Malrotation</td>
</tr>
<tr>
<td></td>
<td>Gastrochisis</td>
</tr>
<tr>
<td></td>
<td>Intestinal obstruction provided there is no evidence of perforation or peritonitis, for example, anorectal malformations, Hirschsprung's disease, duodenal atresia, midgut atresia, duplication cysts, Meckel's diverticulum</td>
</tr>
</tbody>
</table>

Preoperative

History

- general:
  - pregnancy, delivery, birth weight, apgar score
  - post conceptual age, gestational age
  - problems since birth incl surgeries (rpt laparotomies are very bloody)
  - prev anaesthetic info from prev surgeries

- airway:
  - if prolonged intubation & needs tube exchange consider tracheal stenosis
  - CXR - tip aligned with T1-2 on CXR

- Resp Hx:
  - Infant respiratory distress syndrome (IRDS):
    - likely <28 weeks esp if <2 doses of steroids anenatally
    - surfactant given as Rx?
    - ?ventilation difficulties in NICU
  - length of ventilation
  - prematurity = postoperative apnoeas (POA):
    - RFs
      - gestational age
      - post conceptual age
      - Hb conc
    - single dose IV caffeine 10mg/kg - although poor evidence
  - current vent settings

- CVS Hx:
  - ?CHD - ?progress
  - Ax CVS decompensation & Rx
Exam:
- HR, MAP, CRT, core & periph temp, UO
  \[\text{MAP} < 30 \text{ or } \text{MAP} < \text{numerically gestational age} \Rightarrow \text{need inotropes}\]
- IVF regime - if unresponsive to bolus should have ECHO done
- BSL

access:
- have x2 IV's bilat ULs
- avoid fluid boli through PICCs

Investigations
- Hb norm value = 170-240
- platelets - term = adults; preterm 50-150 normal
- coags - check vit K been given
- ECHO & CXR

Perioperative
• Induction
  - temp cares - room, under & over heating mat, inline fluid warmer, minimal exposure
  - position to allow access to body part for CRT, stethoscope for breath sounds & HR
  - CPAP dependant babies are intubated on NICU
  - aspirate Ng tube & move baby from side to side during this
  - pre-oxygenate for 60secs even if difficult
  - Drugs:
    - MAC lower in neonates than infants
    - thio offset is markedly prolonged - use propofol
    - NMBs same dosing (more sensitive but higher VD)

• Maintenance
  - ventilation:
    - aim consistent VT & adequate MV at low pressures = PCV & PEEP
    - ETCO2 not as reliable as adults due to large amount of dead space \(\Rightarrow\) cap gases
    - permissive mild hypercapnia is acceptable
    - aim SpO2 95% to avoid retinopathy & bronchopulmonary dysplasia
  - CVS:
    - fluid loss should be categorised:
      - insensible loses = up to 8-10ml/kg/hr in laparotomy
      - blood loss:
        - estimate blood volume prior to surgery: (premature = 100ml/kg; term = 90ml/kg)
        - meticulous attention to swabs & blood loss
        - triggers for transfusion is debated & dependant on comorbidities & starting Hb:
          - sick neonate: 10% total blood loss
          - Hb trigger 120-140
        - syringe in blood:
          - PRCs are twice as concentrated as babies blood
          - \(\therefore\) give 1ml PRCs added to 2mls of crystalloid, or albumin or FFP

• Extubation
  - often return to NICU ventilated

Postop
• analgesia:
  - options:
    - caudal
    - lumbar epidural - 0.1-0.3ml/kg of 0.1% bupiv
    - IV opioids:
      - infusion 0.5mg/kg in 50mls running at 0-2ml/hr with NCA on top 0.5ml bolus, lockout infant/child 5min, neonate 20min
    - IV paracetamol; prem max 25mg/kg/d; term 30mg/kg/d
    - LA's
  - Note ↓ed dosing of all analgesics due to immature liver enzymes
Nectrotising Enterocolitis

- = most common GI emergency in NICU
- close assoc with preterm babies (90%) who have survived other immediate life threatening problems (resp distress & congen cardiac problems
- signs 3-10days post preterm birth post first feed:
  ‣ intolerance to feed
  ‣ abdo distension
  ‣ bloody diarrhoea
  ‣ lethargy - ↓ed spont movements
  ‣ resp distress
  ‣ shock
  ‣ temperature instability
- Diagnosed:
  ‣ XR - look for perforation & distended bowel loops
  ‣ ultrasound doppler - to check mesenteric blood flow : dead bowel
  ‣ bloods - sepsis with coagulopathy but needs differentiating
- Pathophysiology poorly understood:
  ‣ post 26 weeks fetal bowel produces protective mucosa
  ‣ preterms lack goblet cells which produce IgA
- breast milk ↓risk of NEC by x3-10

Medical Rx
- bowel rest
- bowel decompression
- broad spectrum Abx for 10-14days
- supportive Resp/ICU care:
  ‣ inotropes
  ‣ Haem support
  ‣ careful fluids

Surgical Rx
- 20-40% will need surgery:
  ‣ bowel perf
  ‣ gangrenous bowel
  ‣ pneunoperitoneum
- resect dead bowel & enterostomy formation

Anaesthetic Management

Preoperative
- unstable may need to be operated on in NICU

Perioperative
(avoid NO
- Induction
  ‣ induce with high dose fentanyl - 10mcg/kg
    ↳ prevents postop catabolism from surg stress response
  ‣ may not need volatiles due to high dose fentanyl & benzo’s from NICU
- Maintenance
  ‣ often need large volume fluid - 20ml/kg/hr & albumin boluses
    - aim for UO >2ml/kg/hr
  ‣ replace blood with blood/FFP/albumin
  ‣ inotropic support
  ‣ careful temp control incl heated humidifier (as poikilothermic )
- Extubation
Tracheo-Oesophageal Fistula (TOF)
(also in Thoracics notes)
- 92% of neonates with oesophageal atresia have a TOF

History
- 1:3,000 births
- copious secretions in mouth
- pulmonary aspiration of feeding
- presents with choking and cyanosis on feeding
- inability to pass a N/G
- constant risk of aspiration (can pass a double lumen tube that allows irrigation and suction)
- high incidence of cardiac disease and prematurity
- 5 types -> most common = blind loop oesophagus + distal oesophagus to carina
- 50% of newborns with this have other congenital abnormalities:
  ❯ Vertebral
  ❯ Anorectal
  ❯ Cardiac
  ❯ Tracheoesophageal
  ❯ Renal
  ❯ Limb abnormalities

Exam
- standard + for cardiac abnormalities

Investigations
- passing a radio-opaque N/G tube + CXR
- ECHO
- electrolytes

Preoperative
- IVF for hydration as neonatal fluids
- nurse head up
- continual suction on NG
- prophylactic Abx
- should not delay T/F to specialist centre - rapid surgery better prognosis
- ECHO ?congen cardiac problems
- routine bloods

Perioperative
- Induction
  ❯ suction pouch where Ng sitting & remove
  ❯ inhalational induction with spont vent or IV induction
  ❯ confirm bilat vent with cuff distal to fistula:
    ❯ usually situated post trachea immed proximal to carina
  ❯ avoid BMV if possible
  ❯ 2IVs & A line

- Maintenance
  ❯ removal of ETT & bronchosocpic exam to identify TOF
  ❯ place T piece on side port of bronch to allow spont vent during scoping
  ❯ reinsertion of ETT so that to occlude TOF - use small bronchoscope - may be difficult
  ❯ only then allow to give NMBs
  ❯ access via R thoracotomy (thorascopic repair becoming possible)
  ❯ manual ventilation useful:
    ❯ Ax lung compliance after ligation of fistula
    ❯ to assist in repair of oesophagus
    ❯ periodic reinflation of lung

- Extubation
  ❯ extubate as soon as possible

Postop
- complications:
  ❯ early =

Paeds - 37
- tracheomalacia of varying severity
- rep’ed infections
- anastomotic leak in 10-20%
- GORD - antacids initially +/- fundoplication later
  › late =
  - resp problems: pneumonia, tracheomalacia, recurrent TOF, recurrent stricture

**Special Points**
- prognosis based on weight & other cardiac problems

**Patent Ductus Arteriosus**
= ligation or clipping of ductus arteriosus

**Preoperative**
- small premature babies (<1.5kg)
- often have hyaline membrane disease
- associated with other cardiac anomalies
- indications = failure of medical treatment, ventilator dependence and risk of developing bronchopulmonary dysplasia

**Intraoperative**
- left thoracotomy
- bleeding can be massive if vessel torn
- IPPV
- fentanyl 10mg/kg + low dose volatile +/- N2O
- IV for transfusion
- arterial monitoring
- hypothermia conservation
- avoid saturations >96% because of retinopathy of prematurity
- LA by surgeon, intrapleural block or thoracic epidural
- Sudden CVS changes intraop:
  - ligation ⇒ acute rise in systemic BP ⇒ intraventricular pressure ⇒ risk of intraventricular haemorrhage
  - Rx: clamp duct gently and turn volatile up
- older well children can have done as day case coiling

**Postoperative**
- NICU

**Pyloric Stenosis**
= splitting of the pylorus muscle longitudinally down to the mucosa (myomectomy)

- Pyloric Stenosis = medical emergency needs urgent fluid resuscitation and resolution of biochemical abnormalities.
- Definitive surgical treatment then undertaken later to restore enteral nutrition.

**Presentation**
- projectile vomiting in neonate (not billous)
- dehydration
- peristaltic waves on upper abdomen resembling golf ball moving L to R
- olive sized mass to R of umbilicus
- weight loss

**Pathophysiology & Biochemistry**
- develops:
  1. hypochloraemia
  2. metabolic alkalosis
  3. hyponatraemia
4. hypokalaemia
5. initially, alkaline urine -> later, acidic urine
   → cos dehydrated, ↑HCO₃ absorption in PCT, reabsorb Na instead of H, & lactic acidosis
6. dehydration

**Hypochloraemia**
- loss of chloride in vomitus
- must correct to >100 to ensure adequate resus

**Met Alkalosis**
- loss of H+ in vomitus
- decreased secretion of pancreatic HCO₃-
- increased HCO₃- presented to distal tubule and eliminated producing an alkaline urine

**Hyponatraemia**
- loss of Na+ in vomitus
- decreased absorption of Na+
- loss of Na+ in urine until kidney adjusts to increased HCO₃- load
- activation of rennin-AG-ALD system to off set this and restore Na+ and H₂O

**Hypokalaemia**
- K+ loss in vomitus
- activation of rennin-AG-ALD system which produces loss of K+ in urine
- with extreme K+ loss in urine -> it gets reabsorbed in distal tubule with loss of H+ worsening metabolic alkalosis and producing acidic urine

**Dehydration**
- inability to absorb enteral fluid and vomiting
- activation of rennin-AG-ALD system + ADH

**Fluid resuscitation**
- Fluid resuscitation determined by:
  - weight
  - degree of dehydration assessed clinically (tissue turgor, pulse, fontanelle, CR centrally, peripheral perfusion, respiratory rate)
  - Symptom severity
  - resus:
    - severe = IV boluses of normal saline or 4% albumin – 10-20mL/kg
    - mod = 5% glucose & 0.9% saline (with 10mmol KCL/500ml bag) = 6-8mL/kg/hr
    - mild = give maintenance @ 4mL/kg/hr = 11.2mL/hr
  - replace NG losses with 0.9% NaCl ml/ml
- fluid therapy should be titrated to clinical variable including urine output (2mL/kg/hr for this child)
- need a lot of K+ once they pee

**Preoperative**
- commoner in first born males
- 80% males
- 10% are premature
- ensure fully resuscitated
- Cl⁻ (>100), HCO₃- and pH should be all within normal limits
- never an emergency operation - may take 24-48hrs
- Place Ng tube with 2hrly aspirates. Aspirate immediately prior to theatre.

**Intraoperative**
- quick procedure
- risk of pulmonary aspiration from gastric outflow obstruction
- aspirate N/G (in L & right sidelying) and don’t remove as will help to decompress stomach from vigorous ventilation
- RSI or use of NDNMBD
  ⬤ although inhalational may be safe
- atropine - always given to prevent bradycardia assoc with ETT
- avoid N2O
- fentanyl 1mcg/kg
- bupivacaine infiltration
- 
- extubate awake and in left lateral position

### Postoperative
- remove N/G
- feed within 6 hours
- non-opioid analgesia fine
- give maintenance IVF until feeding established
- use apnoea alarms overnight

### Intussusception

= reduction of invaginated bowel
- commonest cause of obstruction in infants >2 months old

#### Preoperative
- >2 months
- paroxysmal pain, blood and mucous (redcurrant) in stool + sausage shaped mass in right abdomen
- terminal ileum or ileocaecal valve (meckels in 5%)
- 70% can be reduced by air or barium enema
- may be badly shocked -> fluid resuscitation
- urgent surgery - may perform at base hospital. If transferring begin resus & send blood with pt
- N/G

#### Intraoperative
- supine
- +/- caudal
- potential for marked blood loss
- RSI with NG insitu
- IPPV
- fentanyl 2-5mcg/kg + volatile
- 2 IV's
- CVP in severe cases - ischaemic gut ⇒ acidosis

#### Postoperative
- if severe -> PICU
- epidural, TAP or local wound infiltration
- nurse controlled analgesia

### Herniotomy

= excision of patent processus vaginalis

#### Preoperative
- otherwise ASA 1
- more common in preterms - often repaired prior to leaving SCBU

#### Intraoperative
- supine
- LMA + SV/IPPV
- caudal or regional block or LA infiltration or spinal
- > 5kg -> inhalational or IV induction with LMA + caudal/ilioinguinal block + opioids
- < 5kg -> intubate + IPPV + caudal + LA infiltration
- if strangulated use RSI + N/G

- >1 year; diclofenac 1mg/kg PR
- <1 year; paracetamol 20-40mg/kg PR
- neonates; 20mg/kg PR, can give caffeine 10mg/kg IV to decrease risk of apnoea post op by 70%

**Postoperative**
- daycase = paracetamol and diclofenac PRN
- neonate or ex prem up to 60weeks post conceptual age = paracetamol PRN, admit overnight for monitoring of apnoeas and bradycardias

---

**Circumcision**

- = removal of prepuce (foreskin)

**Preoperative**
- day case procedure
- trend towards more conservative management (stretch or preputioplasty)
- physiological phimosis is not an indication for surgery as will retract with age
- indications:
  ‣ recurrent balanitis
  ‣ balanitis xerotica obliterans (BXO)

**Intraoperative**
- supine
- SV + LMA
- caudal/penile block/ring block (all effective)
- inhalational or IV induction
- diclofenac or paracetamol suppositories

**Postoperative**
- paracetamol 20mg/kg
- topical lignocaine gel
- warn parents that it is very painful post op and they need to keep the analgesics and topical going

---

**Orchidopexy**

- = release of an undescended testis into scrotum
- cryptorchidism = absence of 1 or both testes from scrotum
- indications:
  ‣ preserve fertility
  ‣ ↓ risk of torsion
  ‣ aid malignancy detection (x3-4 incr of malignancy in these pts)

**Preoperative**
- usually over 2 years
- common day case procedure

**Intraoperative**
- supine
- LMA + SV (if torsion RSI)

  - if require laproscopy to free testis then may be 2 stage procedure needing ETT
- can do regional:
caudal: if testes high need high volume, low conc mid thoracic caudal: 1.25ml/kg of 0.19% bupiv (1pt saline, 3pt 0.25% bupiv
ilioinguinal - only covers ant scrotum. will need local infiltration for incision
diclofenac 1mg/kg PR if > 1 year, paracetamol 30-40mg PR if < 1 year
- opioids may be required
testicular traction can produce bradycardia and laryngospasm
  ➔ esp with ilioinguinal block
- sometimes needs laparoscopy to find testis (ETT)

Hypospadias
= restoration of proximal urethral opening to the tip of the penis from ventral surface
(epispadias = meatus on dorsal surface = rare)

Preoperative
- usually an isolated problem but can be in association with dysmorphic syndrome
- can be simple -> complex repairs with buccal grafts

Intraoperative
- inhalational or IV induction
- LMA or ETT
- SV or IPPV
- caudal; 1mL/kg of 0.25% bupivacaine + ketamine/morphine/clonidine/diamorphine
- avoid erection by regional block + adequate depth of anaesthesia

Postoperative
- regular NSAIDS or paracetamol
- consider morphine NCA (0.5mg/kg up to 50mL = 10mcg/kg/mL, dose 1mL, lockout 5min, basal 1mL/hr)
- admit overnight

Cystoscopy & Perc Nephrolithotomy
- cystoscopy = most common diagnostic procedure done in children under GA
- deep anaesthesia required for scope insertion as stimulation++
- careful positioning in lithotomy
- options to remove stones:
  ➔ extracorporeal shock wave lithotripsy (ESWL)
  ➔ perc nephrolithotomy (PCNL)
- high risk of PONV

Cleft Lip & Palate
= repair of defect in upper lip and palate
- more common in males & on L side
- more common in 1st deg relatives of CLP
- cleft lips diagnosed reliably at 18-20weeks US scan
  ➔ palates not seen until post natal exam

Preoperative
- lip and palate involved in 50% of cases
- increased incidence of congenital abnormalities
- careful assessment - associated with
  ➔ Pierre-Robin = 80% assoc. Micrognathia, glossoptosis. Intubation easier with †age
    ➔ = downward displacement or retraction of tongue
  ➔ Treacher-Collins = 28%. Micrognathia & maxillary hypoplasia. intubation harder with †age
  ➔ Goldenhair syndromes
- IM atropine 20mcg/kg 30 min if difficult airway suspected
- lip usually repaired @ 3 months
- palate usually repaired @ 6-9 months

**Intraoperative**
- supine
- intubation rarely complicated: armoured RAE
  - can use roll of gauze in cleft if having problems with laryngoscope
- IPPV
- head ring, shoulder support
- inhalational or IV induction
- throat pack cares
- LA infiltration + adrenaline
- fentanyl 2-4mcg/kg
- dexamethasone 0.1mg/kg to minimise post op swelling
- consider infraorbital nerve block for cleft lip repair
- consider nasopalatine + palatine block for cleft palate repair

**Postoperative**
- suction pharynx gently
- check tongue - prolonged surgery & gag use ⇒ swollen tongue
- extubate awake
- tongue stitch is rarely used
- routine analgesia
- SpO2 and apnoea alarm
- HDU

**Laryngeal Clefts**
- rare problem but if chronic cough & aspiration may be up to 8%
- high incidence of associated anomalies - most commonly upper airway issues
- overall mortality 6-25%

**Presentation**
- generally present early
- (but smaller grades may be missed & found in adulthood)
- presentation shares common features with resp disorders:
  - poor feeding
  - failure to thrive
  - persistent cough
  - recurrent aspiration
  - stridor
  - cyanosis
  - choking episodes
  - resp failure

**Airway Management**
- ETT into cleft may give false impression of oesophageal intubation
- ETT in trachea may ⇒ lung ventilation fills stomach with air or persistent crying in neonate with tube in situ
- rescue techniques:
  - advance ETT further into trachea
  - emergency trachy
  - OLV with DLT
  - bilat endobronchial intubations with 2 small ETTs
  - CPB or ECMO

**Anaesthetic Concerns**

**PreOperative**
- MDT Ax
- CXR & ECHO
- renal US
- CT vertebrae
- genetic testing
- d/w parents: high mortality with severe clefts

**IntraOp**

**Induction**
- antisylogogue premed
- gas induction or careful propofol titration - **must** keep spont vent
- topical lignocaine to larynx
- high dose dex 250mcg/kg
- avoid long acting opioids

**Maintenance**
- Airway:
  - Gold standard = suspension microlaryngo-bronchoscopy with SV
    - O2 supply via:
      - nasal ETT whose tip sits proximal to larynx
      - connect to T piece
      - high flows
      - acknowledge no Et monitoring
  - Rigid or flexible bronchoscopy:
    - O2 via T piece onto sidearm
  - Jet ventilation an option but ↑risk of barotrauma/PTX/gastric distension
- Anaesthetic:
  - volatile
  - TIVA - titrate remi or alfentanil carefully
  - dexametomidine -
    - potent α agonist 8x ↑affinity for α2 than clonidine
    - 1mcg/kg loading then 1-2.5mcg/kg/hr
  - ketamine 0.5mg boluses hourly

**Surgery**
- post diagnosis stabilisation prior to repair:
  - thickened fluids
  - Nissen fundoplication
  - gastrostomy or tracheostomy
- repair options:
  - endoscopic repair
    - for lower grades
    - should remain unintubated throughout periop course
    - adv: much ↓postop complications
    - disadv: laser use, airway debris
  - open repair:
    - high grades
    - may need CPB or ECMO
    - post op prolonged ICU care with prevention of coughing for 1-8days
Congenital Talipes Equinovarus
= correction of club foot abnormality

Preoperative
- usually isolated abnormality but can be associated with myopathic diseases (poss ↑ risk of MH)

Intraoperative
- may be done prone occasionally
- IV or inhalational induction
- LMA or ETT
- opioid
- caudal blockade (1mL/kg 0.25% bupivacaine with clonidine 1-2mcg/kg to extend block)

Femoral Osteotomy
= stabilising the hip in congenital dislocation by realignment of proximal femur

Preoperative
- usually isolated defect

Intraoperative
- supine
- SV with LMA or IPPV with ETT
- caudal + clonidine (avoid opioids in caudal - avoid catheter) or epidural or opioids
- hypothermia cares
- attention to blood loss

Postoperative
- epidural infusion
- NSAIDS, paracetamol
- hip spica

Scoliosis Surgery
- see ortho notes

NeuroSurgery

Physiology
- CBF:
  ‣ neonate = 40ml/100g/min (lower than adults)
  ‣ infants to children = 90-100ml/100g/min (higher than adults)
- CMRO2 -
  ‣ neonate = 2.3ml/100g (vs 3.2ml/100g adults)
  ‣ children = 5.2ml/100g (vs 3.2ml/100g
- PaCO2:
  ‣ @birth vaso-response less developed
- PaO2:
  ‣ neonates: ↑ed sensitivity to ↓PaO2 (vs adults <50mmHg)
- autoregulation - impaired if:
  ‣ hypotensive
  ‣ resp distress
- Monro-Kellie doctrine:
  ‣ no fixed box as cranial sutures havent fused
fontanelle fixture times:
- posterio - 6months
- anteroir - 1yr to 1.5yrs
- final suture - up to 10yrs old

: if slow ↑intracranial volume then compensation can occur
- acute trauma will still ⇒ ↑ICP

Anaesthesia Conduct

Preoperative

- lack characteristic morning headaches
- paediatric GCS
- cardiac exam - ?and septal defects which may ⇒ paradoxical air embolism
- other considerations:
  - anticonvulsant meds - and effect on NMB
  - hypovolaemia
  - derranged electrolytes 2nd to vomiting
  - perinatal Hx

Intraoperative

- induction:
  - standard stable CVS induction:
    - TIVA ideal
    - sevo gas induction if no IV access
  - if RSI: avoid fasciculations of sux with opioids or NDNMBs
- maintenance:
  - standard neuro cares
  - fluid - avoid glucose solutions & hypotonic solutions

Postoperative

- morphine is fine
- non-specific COX inhibitors may be withheld until 24hrs

Special Points

- complications:
  - VAE -
    - small children & infants = ↑risk
      - head always lies above heart
      - head bigger surface area to rest of body
      - sinuses & bridging veins held open by bony connections

Specific Cases

Hydrocephalus & Shunts
- shunts may require revision due to growth
- blockage commonly occurs distal to cranial valve
- tunnelling painful, but post op minimal pain

**Tumours**
- brain tumour = most common solid tumour of childhood
- most arise post fossa (adults is opposite) :
  - ↑ ICP 2nd to CSF outflow obstruction
  - ↑ed post op resp complications due to impingement on resp centre
- watch for endocrine disturbance & DI

**Congenital Spinal Lesions**
- = failure of neural tube to close during 1st trimester
- range of conditions from spina bifida occulta to anencephaly
- most common corrections are lumbosacral meningocoeles (=herniation of dura posteriorly) :
  - ↑ed risk of latex allergy
  - induction in lateral position to prevent pressure on cystic sac
  - ↑ed risk of latex allergy
  - majority assoc with Arnold-Chiari malformation

**Inhaled Foreign Body**
- removal of FB from bronchial tree
- commonest reason for bronchoscope in 1-3yrs
- Peanut = high risk as may disintegrate in airway

**Preoperative**

**HISTORY**
(may be similar to asthma - or refractory asthma)
up to 30% present >1week after ingestion
- 1-3 year old emergency or subacute presentation
- coughing with food
- stridor
- respiratory distress
- wheeze
- cyanosis
- collapse
- infection symptoms (pneumonia)

**EXAMINATION**
- stridor
- decreased SpO2
- increased RR and WOB
- decreased AE on affected side
- rhonchi and wheeze on affected side
INVESTIGATIONS
- CXR (inspiratory and expiratory): in expiratory there may be areas of hyperinflation +/- mediastinal shift → 10% radio-opaque

MANAGEMENT
- referral to a centre with appropriate paediatric and ENT skills (lack of experience is cited as a major reason for morbidity)
- airway obstruction takes precedence over starvation
- EMLA for IV access
- consider:
  ‣ premedication: 0.25mg/kg PO midazolam, 2.5-5mg/kg PO ketamine, 20mg/kg paracetamol PO
  → unlikely if any airway obstruction
- bronchodilators
- antibiotics and steroids (as indicated)

Intraoperative
- IV access
- inhalational induction vs IV induction
  ← can use TIVA to supplement gas induction (100-300mcg/kg/min propofol)

INHALATIONAL
- advantages:
  ‣ lower risk of F/B moving distally
  ‣ easier to remove
  ‣ allows for rapid assessment of ventilation after removal
  ‣ T piece apparatus ⇒ then connect to Storz bronchoscope
- disadvantages:
  ‣ depth of anaesthesia required decreases CO and ventilation,
  ‣ increased resistance to ventilation with scope in
  ‣ hypercarbia

IV
- advantages:
  ‣ airway immobilized,
  ‣ balanced anaesthetic,
  ‣ decreases atelectasis
- disadvantages:
  ‣ apnoea
  ‣ ↓ airway mm tone

Conduct
- FiO2 1.0
- topical anaesthesia to vocal cords (4% lignocaine – 3mg/kg)
- antisialogue (glycopyrulate 5mcg/kg or atropine 20mcg/kg – this is controversial)
- full monitoring
- avoid N2O - risk of air trapping beyond FB
- prior to scope use BMV or LMA
- rigid bronchoscope eg Storz ventilating bronchoscope
  ‣ ventilation + visualisation on insertion,
  ‣ 3 options for ventilation:
    ‣ SV: circuit connected to side arm and provides O2 and inhalational agent when eye piece in
    ‣ IPPV: via Jackson Rees - must allow long expiratory time (5-10s)
    ‣ Jet ventilation -
      • via inline jet ventilator nozzle
      • use lower jet pressures in paeds <20PSI
- position of FB:
  ‣ upper airway: maintain SV
  ‣ lower airway:
    ‣ muscle relaxation and IPPV may be required as body will be pushed distally until can be grasped
By A Hollingworth & J Fernando

- give assisted ventilation via T-piece or high frequency jet ventilation
- intubate once FB removed
- may be difficult & long
- just prior to FB removal - consider small dose of NMB or propofol
- management of hypoxia -> re-insert eye piece and deliver O2
- management of F/B in trachea and can’t remove -> push down a main bronchus
- dexamethasone 0.25mg/kg IV to ↓oedema

**Postoperative**
- cont dex post op: x2 doses of 0.125mg/kg 8hrly
- nebulised adrenaline
- physio
- bronchodilators
- antibiotics

- complications: infection, bleeding, pneumothorax, airway trauma and swelling, tracheal perforation

**Dentistry**
- Primary dentition = 20 teeth
- Permanent teeth = 32
- Named:

![Diagram of primary deciduous dentition](image1)

Fig 1: Primary deciduous dentition. A, incisor; B, incisor; C, canine; D, molar; E, molar.

![Diagram of permanent/succedaneous dentition](image2)

Fig 2: Permanent/succedaneous dentition. 1, incisor; 2, incisor; 3, canine; 4, premolar; 5, premolar; 6, molar; 7, molar; 8, molar.

**Pain In Children**
- by age:
  - <2yr - unable to differentiate pain & pressure ⇒ GA
  - 2-10 yr - differentiate but might still require GA depending on procedure
  - >10yrs - ↑ed likelihood of cooperating
- GA indications:
  - LA contraindicated or localised infection
  - previous failure of LA or sedation
  - pt unable to cooperate due to comorbidities
severe anxiety
- extensive Rx
- note LA safe doses are lower than in adults due to ↑ed uptake eg lignocaine & adren = 4.4ml/kg
  ⇔ use ⅔ dosing due to ↑penetration of bbb, ↓ppb

Preoperative
- ideally pre Ax

Perioperative
- Induction
  - use of physical restraint is considered major infringement of individuals right to civil liberty . should consider Rx based on principles:
    - first do no harm
    - act in best interests of child
    - respect childs right to refuse
  - a child will not die without dental Rx
  - routine Abx prophylaxis is no longer given to children with cardiac lesions
- Maintenance
  - throat pack policies
  - sedation levels as defined by NICE:
    - minimal = awake & calm
    - moderate (conscious sedation) = sleepy but responds to verbal commands
    - moderate level II = sleepy & requires tactile stimulation to produce purposeful response
    - Deep = asleep & cannot be easily aroused - may require assistance to maintain airway, spont vent inadequate, needs painful stimuli. CVS normally maintained.
- Extubation

Postop

Special Points
- maxillary LA blocks:
  - maxillary teeth supplied by ant, mid, post superior alveolar nerves which branch of maxiallary division of trigeminal nerve
  - teeth block = inject into sulcus adjacent to tooth & gums on buccal & labial surface
  - hard & soft palate = infraorbital block via upper labial sulcus directly above canine tooth
    ⇔ also includes ant sup alveolar nerve ⇒ block to upper lip & maxilla
- mandibular anaesthesia:
  - mandibular teeth supplied by inf alveolar nerve which branch of mandibular division of trigeminal nerve
  - block this nerve before enters nerve at mandibular foramen on medial aspect of ramus behind lingula
    - gives all ipsilat teeth pulps except lower central incisor (cross over from contralat side
  - mental nerve - LA at mental foramen ⇒ labial gingiva, lower lip  chin

Procedural Sedation
- likely not cheaper or safer
- must address analgesia as well as sedation
- levels of sedation are a continuum. very difficult to remain in one plane consistently esp painful procedures
- indications:
  - painless procedure eg MRI
  - painful procedure eg laceration repair
  - endoscopy eg colonoscopy
  - dental eg extractions
- contraindications:
  - airway problems
  - apnoeic episodes
  - resp disease
  - ↑ICP
  - risk of pulmon aspiration
  - epilepsy
- oral drugs:
  - chloral hydrate for <15kg children = (foul taste)
    - dose 50-100mg/kg (max 1g)
- onset 10-60min, offset 1hr
  - midaz
    - anxiolysis, sedation & amnesia
    - 0.5mg/kg (max 15mg)
  - ketamine: dose 5mg/kg

- IV drugs:
  - midaz 0.05mg/kg incrementally up to 0.2mg/kg
    - can see paradoxical excitement - reversed by flumazenil
  - ketamine:
    - IM = 3 mg or IV 2mg/kg; top up 0.5mg/kg to total 5mg/kg
  - propofol + remi useful for endoscopy
  - reversal agents:
    - flumazenil 20-30mcg/kg - note short half life
    - naloxone = 10mcg/kg

**Preoperative**
- conset as normal
- fasting for all procedures lose verbal contact although recent evidence casts doubt on this

**Intra-Operative**
- moderate sedation = SpO2, ECG
- deep sedation = ETCO2 & art pressure
Anaesthesia with Paeds Problems

With Cerebral Palsy

Preoperative
= nonprogressive disorder of motion and posture

- causes: damage to CNS during antenatal, perinatal or postnatal period i.e during early brain growth.
- there is a spectrum of disability
- types:
  › spastic (70%),
  › dyskinetic,
  › ataxic,
  › mixed
- common operations: osteotomies, tendon releases, dental care, fundoplication, neurosurgical procedures to help with seizure control or to reduce dyskinesia or decrease tone.

CLINICAL ASSESSMENT
- AIRWAY: can be difficult c/o dental caries, contractures, loose teeth, TMJ dysfunction, malocclusion
- RESP: recurrent aspiration (bulbar palsy), poor cough, scoliosis -> restrictive lung disease, may require preoperative physio, antibiotics and bronchodilators
- CNS: epilepsy, visual and hearing deficits, behavioural and communication problems,
- GI: GORD, impaired swallow -> aspiration risk, malnutrition, constipation
- common medications used: anticonvulsants, antispasmodics, anti-reflux agents, antacids, laxatives and antidepressants.
  › baclofen:
    - GABAb agonist
    - decreases pain from muscle spasm and delays contractures
    - watch for bradycardia, hypotension and delayed waking during anaesthesia
  › botulinum:
    - antagonises reuptake of Ach @ NMJ ⇒ reversible muscle denervation with reduction in tone
    - causes: prolongation of NMB

MANAGEMENT

Preoperative
- premedication (not if aspiration risk)
- antacids
- LA to skin for IV placement - may be difficult
- check anti-convulsant levels & continue all regular medicines

Intraoperative
- carer/parent in room for induction
- may need gas induction 30deg head up (but may need RSI c/o aspiration risk)
- NMBs:
  › sux not CI’ed but 30% may have extra-junctional Ach R
  › NDNMBs less potent & shorter duration of action
- ETT - due to aspiration risk
- PONV cares
- careful positioning
- may be resistant to NDNMBD
- higher risk of bleeding intraop - mm unable to contract
- TOF may not be as reliable
- avoid pro-convulsant agents
- latex allergy care
- hypothermia cares
- RA recommended

**Postoperative**
- slow emergence
- suction secretions
- get parents into recovery
- physio
- meticulous pressure cares
- monitor for compartment syndrome
- bowel care
- consult with carers regarding adequacy of analgesia
- diazepam 0.1-0.2mg/kg for muscle spasms
- epidural can be great for analgesia and reduction in spasms

**With Epilepsy**
- 70% of patients with epilepsy will become free of seizures within 5yrs of Rx
- 20% patients in long remission will have a relapse

**Causes**
- primary = idiopathic
- secondary (more common):
  - prenatal:
    - inborn errors of metabolism
    - chromosomal abnormalities eg Downs, fragile X
    - infection eg toxoplasmosis, rubella etc
    - congenital malformations eg AVM, cortical dysplasias
    - neurocutaneous disorders eg neurofibromatosis
  - perinatal:
    - neonatal hypoglycaemia
    - ↓Ca
    - hypoxic encephalopathy
    - ICH with prematurity
  - post natal:
    - infections eg HIV, encephalitis, abscesses, tape worm
    - trauma incl NAI
    - malignancy
    - hypoxic events

**Classification**
- partial:
  - subclassified:
    - simple - normal conscious level
    - complex - impaired conscious level
  - presentation based on area of cortex involved eg motor, sensory, autonomic
- generalised:
  - bilateral
  - types:
    - LOC only
    - LOC with bilat UL & LL muscle contractions
- partial with secondary generalisation
- status epilepticus =
  - seizure >30mins or
  - 2 or more seizures without complete recovery of consciousness between them
  - 25% overall mortality
Mechanism
- related to:
  ‣ loss of post synaptic inhibition by ↓GABA activity
  ‣ new excitatory connections with ↑glutamate release
  ‣ appearance of pacemaker neurones with abnormal voltage mediated Ca channels

Treatment
AEDs
- start with monotherapy & progress as required
- Common side effects:
  ‣ hepatic enzyme inducers: phenytoin, carbamazepine, valproate
  ‣ hepatotoxic effects: valproate & carbamazepine
  ‣ thrombocytopenia & platelet abnormalities = valproate, carbamazepine
  ‣ high anion gap met acidosis = topiramate
  ‣ interactions: valproate prevents metabolism of gabapentin

Diet
- ↑fat:carbohydrate diets may help to control seizures eg Ketogenic (4:1 & low calorie intake) or Atkins (1:1 & unrestricted calories)

Status Epilepticus
- 30mins to stop seizure due to eventual failure of cerebral autoregulation:
  ‣ ↓CBF
  ‣ ↑ICP
  ‣ ↓MAP
  ‣ ↓glucose
  ‣ ↑ing acidosis
- 1st line - midazolam IV=0.15mg/kg; IM=0.2mg/kg; intranasal/buccal 0.5mg/kg)
- 2nd line - phenytoin 20mg/kg (max 1g) in NSL (max conc 10mg/ml). Give over 20mins
- 3rd line - valproate 30mg/kg over 10min
- 4th line - GA with thiopentone 4-5mg/kg (or propofol 3-5mg/kg) & midaz infusion 2-20mcg/kg/min

Anaesthetic Management
Preoperative
- identify if any known causes of epilepsy as assoc. comorbidities may have impact on other aspects of management

History
- epilepsy aetiology
- type & pattern of seizures
- frequency & control of seizures
- AED therapy
- complications of AEDs

Investigations
- Bloods -
  ‣ screen for AED side effects eg coags, LFTs, platelet counts
  ‣ AED plasma levels checked in order to optimise
- ECHO - if murmurs or known tuberous sclerosis

AED Plan
- continue through surgery
- if unable post op - will need d/w neurologist for post op IV therapy plan/NG tube
- premedication - hyperventilation ⇒ ↓seizure threshold

Perioperative
- Induction
  ‣ balance risks eg sevoflurane & nitrous induction may cause epileptiform activity but may be much less stressing to child than IV line & TIVA
  ‣ NMBs:
    ‣ AED enzyme induction ⇒ resistance to NMBs ⇒ ↑dose & frequency
    ‣ use nerve stim to monitor
- if RSI post long seizure then should attempt to avoid sux ⇒ may cause ↑TK levels
- should avoid large doses/prolonged atracurium use (laudanosine metabolite is epileptogenic)
  ▶ consider regional in older children:
    - caution if using as sole technique due to risk anxious child hyperventilating ⇒ intraop seizure
    - if LAST then Rx seizure with midaz; consider intralipid

**Maintenance**
- target normocapnia
- volatile or TIVA
- Ted opioid requirement due to enzyme induction
- should avoid ketamine & alfentanil - epileptogenic
- many agents may be proconvulsant at low doses & anti-convulsant at higher doses

<table>
<thead>
<tr>
<th>L.V. anaesthetics</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiopental</td>
<td>Anti-convulsant</td>
</tr>
<tr>
<td>Propofol</td>
<td>Dependant effect: activation in small doses and burst suppression in higher (clinical) doses</td>
</tr>
<tr>
<td>Benzodiazepines</td>
<td>Anti-convulsant</td>
</tr>
<tr>
<td>Ketamine</td>
<td>Proconvulsant with subcortical electrical activation</td>
</tr>
<tr>
<td>Etomidate</td>
<td>Dependant effect: activation in small doses including induction dose and burst suppression in higher doses</td>
</tr>
</tbody>
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**Inhalation anaesthetics**
- Nitrous oxide: Predominantly anti-convulsant with marked EEG suppression at higher concentrations
- Isoflurane: <1 MAC: EEG activity maintained but background epileptiform activity may be suppressed >1 MAC: profound EEG suppression >2 MAC isoelectric EEG
- Sevoflurane: Similar to isoflurane, but with epileptiform EEG activity at higher concentrations associated with hyperventilation
- Desflurane: Similar to isoflurane
- Halothane: Suppression of background epileptiform activity at clinically useful concentrations

**Opioids:** generally a minimal effect at clinical doses and slowing of EEG at high doses
- Fentanyl: In doses up to 5 μg kg⁻¹ minimal effect
- Alfentanil: Epileptiform EEG activity even at low doses
- Remifentanil: Minimal effect
- Morphine: In clinically relevant doses minimal effect. In high doses (animal studies), morphine is proconvulsant

**Local anaesthetics**
- Lidocaine: Biphasic effect: anti-convulsant EEG effect at low doses and proconvulsant at higher doses
- Bupivacaine: As lidocaine
- 0-Bupivacaine: More anti-convulsant effect than bupivacaine at lower doses and less convulsant effect at higher doses
- Ropivacaine: As 0-bupivacaine with higher seizure threshold

- monitor glucose
- if on ketogenic diet then avoid glucose & lactated ringers solution

**Extubation**

**Postop**
- seizures more common post op
- check plasma AED levels
- ensure normal electrolytes, BSL, CO₂, O₂
- give midaz if required

**Special Points**
- detecting seizures under GA:
  ▶ difficult esp if NMBs used
  ▶ subtle signs:
    - sudden ↑EtCO₂
    - ↑HR
    - HTN
Anaesthesia for Epilepsy Surgery
- done by identifying epileptic foci with EEG or ECoG (electrocorticography) & cerebral cortex mapping
- intraop monitoring of language & motor loci ≈ awake unintubated patient
- pt special requirements:
  - multiple surgeries
  - stop AEDs prior to procedure in order to identify foci
  - ↑ blood loss due to larger head:body
- technique:
  - TIVA: remi propofol - as volatiles suppress motor potentials
  - avoid nitrous as it inhibits cortical electric activity even at low doses
  - avoid NMBs if cortical stimulation planned
  - use more standard technique
  - continue AEDs periop
  - if seizure induction planned then ensure can see limbs
- other operations:
  - neuroendocrine: light sedation if tolerated or GA
  - vagal nerve stimulator:
    - can ↓ seizure frequency in some pts with intractable epilepsy
    - risk of intraop bradycardia/asystole during lead placement
  - Grid & strip placement:
    - monitoring electrodes placed on surface of brain for ~1wk to identify epileptic foci
    - involves craniotomy with risk of blood loss & VAE
  - awake craniotomy:
    - only in older & well motivated
  - corpus callosum:
    - bleeding & VAE risk
    - postop lethargy & somnolence

With Liver Disease

Chronic Liver Disease
- general principles relate to features of liver disease:

Portal Hypertension Problems
- Ascites:
  - distended abdo ⇒ diaphragmatic splinting ⇒ ↓FRC ⇒ ↑WOB ⇒ ↑risk of hypoxaemia
- splenomegaly:
  - intraabdo mass effect as above
  - blood probs: thrombocytopenia ⇒ pancytopenia
- varices:
  - around stomach, lower oesophagus, rectum, ant abdo wall
  - risk of major bleeding or chronic small bleeding ⇒ anaemia & iron def
  - can do TIPS procedure if liver synthetic function is normal
- coagulopathy:
  - only end stage liver disease
  - all clotting factors are synthesised in liver except XII & vWF
  - 2,7,9,10 vit K required factors. vit K is fat soluble & requires bile salt excretion for absorption
  - can give parenteral vit K but not possible to fix other synthetic functions
  - clotting factors may be required for large operations - risk of fluid overload
- drug metabolism:
  - albumin & plasma proteins ⇒ fluid shifts & altered VD
  - phase I reactions variably altered
  - conjugation reactions altered
generally drugs with sedative effects will show enhanced & prolonged action

**Extra Hepatic Problems**
- **haemodynamic effects:**
  - assoc with high output low resistance circulation
  - flow murmur & atrial enlargement common
  - usually stable during GA - but may tolerate hypovolaemia less well
- **resp system:**
  - ascites mechanical effect on diaphragm
  - hepatopulmonary system:
    - 5-10% of pts with chronic liver disease
    - V/Q mismatch & pulmonary angiogenesis with true R to L shunt ⇒ progressive hypoxaemia
    - marked changes in bases meaning lying flat may improve problem
    - degree of problem not related to severity of liver disease
    - only effective Rx is liver transplant
- **renal:**
  - hepato-renal syndrome:
    - rare in children
    - intense renal vasoC ⇒ pre-renal failure
  - acute renal impairment:
    - more common
    - pre-renal cause: hypovolemia
- **encephalopathy:**
  - more common in acute liver failure
  - possible in decompensating chronic liver disease eg by sepsis, GI bleed
  - chars: ↑ammonia, ↑ICP, neuronal inflamation
  - diff to identify in children due to lack of encephalopathy grading tests
  - watch for inversion of sleep pattern, lethargy, irritiability
- **other:**
  - electrolyte probs esp ↓Na due to ↑ed water retention in kidneys
  - poor nutrition ⇒ ↓wound healing
  - failure of vit D absorption ⇒ osteopaenia
  - itching - bile acid retention

**Acute Liver Failure**
- fulminant failure in <8wks between onset & encephalopathy
- encephalopathic pts:
  - sensitive to anaesthetics
  - may require continuous glucose infusion
  - hyperdynamic hypervolaemic circulation

**Giving Anaesthesia**

**Drugs**
- **volutaries:**
  - modern agents fine.
  - Des may be best:
    - ↓proportion metabolised
    - preserves hepatic blood flow - perhaps better than others
- **NMBs:**
  - atracurium - best choice due to organ independant metabolism
  - cisatracurium may be best - ↓ed level of laudanosine ⇒ ↓neurotoxicity
- **Opioids:**
  - remi good
  - must give opioids for pain relief - just need careful titration & monitoring

**Preoperative**
- ?sig resp compromise
- pre-op fluids & glucose during fasting

**Perioperative**
- **Induction**
  - keep child head up to minimise diaphragm splinting
use ETT
- Maintenance
  - standard good paed care
  - consider central access
  - monitor coagulation in high risk cases with coag screen/TEG
  - regional useful (neuraxial only if coagulation acceptable)

**Postop**
- may require prolonged monitoring

**Special Points**
- operations for hepatobiliary procedures:
  - biliary atresia:
    - rare congen anomaly $\Rightarrow$ cholestasis $\Rightarrow$ heaptic fibrosis $\Rightarrow$ cirrhosis
    - 25% also have polysplenia, abdominal situs inversus & ASD
    - Kasai portoenterostomy which needs to be done <8wks old
    - anaesthetic issues:
      - fluid loss
      - intermittent IVC obstruction
      - analgesia - epidural useful if coags normal
  - liver tumours:
    - primary tumours rare - hepatoblastoma most common
    - liver function usually normal
    - chemo with doxorubicin (need ECHO to r/o cardiomyopathy) or cisplatin
      - 3 anaesthetic challenges:
        - haemorrhage - lines into upper limb
        - air embolus - fluid restriction used to ↓ liver congestion & bleeding
        - post liver resection insufficiency
  - liver transplant
    - only effective Rx for end stage liver disease
    - 5yr survival ~90% for chronic problems
    - same as adult
    - use smaller L liver lobe
    - livers need matched for blood group only
    - aim to reperfuse liver within 12-16hrs of harvest

**With Neuromuscular Disease**

**Physiology**
- normal mm function requires:
  - efferent somatic nerves
  - release of Ach
  - stimulation of motor end plate
  - Ca release from SR
  - contraction via actin & myosin (myofibrils)
  - all processed = energy dependant . high no's of mitochondria
  - abnormalities based on location of problem:
    - release of Ach = myasthenic syndromes
    - post synpatic membrane or SR = channelopathies
    - myofibrils = dystrophies & myotonias
    - mitochondria = mitochondrial myopathies

**Myasthenic Syndromes**
- problem with Ach release or action at post synaptic membrane
- symptoms = mm weakness & fatiguability
- Myasthenia gravis =
  - autoimmune response to NMJ
  - rare to present in children
  - assoc with thymoma in children
- neonatal myasthenia gravis =
  - passive transfer of anti-nicotinic Ach receptor antibodies from affected mother
- congenital myasthenia syndromes:
  ‣ rare heterogeneous group
  ‣ inherited gene mutations effect release, manufacture or recognition of Ach at NMJ

**Channelopathies**
- rare genetic disorders
- abnormal chloride channels = myotonia congenita
- hypokalaemic or hyperkalaemic periodic paralysis
  ‣ rare autosomal dominant conditions affecting Na & Ca channels
  ‣ CK syndrome ⇒ periodic severe paralysis

**Dystrophies**
- genetically determined disorders
- dissociation of mm cell contraction from surrounding connective tissue
- have abnormal dystrophin or other proteins which stabilise myofibril
- see:
  ‣ actin - myosin coupling fail to produce effective contraction due to defective CT components
  ‣ unstable cell mm membrane ⇒ inflammation, degradation & atrophy
  ‣ mm slowly replaced by fat and connective tissue

**Duchenne (DMD)**
- 1:3500 live male births
- X linked recessive inherited
- abnormal or absent dystrophin ⇒ chronic mm fibre necrosis, degeneration in skeletal, smooth & cardiac mm
- presentation:
  ‣ normal infants at birth
  ‣ weakness begins before 8yrs ⇒ rapidly progressive
  ‣ difficulty managing stairs and standing from sitting
  ‣ wheelchair by teens
  ‣ death in 20-30s from cardiac/pulmonary problems
- heterozygous females have ↑ed cardiac risk late in life

**Becker MD**
- less common 1:30,000
- milder & slower onset
- presents @ 11yrs
- life expectancy virtually normal but risk of severe dilated cardiomyopathy

**Myotonias**
- difficulty initiating mm contraction & delayed relaxation
- myotonic dystrophy:
  ‣ autosomal dom disease
  ‣ abnormal nucleotide triplet repeat sequence on chromosome 19
  ‣ delayed inactivation of Na channel following AP at mm cell membrane
- usually diagnosed in neonatal period

**Mitochondrial Myopathies**
- ↑ing recognition 1:4000
- varied presentation
- also effect other high metabolic demand tissues eg brain, cardiac mm, endocrine organs, kidneys
- 2 most common:
  ‣ mitochondrial encephalopathy, lactic acidosis & stroke (MELAS)
  ‣ myoclonic epilepsy with ragged red fibres (MERRF)
- defects seen in electron transfer chain on inner mitochondrial membrane ⇒ ↓ATP levels

**Anaesthesia**

**Preoperative**

**History**
- how long child weak?
- weakness stable or progressive?
- associated fatigability?
- what limits activity?
- milestones - older children crawling?
- how quickly recover from resp tract infection?

**Prev Anaesthetics**
- previous GA problems?
- prev uneventful use of sux or volatiles does not guarantee safety

**Exam**
- DMD \( \approx \) hypertrophied calf mms
- neonatal myotonic dystrophy \( \approx \) typical facies, ptosis, diplegia, tent shaped mouth
- mitochondrial disorders \( \approx \) developmental delay
- functional exam: sit, stand, walk
- \( \downarrow \) poor discriminator for myocardial problems
- adequate cough
- kyphoscoliosis with restrictive lung disease?

**Investigations**
- ECG, EMG, CK
- recent electrolytes incl pH, HCO3, lactate
- ECHO - if known likely problem eg DMD

**General Plan**
- good paeds care - temp, fluids, electrolytes
- avoid NMBs = ↑ ed sensitivity
- never use sux: channelopathies see life threatening ↑ in K & rhabdomyolysis
- Anaesthetic agent choice:
  - \( \text{progressive muscular dystrophy} = \text{TIVA (avoid volatiles if possible or induction only)} \)
  - \( \text{mitochondrial disease} = \text{propofol for induction only} \Rightarrow \text{volatile} \)
- cardiac monitoring
- use short acting & rapidly metabolised drugs
- post op resp insufficiency major concern .: use opioids sparingly & consider regional

**Malignant Hyperthermia**
- linked risk of MH only seen in:
  - central core disease
  - specifically no link with DMD

**Anaesthesia Induced Rhabdomyolysis (AIR)**
- Muscular dystrophies with no dystrophin have an unstable & permeable sarcolemma
- volatiles & sux may \( \Rightarrow \) ↑ instability & permeability \( \Rightarrow \) ↑ intracellular Ca & leakage of K & CK into blood
- hyperkalaemic arrest
- \( \text{risk with volatiles use} \)
- can be seen at extubation in conjunction with shivering
- highest risk <8yrs
- outcome often fatal

- \( \Rightarrow \) only use TIVA if at all possible

**Volatiles in Undiagnosed Floppy Child**
- \( \sim 1.09\% \) risk in this popn of AIR or MH
- children presenting for mm biopsy have 10-20% chance of positive finding
- safest technique = TIVA
- to ↓ risk & support use of volatile:
  - FH
  - Ck levels
  - genetic testing
  - \( \sim 50\% \) of these = muscular dystrophy

**Propofol Infusion Syndrome**
- ↑ risk in :
  - \( \text{mitochondrial conditions} \)
  - \( \text{longer operations} \)
- \( \Rightarrow \) lipaemia
- met acidosis
- renal & liver failure
- use regional & remi to ↓ propofol dose to <4mg/kg/hr

## With Renal Disease

### CKD
- classified according to GFR - see table
- double incidence of renal disease Asian:Caucasian
- mortality highest <1yr old

<table>
<thead>
<tr>
<th>CKD stage</th>
<th>GFR [ml min⁻¹ (1.73 m²)⁻¹]</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&gt;90</td>
<td>Mild</td>
</tr>
<tr>
<td>II</td>
<td>60-89</td>
<td>Moderate</td>
</tr>
<tr>
<td>III</td>
<td>30-59</td>
<td>Moderate</td>
</tr>
<tr>
<td>IV</td>
<td>15-29</td>
<td>Severe</td>
</tr>
<tr>
<td>V</td>
<td>&lt;15</td>
<td>End-stage</td>
</tr>
</tbody>
</table>

- most common causes are different from adults:
  - reflux dysplasia
  - obstructive uropathy
  - glomerular disease
  - Congenital nephrotic syndrome
- younger children <6yrs likely to have developmental or congenital causes eg Alport or polycystic kidneys
- >6yrs more likely acquired

### Features
- = multisystem disease
- CKD stage 1-3 generally asymptomatic

#### Renal
- min acceptable urine output in children 1-2ml/kg/hr
- may be polyuric or oliguric/anuric
- need to watch electrolytes
- chronic metabolic acidosis common
- drug bioavailability altered by:
  - acidosis
  - ↓ protein binding
  - different fluid distribution
- dosing:
  - normal loading doses
  - ↓ maintenance & infusions

#### CVS
- HTN -
  - although not all children
  - causes:
    - fluid overload & Na retention + ↑ renin secretion from diseased kidney
    - sympathetic hyperactivity to kidney
  - uraemia induced cardiomyopathy
- CCF
- pulmon oedema
- accelerated atherosclerosis
  - all manifests as SOB, ↓ ex tolerance, ↓ growth

#### Haem
- normocytic normochromic anaemia caused by:
  - ↓ EPO
  - uraemia induced bone marrow suppression
  - premature haemolysis
- coagulopathy caused by:
  - uraemia induced platelet dysfunction
- hypercoagulable caused by:
  - protein losing nephropathy eg cong nephrotic syndrome

**Resp**
- see overall R shift of O2 curve but different effects:
  - ↑2,3DPG => R shift (biggest impact)
  - anaemia => L shift
- pleural effusions or ascites => mechanical effects on breathing

**Neuro**
- uraemic encephalopathy - can reverse with dialysis
- may see seizures - uncontrolled HTN or ↓↑Na
- autonomic dysfunction rare

**GI**
- poor nutrition => lethargy N&V
- uraemic induced delayed gastric emptying

**MSK**
- ↓Ca => secondary ↑parathyroidism +/- => tertiary ↑parathyroidism
- ↑Ca reabsortion from bone => bone/joint/growing problems

**Psych**
- delayed language & motor skills
- poor behaviour & social interaction

**Diagnosis**
- FH of polycystic kindeys or recurrant UTI => further Ix
- US
- urinalysis, urine albumin:creat ration
- measure GFR, creatinine, electrolytes
- renal biopsy - if intrinsic suspected

**Management**
- depends on primary cause
- general themes:
  - Rx of recurrent infections
  - HTN - target SBP
  - anaemia - EPO
  - bone disease - phosphate & growth hormone
  - nutrition - gastrostomy if required
- Specific Rxs:
  - steroids & immunosuppressants
  - surgical interventions - anatomical issues
  - dialysis - CAPD or RRT
  - renal transplant - stage IV-V

**Anaesthesia**

**Preoperative**

**History**
- renal impairment: cause, duration & severity
- ?fluid restricted
- daily urine output
- any disease specific meds
- if dialysed:
  - mode & when last
  - dry weight = lowest can tolerate post dialysis before symptomatic

**Investigations**
- routine bloods
- CXR & ECHO useful if pleural or pericardial effusions suspected

**Rx**
- preop dialysis: wait 4-6hrs post dialysis prior to surgery - risk of heparin
- premed antacids & standard midaz

**Perioperative**

- **Induction:**
  - Modified RSI with roc (avoiding sux)
  - LMA if Hx suggests no aspiration risk
  - indwelling lines - likely have heparin insitu
  - drugs which ↓ protein binding but likely ↑ volume of distribution:
    - thiopental = follow above - normal dosing
    - ketamine = risk of HTN
    - propofol = normal dose
    - sux = avoid due to ↑ K risk
    - atracurium perfect
    - ↓ dose of morphine
    - avoid NSAIDs
- **Maintenance:**
  - sevo is fine - compound A is a farce
  - fluid:
    - suggest balanced crystalloid rather than NaCl (↑ Na ↑ Cl met acidosis)
    - use 5ml/kg boluses rather than 20
    - Transfuse Hb <80
  - avoid blood pressure cuff to AV fistula
  - aim normal EtCO2
- **Extubation**

**Postop**

- regional is fine
- epidural - consider risk of ↓ bp & effect on renal perfusion

**Paediatric Renal Transplant**

- performed when child > 10kg:
  - ↓ tech difficulty
  - ↓ thrombosis
  - donor anatomical size
  - recipient CO better able to adapt
- absolute contraindications:
  - active malignancy or sepsis
  - incompatible cross match
- relative CIs:
  - prev malignancy
  - infection HIV, HBV, HCV
  - < 6 month old
- often live donors from eg parents

**Periop Management**

- CVL & dopamine infusion
- follow local protocols
- volume loading during vascular unclamping to compensate for ↓ SVR
- vascular thrombosis is leading cause of graft failure:
  - careful MAP control
  - heparin
- careful warming impt
- post op complications:
  - acute rejection
  - renal vein or artery thrombosis
  - ureteric leaks
  - strictures
  - lymphocele

**With Intellectual Disability/Autism/ADHD**

- inclds learning disability, language and communication disorder, disability which prevents child coping well with new experiences
- boys 4:1 girls

**Challenges**
- difficult history & exam
- unable to perform investigations
- problems with unfamiliar environment, unfamiliar routine
- unable to communicate their distress
- unable to accurately Ax pain

**Autism**
- spectrum of disorders which incl impairments:
  - **social triad:** difficulty with communication, interaction (behaviour) & imagination
  - sensory processing
  - Intellectual/mental health problems incl anxiety & anger
  - motor problems
- reluctant to be touched or examined
- display repetitive behaviour
- reluctant to make eye contact

**Strategies for Management**

**Preoperative**
- advanced notice of child.
- weight/height performed in community
- family should start educating child >1wk with social story of what will happen
- quiet waiting area
- plan for 1st on list to minimise waiting & fasting times
- bring own items/toys
- familiar carer with pt at all times
- learn & use child’s alternative communication techniques
- quiet, dimly lit OR with minimal people in there
- chart EMLA & premed (mask in cordial +/- may be needed prehospital)
  - clonidine 5mg/kg or ketamine.
  - midaz can cause paradoxic agitation
- simple comms -
  - 4Ps = presentation, posture, position, performance
  - 4Ts: tone, timbre, tempo, text

**Perioperative**
- Induction
  - calm & quiet with minimal people
  - low lighting
  - avoid physical restraint although be guided by carers if this is normally required at home
- Maintenance
  - simple anaesthetic with
    - analgesia ++
    - IVF & antiemetics
- Extubation

**ADHD**
- = characterised by combination of attention problems & hyperactivity which manifest <7yrs old
- most common psych problem in paeds affecting 3-5%
- 30-50% will continue to have symptoms in adult life
- 3 subtypes:
  - mostly hyperactive-impulsive
  - mostly inattentive
  - combined (most common)
- 25% suffer concurrently from anxiety neurosis
- triggers of problems = stress & anxiety, poor communication

**Pre & PeriOp Plan**
- as autism
With Obesity
- gender specific BMI charts exist

Preoperative
- obese children are just as likely to have comorbidites as adults. Need to screen
  - HTN
  - type II DM
  - asthma
  - GORD - ?start PPI
  - OSA - ?overnight oximetry, sleep study

Perioperative
- Induction
  - IV induction preferred
  - consider RSI due to aspiration risk
  - US access or may have to perform inhalational
  - if inhalational:
    - ↑likelihood to occlude airway
    - quicker desat
  - try to avoid premed
  - use ETT:
    - LMA difficult to size
    - ↓lung compliance

- Maintenance
  - ↑PEEP required
  - ↑vent pressures
  - see ↑ed risk of bronchospasm, laryngospasm, O2 desat
  - bp monitoring may be difficult due to cuff sizing -
    - ↓may need to consider A line but difficult & risk of ischaemia
  - positioning may be challenging esp extremes:
    - steep head down
    - prone - splinting of diaphragm due to ↑ed abdo girth

- Drug dosing:
  - may prefer dosing on IBW or lean body mass especially:
    - NDNMBs
    - IV paracetamol
      - EXCEPT sux should be given on TBW

- Extubation
  - ↑ed incidence of obstruction post op
  - extubate fully awake

Postop
- ↑ed length of stay in PACU
- use regional anaesthesia where possible

Special Points

With Inherited Metabolic Disorders
- inborn error of metabolism = IMDs
- failure of steps in metabolic pathway
- very heterogenous which may present at any age

Clinical Presentations
- varied:
  - neurological eg ↓consciousness
  - metabolic acidosis - lactate or ketoacids
  - hepatic syndromes - jaundice, ↓BSL
  - Cardiac - cardiomyopathy + arrhythmias & valvular problems
  - dysmorphism
**Preoperative**
- MDT approach with metabolic team & prev anaesthetic record
- defer elective surgery if concurrent infection \( \Rightarrow \) decompensation metabolic function
- examine carefully: CVS & resp - ECG, ECHO
- correct significant acidosis
- continue special diets & avoid prolonged fasting & dehydration:
  ‣ 1st on list
  ‣ 10% dextrose or IV fat emulsion fluid once fasting commences
- premeds with extreme caution

**Perioperative**
- Induction:
  ‣ avoid sux - risk of \( \uparrow\uparrow K \)
  ‣ careful neck handling
- Maintenance
  ‣ temp cares
  ‣ bicarbonate to minimise acidaemia - A line with regular sampling
  ‣ if blood into Gi tract - place Ng tube to aspirate to avoid high protein loads
  ‣ avoid N2O

**Postop**
- quick resumption of special diet
Medical Problems

Airway Syndromes

Trisomy 21
- issues related to:
  ‣ short neck
  ‣ macroglossia
  ‣ microodontia
  ‣ midfacial & mandibular hypoplasia
  ‣ Atlanto-axial instability
  ‣ Tincidence of subglottic stenosis
- also common to see tonsils/adenoids hypertrophy ⇒ OSA
- BMV often hard, DL easier

Beckwith-Wiedemann
= omphalocele, macroglossia, visceromegaly (big spleen & liver ⇒ ↓FRC) & gigantism
- issues:
  ‣ maxillary hypoplasia & macroglossia ⇒ obstruction
  ‣ OSA
- difficult DL, obstruction on induction & emergence

Pierre Robin
= triad of micrognathia, glossoptosis (down & back retraction of tongue) & cleft palate
- as above
  ‣ mandibular hypoplasia
- DL becomes easier with age (hard in neonate)
- obstructive problems

Treacher Collins
= disorder of neural crest ⇒ head & neck symmetrical bilateral abnormalities
- issues:
  ‣ hypoplasia of maxilla, mandible, zygoma
  ‣ high arched cleft palate
  ‣ small mouth
  ‣ abnormal TMJs
- difficult BMV, easier LMA vent, 50% >gd 3 DL's

Goldenhar
= hemifacial microsomia with undevelopment of eye, ear, nose, soft palate, lip & mandible
- issues with:
  ‣ facial asymmetry
  ‣ tracheal deviation
  ‣ craniovertebral abnormalities
  ‣ C1-2 subluxation or limited Cx movement
- difficult BMV; use VL or bronchoscope via LMA

Klippel-Feil
= triad of short neck, low post hairline, ↓neck mobility caused by Cx fusion
- issues with:
  ‣ as above - any rotation ⇒ brain ischaemia
  ‣ micrognathia
  ‣ mandibular abnormalities
- use VL or bronchoscope

Croup
= acute laryngotracheobronchitis
- cause of 80% of stridor in children

**Presentation**
- autumn & early spring
- 6 months -> 2 years
- viral - parainfluenza, influenza, RSV
- URTI -> barking cough, hoarseness, stridor secretions +++
- anxious child ⇒ tracheal collapse on inspiration ⇒ ↑ stridor
- mild fever
- dysphagia

**Pathophysiology**
- parainfluenza, influenza or RSV
- oedema of larynx, trachea and bronchi

**Management**

**Medical**
- keep child calm
- O2 - NB consider other diagnosis if pt is hypoxic
- oral dexamethasone 0.3mg/kg - 0.6mg/kg - onset of effect 6-24hrs
- nebulised adrenaline
  - >10kg = 5ml 1:1000
  - <10kg = 0.5ml/kg of 1:1000 up to max of 5ml - immediate onset
- heliox

**Failure of medical treatment**
(O2, nebulised adrenaline, dexamethasone) and progression to:
- Causes:
  - exhaustion from increased work of breathing
  - hypercapnic respiratory failure
  - hypoxic respiratory failure (child would usually be obtunded)
  - decreased LOC (and not protecting own airway, responding to pain only)
  - imminent airway obstruction
- Intubation:
  - will be difficult - critical laryngeal oedema and airway obstruction below the level of vocal cords.
  - transfer to theatre if possible,
  - help: another anaesthetist to be present, an ENT surgeon scrubbed and ready to perform emergency tracheostomy
  - obtain IV access (using EMLA and parents comforting patient) – if child distressed ⇒ defer till post induction
  - inhalational induction with maintenance of spontaneous ventilation until airway is secure.
    - slowly and gently apply facemask
    - slowly turn up sevoflurane concentration to 8% mixed with O2
    - wait until adequate depth of anaesthesia (eyes are mid line, conjugate, pupils small, HR slowing)
      - induction will take longer (20-30min)
  - gentle laryngoscopy with assessment of laryngeal inlet
  - intubation:
    - generally easy apart from tube sizing
    - small uncuffed endotracheal tube (try one size smaller than anticipated)
    - consider nasal tube for PICU care - likely need 2-3 day intubation
- if patient obtunded and needs emergency intubation ⇒ RSI with cricoid pressure
- an LMA or fiberoptic bronchoscope are unlikely to be helpful
- slower resolution of symptoms - 2-10 days

**Post Intubation Croup**
- = stridor & other resp obstruction caused by subglottic oedema
- generally from too big ETT
- signs appear within 30 min extubation
- respnd well to neb adrenaline & dex
- if Rx'ed must be observed for 2hrs post resolution of symptoms

**Acute Epiglottitis**
- = infection of epiglottis, aryepiglottis & arytenoids

**Presentation**
- 2-6 years (peak @3yrs)
- high temp >39.5
- drooling
- leaning forward
- unable to swallow
- tongue pushed forward
- lat C spine = thumb print sign
- inspiratory and expiratory stridor = late sign

**Pathophysiology**
- Haemophilus influenzae type B - post vaccine intro has become ↑ingly rare
- rapid onset oedema of epiglottis and aryepiglottic folds

**Management**
- = medical emergency
- ceftriaxone 50mg/kg IV
- intubation - needed in 60% of cases
  - ENT surgeon scrubbed ready for emergency cricothyroidotomy
  - IV - if successful topical LA & easy vein
  - traditionally:
    - inhalational induction in sitting position with sevoflurane in FiO2 1.0, CPAP
      ↳ but is it possible to wake up if lose airway as obstructed
  - other options but need to keep SV induction:
    - gradual TIVA
    - ketamine
  - move to supine
  - intubation:
    - likely very hard - no obvious glottic opening - look for bubble sign in mucosa
      ↳ can try chest compression to show opening
    - intubate with bougie and rail-road small tube over (or stylet)
    - use smaller tube size than predicted
- quicker resolution of oedema with Abx - 36hrs intubated
- dexamethasone prior to extubation: 0.25mg/kg IV
- check for leak prior to extubation

**Bacterial Tracheitis**
- uncommon but post Hib vaccine may now be more common than epiglottitis
- occur any age
- causes: staph a., Haem influenzae, streptococci, Neisseria
- signs intermediate between croup & epiglottitis:
  - preceding viral URTI 2-3days
  - rapidly ill in 8-10hrs with high fever & resp distress
  - copious secretions & retrosternal pain
  - hoarse voice & stridor but can lie flat
- most will require intubation:
  - easy glottic view +/- pus from trachea
  - risk of tube blockage from so much pus
- ceftriaxone

**Retropharyngeal or Tonsillar Abscess**
- occurs from lymph spread from sinuses, teeth, middle ear
- staph & strep usual causes
- oedema of pharynx ⇒ stridor
- mostly children <6
- diagnosis clinical but lat soft tissue XR of neck can help diagnosis

**TBI in Children**

**Priorities**

1. precise assessment of brain injury + associated injury
2. protection of secondary brain injury
3. management of ICP

**Clinical Assessment**

- mechanism of injury
- associated injuries
- paediatric GCS
- pupil diameter + reactivity
- brain stem reflexes
- signs of increased ICP
- focal neurological deficits

**Investigations**

- standard ATLS care
- transcranial doppler ⇒ quantification of cerebral blood flow, can compare both sides, provides info regarding systolic, diastolic and mean blood flow velocity.
- CT (head and panscan for other injuries)
- arterial monitoring
- ICP monitoring ⇒ EVD
- MRI ⇒ done when there is a discrepancy between clinical evaluation and CT

**Management**

- prehospital: aim for SBP >90mmHg
- prevention of hypotension, hypoxia, hypercarbia, anaemia and hyperglycaemia
- aim for CPP of 40-65mmHg (age dependent)
- continuous EEG monitoring (ideal)
- triggers for ICP management =

  8yrs = 20mmHg
  1-8 = 18
  Infants = 15

- Anaesthetic aims summary:
  - **adequate anaesthesia & analgesia** -
    - TIVA although volatile MAC ≤1 may be as good
    - avoid N2O = ↑CMRO2
  - **optimise surgical conditions**
  - **Good secondary brain injury care normo...**
    - temp
    - bp - single episode of intraoperative ↓bp can affect outcome
    - O2: SpO2 >90% or PaO2 >60
    - CO2: low normal (35mmHg). Hyperventilation reserved for brief rescue only
    - BSL <10
  - **maintain adequate CPP**
    - normovolaemia (fluid +/- vasopressor therapy)
    - should be kept >40
  - **avoid ↑ in ICP:**
- PEEP can ↑ICP
- rescue:
  - mannitol 0.5-1g/kg Q 6 hourly
  - hypertonic saline 5ml/kg of 3% or 0.25ml/kg of 23.4%
- avoid jugular venous outflow obstruction
- 15-30 degrees of head up with neutral midline
- CSF drainage via EVD
- treat seizures aggressively
- if for RSI:
  ‣ ketamine - modern evidence states no ↑ICP & CVS stable + bronchodilatory
  ‣ rocuronium - sux ↑s ICP & risk of undiagnosed neuromuscular disorders
- Hb transfusion - restrictive transfusion strategy as good as liberal
- Seizure prophylaxis:
  ‣ paed TBI more likely to have seizure
  ‣ recommended for severe TBI in children for 1/52 post trauma
  ‣ phenytoin

**Burns**

**Assessment**

**History**
- how long patient was in the H2O,
- whether appropriate first aid has been carried out (20min of cooling under running water),
- treatment instituted by ambulance staff (analgesia and fluid resuscitation)
- other injuries sustained (unlikely)

**Airway assessment**
- examine for patency, protection and any obvious signs of airway burn (unlikely given mechanism of injury)

**Breathing**
- assess RR and SpO2 and apply face mask O2 if hypoxic
- examine whether chest wall has been effective by burn as may develop respiratory failure from exhaustion and extreme pain

**Circulation**
- Pulse and BP
- central perfusion
- state of hydration
- rule out any external haemorrhage
- obtain IV access through intact skin and send off bloods (U+E, FBC and Group + Hold in case patient needs debridement and grafting – can develop massive blood loss)

**Disability**
- level of consciousness
- pain score
- titrate in IV morphine until comfortable (start with increments to 0.2mg/kg however may need more)

**Exposure**
- take all clothes off
- if there are areas that are stuck to patients skin -> cut around

**Head to Toe examination**
- burn as a percentage of TBSA
- depth of burn (superficial, partial (superficial and deep), full thickness)
- photograph
Management

1. Analgesia
- assess using behaviour observation rather than by direct questioning @ this age
- cautious IV opioids + multimodal
- morphine 0.05mg IV, but may need more
- IV paracetamol 20mg/kg
- apply cling film (sterile, non-adherent dressing) to burn
  - prevents heat loss
  - analgesic - prevents depolarisation of burnt nerve endings from air moving over burn

2. Fluid resuscitation
- Resuscitation = Parklands Formula;
  - 3-4mL/kg/percentage burn
  - give 50% over first 8 hours from time of burn, and the other half over 16 hours
- Maintenance - Need to add on top of resus fluids
- use a balanced salt solution like Hartmans
- titrate resus fluid to
  - urine output (>1ml/kg/hr)
  - haemodynamics,
  - mental state
  - lactate.
- close monitoring of blood loss during surgery with infiltration of LA and adrenaline under GA helps limit blood loss

Congenital Heart Disease

Innocent Murmurs
- consider innocent flow murmur if:
  - normal function
  - SpO2 normal
  - CXR - normal lung fields, Norm cardiac silhouette
  - ECG
  - Cardiology ECHO

Classification
- Acyanotic – VSD, ASD, atrioventricular septal defect, PDA, pulmonary stenosis, coarctation, aortic stenosis
- Cyanotic – TOF, transposition of great vessels, hypoplastic left heart, pulmonary atresia, Eisenmengers syndrome (later in life)

- Duct dependant lesions –
  - PDA ⇒ systemic flow = Coarctation of aorta, interrupted aortic arch, hypoplastic L heart, critical AS
  - PDA ⇒ pulmon flow = pulmonary atresia, critical pulmonary stenosis, severe sub-pulmonic stenosis with VSD, tricuspid atresia with pulmonic stenosis

Operations

Fontan Circulation
- = palliative care procedure
- specifics of operation depend on cause esp completion stage

- 3 major phases
1. Blalock-Tausig (BT) shunt placement (A-A)
  - where subclavian artery connected to the pulmonary artery

2. Bidirectional Glen Shunt (V-A)
  - most stable op SVC
  - SVC anastomosed to the right pulmonary artery
  - offloads single ventricular work
  - pt remains cyanotic SpO2 ~85%
- avoid hypovolaemia, must maintain normal PVR

3. Completion of Fontan:
   - depends on cause but overall:
     ‣ homograft valve insertion in the IVC,
     ‣ closure of ASD,
     ‣ connection of RA and PA by a valved homograft conduit.

Key Anaesthesia Points
- must maintain normal PVR
- see ↑ed blood loss due to high venous pressures
- SV preferable
- Rx ↓MAP with volume then vasopressors

Tetralogy of Fallot Repair:
1. large VSD,
2. RV outflow tract obstruction,
3. RV hypertrophy,
4. Overriding aorta.
   -> complete correction undertaking during infancy

VSD repair
- surgical closure and percutaneous closure options (both are associated with problems with ventricular arrhythmias post op)

ASD repair
percutaneously closed

Hypoplastic Left Heart Syndrome
- 2% of CHD
- 3 stage repair:
  ‣ neonatal Norwood operation
  ‣ Glenn Shunt
  ‣ Fontan procedure
- very vulnerable children = tertiary management

Pre-operative Ax
- identification of seriously effected patients with transfer to regional unit
- high risk pts & goals =
  ‣ functional single ventricle - avoid hyperO2/hypervent, maintain vent function
  ‣ suprasystemic pHTN - Norm O2 & ventilation, good depth of anaesthesia, pulmon vasodilators
  ‣ L vent outflow tract obstruction - maintain preload, SVR & contractility, norm/slow HT
  ‣ dilated cardiomyopathy - maintain preload & SVR, avoid ↓contractility, avoid arrhythmias

History
- diagnosis (when, how, age)
- treatment (corrective, palliative or untreated)
- symptoms (cyanosis, heart failure symptoms, pulmonary hypertension symptoms)
- functional capacity
- history of stroke or thrombosis (hyperviscosity)

Examination
- SpO2
- CHF signs

Investigations
- FBC: HCT (high), platelets (low)
- U+E: renal dysfunction from chronic hypoxia
- Coags: coagulation factor deficiencies common in cyanotic heart disease
- ECHO: diastolic dysfunction, decreased ejection fraction, nature and size of lesion, flow reversal,
- MRI - 30min scan
- CT imaging -
  ‣ 5min scan.
  ‣ Unlikely to need breath holding
  ‣ Possible without GA ie feed & wrap

Preoperative
- premedication (decrease O2 consumption and sympathetic tone)

Intraoperative
- all IV induction agent safe (rate of delivery and dose important not actual drug)
- good analgesia (decrease sympathetic activation)
- 100% FiO2 can be used in simple cardiac anomalies with left to right shunt (but caution with complex lesions with right to left shunt)
- controlled ventilation
- invasive monitoring
- TOE helpful (PAC not so much)
- capnography underestimates in patient with right to left shunt
- pulmonary hypertension management (to decrease PVR; increase FiO2, hypocarbia, akalaemia, SV, normal lung volumes, avoid sympathetic stimulation, isoprenaline, milrinone, prostaglandins, NO, sudenafil)
- endocarditis; (see guidelines under IE patient below)
- dexmedetomidine:
  ‣ being used increasingly in CHD due to many perceived benefits
  ‣ advs: blunt SNT response, ↓ anaesthetic requirements, ↓ post op pain, neurprotective, lack resp depression & no effect on airway tone
  ‣ disadv: not licensed in paeds, SEs: ↑↓ MAP, ↓HR

Postoperative
- HDU/ICU
- management of pulmonary hypertension and systemic haemodynamics
- hypoxaemia; from either
  ‣ inadequate pulmonary blood flow (avoid dehydration, maintain SVR, control PVR, minimise oxygen consumption)
  ‣ pulmonary hyperperfusion (minimise cardiac work)

Esienmenger Syndrome
= chronic high pulmonary vascular resistance ⇒ reversed or bidirectional shunt flow across septal defects
- v high risk patients with high mortality

- can be caused by a number of defects
- definitive treatment ⇒ to close defect
- goal when managing is not to decrease SVR as ⇒ increase in right to left shunt ⇒ worsening cyanosis ⇒ death
- arrhythmias, hypovolaemia and large fluid shifts not tolerated well
- no air bubbles
- invasive monitoring with anticipation and treatment of haemodynamic changes

Infective Endocarditis Prophylaxis
- more conservative approach as risks of adverse effects from antibiotics higher than risks of developing IE from dental, GI or GU tract procedure
- high risk patients or procedures that require antibiotics:
1. any prosthetic material in heart (AHA say only within 6/12 postop)
2. un-repaired congenital cyanotic heart disease
3. previous IE
4. cardiac transplant patients with valvulopathy
5. all dental procedures that involve manipulation of gingival tissue or periapical region of teeth or perforation of oral mucosa (thus only check ups and simple fillings that don’t involve gingiva don’t need antibiotic prophylaxis)

- **Abx:**
  - oral = amoxicillin 50mg/kg (2g adults)
  - IV = cephalozin 50mg/kg (1g adults)

**Latex Allergy**
- more common in children underdoing repeated surgery in 1st year of life
- two types of reaction:
  - type 1:
    - bronchospasm & CVS collapse
    - can occur 30-60min after induction or even post op
    - gd III & IV anaphylaxis more common
  - type IV
    - occur 6-48hr after exposure
    - watery & itchy eyes, sneezing, coughing
    - assoc with food allergies eg banana, kiwifruit, avocado
    - gd 1 reactions more common

**Wilms Tumour (Nephroblastoma)**
- = most common childhood malignancy in kidney
- peak incidence 3yrs
- Periop risks:
  - major bleeding as may invade into IVC

**Prune Belly Syndrome**
- 95% boys
- signs:
  - mass of wrinkled skin on abdomen
  - bilat cryptorchidism &
  - urethral obstruction ⇒ dilation of bladder ⇒ dilation or ureters ⇒ hydronephrosis
  - recurrent UTIs
  - abdo distension ⇒ abdo wall mm insufficiency & excessive skin
- surgery:
  - relieve urinary obstruction
  - repair abdo wall

**Haematological Malignancy**

**Immunocompromise**
- different causes:
  - chemotherapy
  - radiotherapy
  - steroids
  - stem cell transplant
  - malignancy itself eg leukaemia
  - latent viral infections eg CMV, EBV
- strategies of infection control:
  - strict hand hygiene
  - limited number of staff
  - isolation from other unwell pts eg URTI, chicken pox .: 1st on list
- FBC to check neutrophil counts
- consider infection risks with regionals/neuraxials
- avoid IM injections
- avoid PR medication
- central line cares:
  - education
  - aseptic technique at insertion
  - disinfection of catheter hubs
  - remove superfluous connectors
  - site checks
  - replace giving sets every 72hrs
  - clean cares of dressings
- using an indwelling line:
  - some avoid altogether
  - use syringes in clean try which are capped
  - access port with sterile gloves & chlorhex swaps
  - must flush line post & document flushing

**Anaesthesia by Surgery**

**Bone marrow biopsy**
- bone marrow harvest consent:
  - parents can consent for child
  - may need involvement with accredited assessor to complete consent
- from iliac crests in lat decubitus or prone
- 60-90min
- consider FBC & G&H
- SV technique

**Long Term Venous Access**
- Sub cut or tunnelled lines.
- carry risk of infection, thrombosis, leakage & dislocation so treat with care
- check coags & platelets
- smaller child - ETT - lines being placed close to airway; older child LMA

**Chemo & Radiotherapy**
- intrathecal chemotherapy
  - drugs injected
  - LP should not be done by anaesthetist
  - should be quick and painless
  - mask holding SV, or prop/remi sedation
- radiotherapy:
  - GA to keep them still
  - sedation vs GA
  - technique with few hangover effects
  - antimetics needed - but avoid dex in case of tumour lysis syndrome

**Anterior Mediastinal Mass**
- common in NHL, Hodgkins, ALL
- 50% of masses asymptomatic at presentation
- signs:
  - resp = wheeze, cough, stridor, orthopnea
  - CVS = chest pain, syncope, headache, SVC obstruction, cyanosis, facial swelling
- if >50% compression of trachea => ↑peripop risk
- compromise may only be obvious in supine or valsalva
- if SVC obstruction - should have tumour shrinkage prior to anaesthesia
  - high dose steroids, or radiotherapy
- Ix:
  - bloods
  - CT/MRI/ECHO
  - PFTs
  - flex bronchoscope under LA - ?tracheomalacia
- GA:
  - gas induction
SV in head up or lat position
- maintenance of SV & awake extubation
- any +ve pressure ⇒ ↑↑ITP ⇒ ↓VR ⇒ cardiovascular collapse
- if crisis move child to lateral or prone

**Tumour Lysis Syndrome**
- = manifestation of metabolic derangement caused by tumour breakdown
- see ↑urea, ↑phosphate, ↑K, ↓Ca
- ↑ing urea ⇒ precipitation in renal tubules ⇒ renal failure
- sign onset ~ 48-72hrs post commencement of Rx:
  - nausea, lethargy, headache, heart failure, arrhythmias, seizures, tetany
- Rx:
  - aggressive hyperhydration & diuresis
  - aluminium hydroxide - Rxs ↑phosphate
  - allopurinol or rasburicase - Rx’s ↑urea

**PICU Problems**
- Resp failure:
  - cytotoxic agents eg bleomycin ⇒ fibrosis, pneumonitis, O2 lung injury
  - radiotherapy - related to cumulative dose of radiation given
  - effusions - from cancer or mediastinal mass obstruction of lymph
  - infection - gram -ve’s
  - GVHD - pneumonitis
  - ↓platelets = careful instrumenting airway
- CVS:
  - chemo - anthracyclines eg doxorubicin, daunorubicin (cumulative dose)
- sepsis
- hyperviscocity:
  - WCC >100 (v high risk if >300)
  - cytoreductive chemo or leucopheresis/exchange transfusion
  - watch for compensatory anaemia & ↓platelets
- post stem cell transplant:
  - sepsis
  - pulmonary complications
  - GVHD:
    - acute (<100days - most common 1st 5 weeks) or chronic
    - signs: rash, D&V, deranged LFTs, ileus, hepatic failure